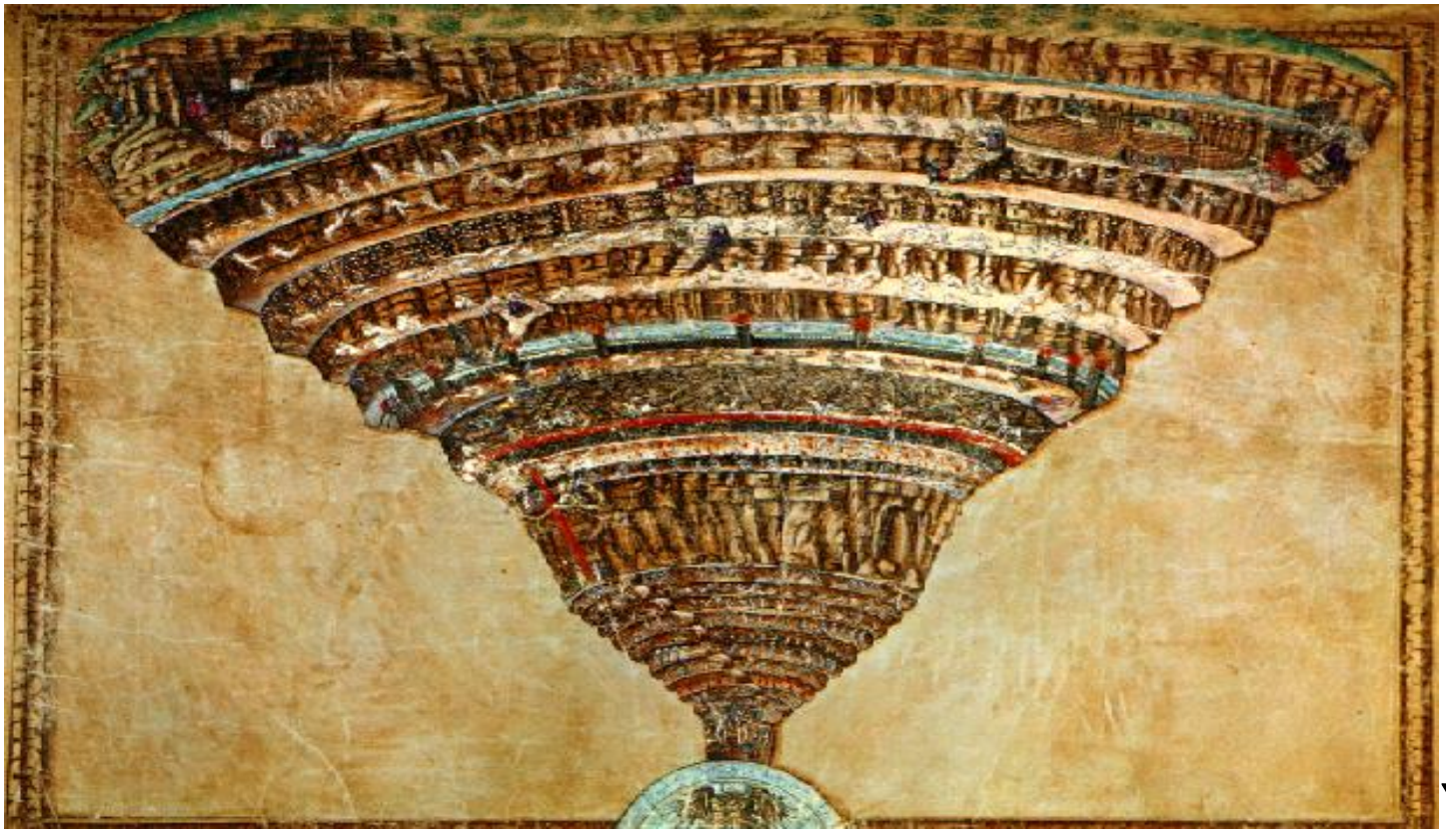
Centre for
Low Carbon Futures
2050

The Circular Economy

A literature review



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Frontispiece: The Abyss of Hell by Sandro Botticelli (1480s Coloured drawing on parchment, 320 x 470 mm Biblioteca Apostolica Vaticana, Rome).

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Executive Summary

For two centuries, the industrial and post-industrial landscape has continued to provide the human race with the essentials and luxuries that define our species, taking raw materials from the planet, transforming them into a myriad of products and then discarding these products when their usefulness has expired. At every stage, from exploration to extraction, to exploitation and finally excretion, we release waste back into the environment.

Dire warnings of disaster, many of them stemming from the oil crisis of the 1970s gave birth to a wide range of transition discourses, calling for a radical change in the global economic model. Emerging from these discourses have arisen numerous concepts targeted at delivering sustainable development. These range from re-alignment within a triple bottom line of economics, society and environment, where each of these three pillars of sustainability informs the others, and a balance point is reached, through *localist* concepts to the *pluriverse*. While much controversy surrounds the very meaning of sustainability, it is generally agreed that change must come.

Emerging from these sustainability philosophies, the *Circular Economy* has taken centre stage due, mainly, to the fastest growing economy in the world embracing it. China has adopted the Circular Economy as its philosophy for economic, environmental and social development.

This literature review traces the history of the Circular Economy, through the key documents that have recorded this history. Beginning with the significance of the environment to business, it then examines the range of sustainable development concepts applied to industry, before examining the circular economy itself. Next, the literature on barriers to the implementation of a circular economy is examined. Here, two forms of constraint are identified: generic barriers, which operate across all business sectors, and specific barriers, which are applicable to individual sectors. Finally, the transition literature is explored, identifying core areas that will be important if business is to move towards a Circular Economy. These include policy, politics, participation and systems thinking.

The Circular Economy: A Literature Review

Introduction

"Anyone who believes exponential growth can go on forever in a finite world is either a madman or an economist" - Kenneth Boulding

Why Should Sustainability Matter to Business?

While rising planetary temperatures are disrupting the geophysical feedback mechanisms that are central to a healthy functioning biosphere, the planet is also suffering from water and air pollution, deforestation, soil erosion, nuclear contamination, acid rain, destruction of wetlands, over-harvesting, the diminishment of biodiversity through extinction, climate change, habitat destruction and fragmentation, ozone depletion and an increase in social inequality within our own species (Wang and Pinkerton, 2007; Kampa and Castanas, 2008; Coe et al., 2011; Dickson and Foster, 2011; Hanish, 2011; Hanski, 2011; Harwell et al., 2011; Loveless and Whitefield, 2011; McKenzie et al., 2011; Quinton et al., 2010; Soufi and Jafari, 2011; Bellard et al., 2012).

This has led to leading environmentalist, Bill McKibben, in his book, *Eaarth, Making a Life in a Tough New Planet* (McKibben, 2010), stating that that the planet is irrevocably broken (McKibben, 2010), while James Lovelock, in his most recent book, *The Vanishing Face of Gaia, a Final Warning: Enjoy it While you Can* (Lovelock, 2009), writes "*There is only a small chance that...we can reverse climate change*". The causative agents of these environmental problems arise from a disruption in the balance of nature, caused by damaging changes to the rates of flow of elements and energy through the planet (Skene, 2011). These changes in flow are caused by our use of the environment as a source and as a sink for our industrial activities, driven by the supply and demand spiral of an increasing population of increasing prosperity and consumption.

We can trace an awareness of supply and demand issues back to the sixteenth century. In 1588, Giovanni Botero, the Italian polymath, observed that a city existed as a balance between reproduction and nutrition, but when nutrition became limiting, the city would die (Botero, 1979). Robert Wallace, writing in 1761, declared that "*the Earth would at last be overstocked, and become unable to support its numerous inhabitants*" (Wallace, 1969). It was Robert Malthus, writing in 1797, who drew attention to the danger of exceeding supply. Painting a picture of apocalyptic horsemen and an age of misery for the human race if population rate of increase exceeded the rate of increase of resource supply (Malthus, 2007), he challenged the Enlightenment view that human reason, combined with technology, could prevail and lead to continued progress towards a utopia.

In 1864, George Perkins Marsh stated, in his book *Man and Nature,* that people endanger themselves by destroying their base of subsistence, in terms of deforestation (Marsh, 1864). Nathaniel Shaler (1905) extended this concern to mineral resources. These views were unpopular at the time, and have remained so since. Even more radical, heterodox movements such as the critical institutionalists, neo-marxists and post-Keynsian schools of thought had little to say, if anything, on environmental issues (Spash, 2009). The American economist, Henry George (quoted in Simon, 1993) famously quipped "*Both the jayhawk and the man eat chickens; but the more jayhawks, the fewer chickens, while the more men, the more chickens!"* And for much of these two centuries of industrial exploitation, economic growth built on resource exploitation has continued with little concern. As Garrett Harden pointed out, "*Each man is locked into a system that compels him to increase his herd without limit – in a world that is limited. Freedom in a commons brings ruin to all*" (Harden, 1968).

A Vicious Circle on Spaceship Earth

By the mid-twentieth century, a number of thinkers had begun to write about the dangers of overconsumption. Harrison Brown, in his provocative book, *The Challenge of Man's Future* (Brown, 1954), argued that the full development of every nation on the planet, to a level already present in the West, would lead to a total collapse of Earth's natural resource base.

The journey to this perceived crisis is worth charting. Haberl et al. (2011) suggest that the evolution of socio-ecological systems transition from relatively stable periods (or *sociometabolic regimes*) interspersed by rapid transitions. They identified three stable systems: hunter-gatherers, agrarian societies and industrial society. This latter transformation has had such an impact on our planet, and represented such dominance by our species over the rest of the biosphere (McMichael et al., 2007), that this most recent two hundred years has been renamed the *Anthropozoic* era or *Anthropocene*: the age of human impact (Turner et al., 1990; Crutzen, 2002). Strikingly, geologists argue that future generations will clearly see the evidence of our recent activities upon the land, water, ice and diversity, as reflected by the parameters used to analyse our geological past (Zalasiewicz et al., 2011).

However, only about one third of the planet's human population have moved into the industrial era completely (Haberl et al., 2011), while the remainder are either mid-way through the transition, or still in an agrarian state. Thus, the full repercussions of the industrial era are still to be realized. For example, energy use in developing countries is 50 GJ per capita per year, which is within in the same range as the typical value for pre-industrial agrarian societies. Yet total energy use of developing countries has risen sharply (Boyden, 1992). Thus the increase in energy use in developing countries is down to population increase, rather than industrialization. By contrast,

the growth of energy use in industrial countries (which is around 400 GJ per capita per year) has slowed down, mostly due to their low population growth, while energy use per capita is still growing there.

While hunter-gatherer societies consumed around one percent or less of the net primary productivity (NPP: the overall energy trapped by photosynthetic organisms such as plants and algae that is available as food) of the ecosystems in which they existed. This proportion rises to over seventy-five percent in the case of agrarian societies (Boyden, 1992). This, in turn, has fundamentally impacted upon the sustainability problems faced by human societies. Before the Neolithic revolution, the primary threat to the viability of societies was the natural variation of the availability of food, dictated by such events as droughts, floods or other natural disasters. In the agrarian era, the main constraints came from area of fertile soil (since there were no artificial fertilizers), its management (mostly by crop rotation and erosion control) and labour (Boyden, 1992).

Transition to the "*fossil energy system*" (the industrial era) enabled humankind to manipulate and control nature, but the flip side of this led to the processes of environmental change on a global scale. The impact upon the rest of the planet is such that this modern era has been called the Anthropocene (Steffen et al., 2007).

Kenneth Boulding, in his landmark essay, *The economics of the coming spaceship Earth,* written in 1966 (Boulding, 1966) set out his now famous analogy of the planet as a spaceship. In this paper, some of which was based on his earlier work (Boulding, 1945; Boulding, 1950), he explained how, as humans have increased in numbers and in their intensity of resource exploitation, the planet has changed from an open world, with apparently limitless assets, to a closed world, akin to a spacecraft. On board spacecraft Earth, we now must carefully use and recycle what we have left, otherwise we risk extinction. He suggests that we must turn from a *cowboy economy*, where consumption and production rule, maximizing throughput, to a *spaceman economy*, where maintenance of stock and minimal throughput are key. Boulding's paper was far ahead of its time, identifying GDP as a measure of flow, and highlighting flow as an important concept in terms of sustainability. He also pioneered the importance of social context.

The Club of Rome issued a similar volume, entitled *The Limits to Growth* (Meadows et al., 1972). Combining the work of an international and multidisciplinary team of experts, the book projected a global economic collapse some time before 2100 AD.

In 1992, the Club of Rome released a follow-up study entitled *Beyond the Limits: Confronting Global Collapse, Envisioning a Sustainable Future* (Meadows and Randers, 1992). The World Health Organization (WHO, 2002) concluded that over 150,000 people a year were already dying from the effects of global warming and predicted a doubling of this number by the year 2020. Rockstrôm et al. (2009) commented that we are nearing a point where we exceed more than one of the

boundaries within which we can with some degree of confidence predict that the earth system will not tip into chaotic behaviour.

The combination of using the planet as a source and a sink, while polluting it with harmful intermediate waste products and altering the flow of energy has had significant repercussions upon our world, both environmentally and socially, and these repercussions result in substantial ramifications upon business.

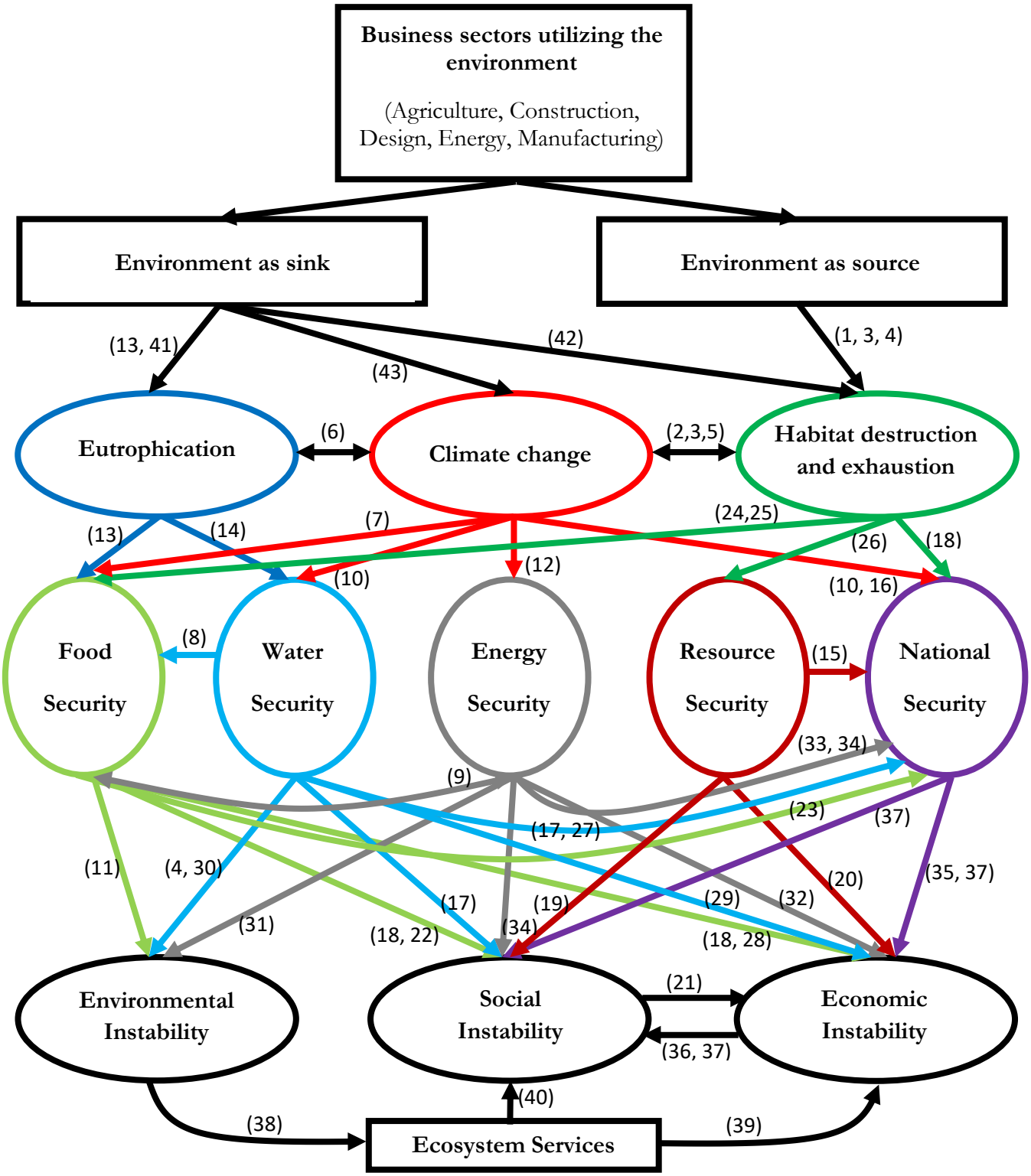
Figure 1 traces this economy-environment-society-economy (EESE) cycle, and the significant literature relating to the key steps, through four stages: i. Sink and source impacts of resource use; ii) the three major outcomes of resource use; iii) the five security issues impacted by these outcomes; iv) the three great instabilities, including economic instability. What is clear from this literature is that current business activity ultimately has a negative impact on economic stability, both directly and through environmental and sociological instability.

Natural resources, both renewable and non-renewable, are always harvested in the same way—the easiest and cheapest supplies are taken first. The process is called *high-grading* (Coufal et al., 2011). Hubert (1955) suggested that the availability of many of the resources would peak in coming years, after which demand would outscale supply, and greater energy would need to be channelled into acquisition of the diminishing resource. Certainly the recent willingness to expand tar sands mining, deep sea drilling and shale oil, previously deemed as economically unjustified (Bureau of Land Management, 2011) and environmentally devastating (Addison and Puckett, 1980; Parrott et al., 2004; Wayland and Smits, 2004; Alberta Environment, 2007; Timoney and Lee, 2009), tends to point towards a more desperate search for oil.

Over the past few years, we have reached, or come very near to reaching, the “peak” of the bell-shaped curve of depletion (*Figure IIa*) of a number of essential resources—including copper, oil, natural gas, coal, uranium, and many of the rare earth elements that are essential for most electronic products and green technology (Kockarts, 1973; Bentley, 2002; Hirsch, 2005; Pfeiffer, 2006; Bardi, 2009). Perhaps more seriously, phosphorus (an essential fertilizer for food production) and water are also thought to have reached peak supply Abelson, 1999; Gleik and Palaniappan, 2010). As resource harvesting passes the peak, both the extraction costs and risks associated with extraction escalate rapidly.

It has been suggested that as an economy evolves, a period of environmental decay gradually decreases as incomes improve, and after a certain point environmental feedback will ultimately solve the problems of the environment itself. Three factors drive this process: a structural change in the economy, from industrial to service industry, a demand for environmental quality and improved technology (Turner and Hanley, 2010).

Figure I. Significant literature on the Economy-Environment-Society-Economy (EESE) cycle.



(1) Sprohge and Sirisom, 2011; (2) Cochard, 2011; (3) Koh et al., 2011; (4) Dobrovolski et al., 2011; (4) Newburn et al., 2011; (5) Mantyka-Pringle et al., 2012; (6) Moss et al., 2011; (7) Beddington et al., 2011; (8) Fereres et al., 2011; (9) Karp and Richter, 2011; (10) Howard et al., 2011; (11) Chappell and LaValle 2011; (12) Farah and Rossi, 2011; (13) Lal, 2007; (14) Falkenmark, 2001; (15) Webersik, 2010; (16) Scheffran and Battaglini, 2011; (17) Arnold, 2009; (18) Gunasekera et al., 2011; (19) Rowhani et al., 2011; (20) Keay and Metcalf, 2011; (21) Okpala and Jonsson, 2002; (22) Schanbacer, 2010; (23) Messer, 2009; (24) Ehrlich et al., 1993; (25) Oldeman, 1998; (26) Zhang and Liu, 2006; (27) Geick, 1993; (28) Timmer, 2000; (29) Gallopin and Rijsberman, 2000; (30) Pfister et al., 2009; (31) Omer, 2008; (32) Ikein, 2009; (33) Kalicki and Goldwyn, 2005; (34) Scheffran and Battaglini, 2010; (35) Lewis, 2009; (36) Perreault and Valdivia, 2010; (37) Burns and Price, 2009; (38) Lant et al., 2008; (39) Fisher et al., 2008; (40) Shackleton et al., 2010; (41) Egertson et al., 2004; (42) Zhang et al., 2007; (43) Küstermann et al., 2008.

This is a form of Smith's *laisez faire* approach, wherein the economy will ultimately lead to a better world. This curve (*Figure IIb*) is called an *Environmental Kuznets Curve* (EKC), and is derived from a relationship between inequality and income, proposed by Simon Kuznets in 1955 (Kuznets, 1955). However, while a small number of pollutants appear to follow this pattern, such as nitrous oxide and water pollution from faecal matter, recent research has shown that for the vast majority of limited natural resources, such as coal, and the damage done to ecosystem services, no such relationship exists (Picton and Daniels, 1999; Fischer-Kowalski and Amann, 2001; Seppälä et al., 2001; Tisdell, 2001; Millimet et al., 2003).

Counting the Cost of Environmental Abuse: The Triple Bottom Line

The relationship between the economy, the environment and society has been termed the *triple bottom line (*Elkington, 1997; Savitz & Weber, 2006, Hacking and Guthrie, 2008), bringing together social, environment, and economic goals (sometimes referred to as *people, planet, and profits*). These three areas are also known as the three pillars of sustainability (Clift, 1995b; Parkin, 2000; Hammond, 2004)

The triple bottom line emphasises that economics is intrinsically linked to both society and the environment. Adam Werbach (2009) has taken this concept further, incorporating culture as a fourth element, in a *quadruple bottom line*. He describes these four coequal components for true organizational sustainability in the following way: economic—operating profitably; social—acting as if other people mattered; environmental—protecting and restoring the ecosystems; cultural—protecting and valuing cultural diversity. However, most writers view culture as a subset of the social element.

Social issues span a wide range of elements which are important to business, including consumer choice, human resources, management, and equality and sovereignty issues (Hoffman, 2003), while environmental impacts range from resource issues, feedback and ecosystem services. Poverty interacts with environmental degradation and economic stability, while gender issues have significant impacts on population rate of increase and social stability. The environment in turn impacts upon social structure and economic stability, as detailed in *Figure I*.

Several authors have explored the relationships between the environment, the economy and society, often using Venn diagrams to represent different emphases. These are summarized in Figure III. Hunter gatherers found their context within the environment, and changes in the environment determined the success and failure of humankind. Human society was clearly a subset of the environment, with little or no economic activity, other than balancing each individual's physiological energy

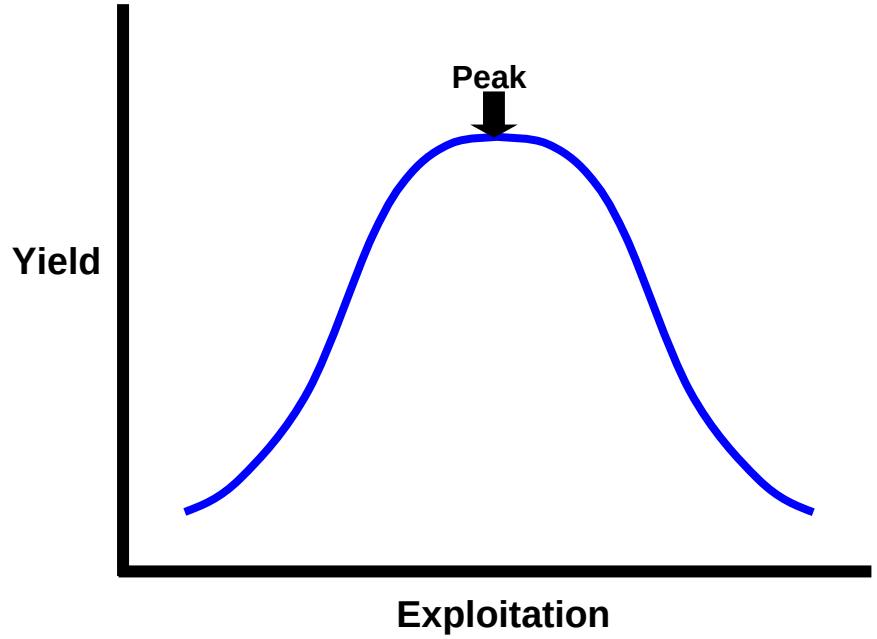


Figure IIa. The peak oil or Hubbert curve. As exploitation increases, yield increases, but, as the resource is limiting (Boulding's '*spaceship Earth*') then yield decreases with increasing exploitation (Hubbert, 1956; Brandt,2007). The tipping point for many of the world's resources may have already occurred, or will occur in the coming years. See text for references.

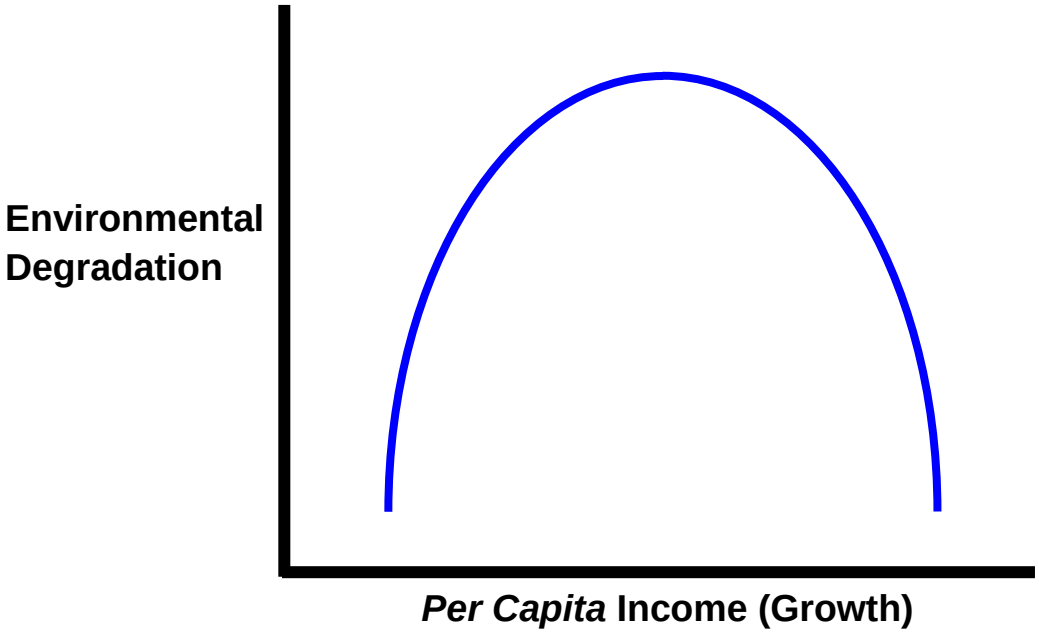


Figure IIb. The Environmental Kuznets Curve (EKC), suggesting that with increasing income, humans spend this money on an increasingly higher energy lifestyle, leading to greater environmental degradation. However with greater income still, they become aware of this damage and seek to conserve their environment. At even higher incomes, they actively seek to restore the environment. This thinking is strongly alligned with economic positivism of Adam Smith, but empirical data does not support it (see text for references).

budget, certainly at the outset. Humans, like most of the rest of nature, either ate, died or migrated (Haberl et al., 2011, Skene, 2011).

The Enlightenment brought the economy to the forefront wherein human progress could be driven by a successful, laisssez-faire economic model, driven by the invisible hand (Smith, 1994). Many of the Enlightenment philosophers viewed Nature as a constraint, as it had been to the hunter-gatherer and the Agrarian era, and with new technology and reasoning, as a burden that could be shaken off (Figure IIIb). The Marquis de Condorcet, a leading philosopher and revolutionary, wrote, in 1779, "*Nature has fixed no limits to our hopes*" (Condorcet, 1980) Instead, nature, raw in tooth and claw, could be tamed and reduced to a resource.

Distilled from this beginning, the *technocentric model*, or *Cowboy Economy* of Boulding (1966) emerged, is represented in Figure IIIc. Here, the economy is the most important aspect, and the environment and society are unimportant, and seen as detached and irrelevant.

A slightly more contiguous model, Figure IIId, places the environment and society as subsets of the economy, with the economy still holding the dominant position, with society as beneficiaries, and the environment as its slave. With the abolition of slavery and improvement in working conditions, workers rights and consumer rights, the economy had to be mindful of the worker and the consumer.

Van Loon et al. (2005) use a sustainability tripod model (IIIe) that incorporates the economic, social, and environmental sectors, and views the overlap of all three areas as a sustainable approach. Here, each pillar supports the others, and informs the others, and a balance is reached.

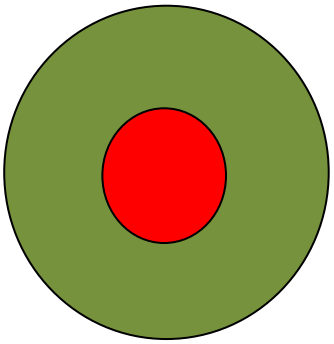
Finally, Figure IIIe represents the latest Biocentric movement, the pluriverse, wherein a diversity of economic models co-exist, and the future is seen as a pluralistic culture, with an end to globalization (Escobar, 2012). In this most radical of , the environment must take priority over all else. Yet in many ways it traces its origins back to the earliest model, Figure, IIIa.

Environment-Economy Interactions

Costanza et al. (1997) estimated that, while global Gross National Product was equivalent to $18 trillion at that time, the contribution of "free" ecological services (not shown on any business ledgers) was calculated to be about $33 trillion—almost twice as much as the human economic activity, as measured by GNP (see also Costanza & Daly, 2002). Dodds et al. (2009) reported that the cost of eutrophication in the United States of America (caused by agricultural waste flowing into fresh water bodies) was around $2.2 billion each year. The cost of overfishing in Europe alone is

Figure III. Different worldviews on the relationship between Economics (**blue**), the environment (**green**) and society (**red**). **a.** The Ancient Biocentric Model or hunter gatherer relationship, where society was entirely shaped by and dependent on the environment. **b.** The Enlightenment Model, where the environment was viewed as one of the constraints from which progress would free humankind, with the economy dominating. **c.** The Technocentric Model, with economics being the only player. **d.** The Post-Slavery Model, acknowledging the existence of society and environment. **e.** The Triple Bottom Line Model, where sustainability emerges from the overlap of all three sectors. **f.** The Pluriverse Model of co-existent non-globalism, a pleuralist movement (See text for references).

IIIa.



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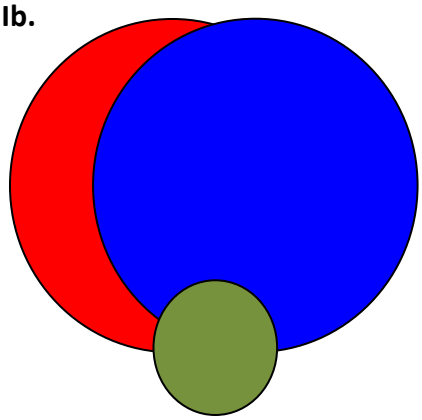
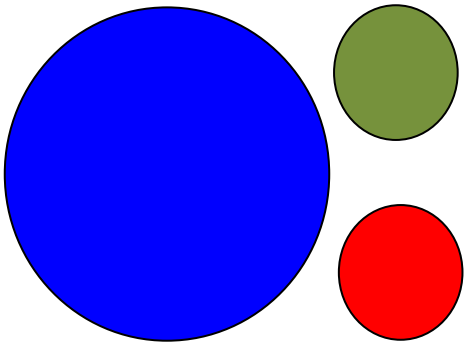


IIIc.



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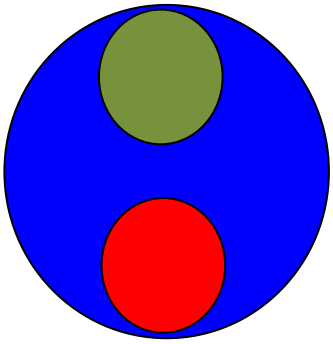
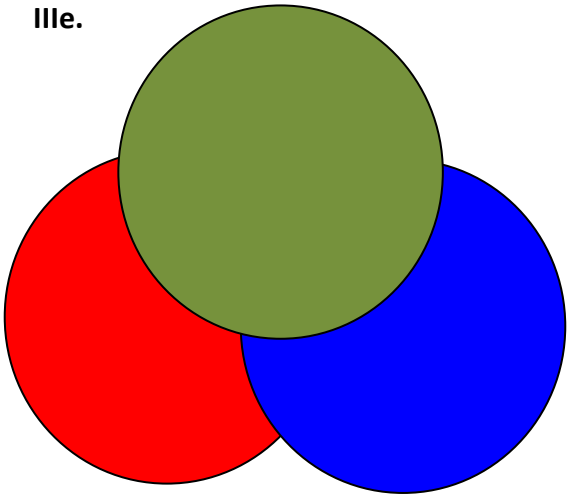


IIIe.



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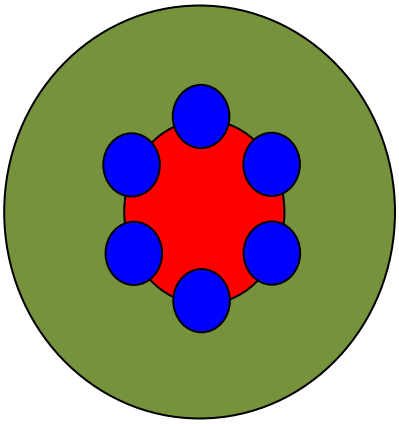

estimated at £2.7 billion each year, and is responsible for the loss of one hundred thousand jobs (Crilley, 2011).

Estimates of costs from global warming range between 5-20% of global GDP each year (Stern, 2006), which currently represents an annual loss of between US$3.2 trillion and US$12 trillion each year (based on World Bank figures of global GDP in 2010 equalling US$63 trillion). UNEP (2010) report that environmental costs to the global economy will rise from US$6.6 trillion in 2008, representing 11% GDP, to US$28.6 trillion in 2050, representing 18% global GDP.

The concept of *natural capital* emerged as a way of valuing the impact of a functioning environment upon economics (Schumacher, 1973; Costanza and Daly, 1992; Hawkins, 1994; Constanza et al., 1997; Hawken et al., 1999). Balmford et al. (2002) noted that protection of a habitat, rather than its consumption, represented an economic benefit to loss ratio of 100:1.

Environment-Society Interactions

The deterioration of the environment plays a significant role in social inequality and instability. The degradation of ecosystems poses a far more immediate threat to the poor than it does to people living in industrial societies (Martinez-Alier, 2002), as they are more impacted by ecosystem service collapse. The World Resources Institute (2004) has stressed the importance of environmental governance at every level of society. Certainly famines induced by droughts have over-turned many dynasties, including the Moche and Mayan civilizations, the Anasazi, the Early Egyptian Kingdom, the Late Uruk Mesopotamian society, the Tinanaku Andean civilization, the Akkadian Empire and the Khmer civilization at Angkor (Abbott et al., 1997; Bar-Matthews et al., 1999; Buckley et al., 2010; Cullen et al., 2000; Dalfes et al., 1997; Goring-Morris and Belfer-Cohen, 1997; Hodell et al., 2001). Drought means crop failure, crop failure means famine, and famine unravels both social structure and economics.

Economy-Society Interactions

Vatn (2005) states that without economic growth industrialized societies would fall into crisis. Indeed political stability is an essential component of economic growth (Jong-A-Pin, 2009). The socio-economic system is complex, often demonstrating paradoxical behaviour (Doener, 1997; Helbing et al., 2000; Helbing and Mazloumian, 2009). Societies can demonstrate discontinuous transition, producing *cusp catastrophes* that can occur extremely quickly without warning (Tainter, 1988; Stiglitz, 2003; Meadows et al., 2004; Newman et al., 2006; Scheffer et al., 2009).

And so it is generally acknowledged that continued resource exploitation at the current rate will not be sustainable, and that sustainability itself can only be achieved if these three pillars, economics, environment and society, are approached in a holistic way. This has led to a range of suggestions for how best to respond to the spectre of economic, environmental and societal collapse. The most recent of these, whose significance is underlined by its adoption by the government of the largest country in the world, China, is called the *circular economy*. In order to understand what a circular economy represents, we need to examine the historical context of this school of thought.

Defining the Circular Economy: A Brief History of Sustainable Development

It has often been remarked that the history of an idea tells us more about the idea than the idea itself. So where did the concept of the circular economy emerge from?

Ancient Beginnings on the Path to Sustainability

Thoughts relating to finite resources, and the implications of diminishing resources, have been around, most likely, for as long as humans have existed. Ancient writings reflect on the need to set aside some part of the harvest in case of failure in the following season.

Desrochers (2002a, 2002b, 2008) argues that the principles of sustainability, based on recycling and the efficient use of resources, stem from ancient times – where lack of imported resources meant symbiosis was essential, for example in Asian village life in the middle ages. At these times, globally, there were limited resources, and so people developed tight cycles of material use.

Desrochers demonstrated that closing the loop of resource use and waste was viewed as a good business opportunity in every facet of activity, questioning why such activities have become so “foreign” to modern industry, in which the linear model of “raw materials in” at one end and “wastes out” at the other end became common practice. He argued that a recycling economy is actually part of our culture, and so it is a matter of re-awakening this within society, rather than needing to create a new approach.

The modern concept of sustainable development was first defined by the Brundtland Commission, otherwise known as the World Commission on Environment and

Development, as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (Brundtland, 1987). Sustainable development has been variously conceived in terms of vision expression (Lee, 1993), value change (Clark, 1989), moral development (Rolston, 1994), social reorganization (Gore, 1992) or transformational processing (Viederman, 1994) toward a desired future or better world. Mason (2011) defined sustainability as intra- and inter-generational justice, with the prevention of social and ecological harm.

Two different operational concepts have developed: *economic sustainability* (the continuance of economic growth and capital maintenance, both produced and natural) and *ecological sustainability* (reduction in source and sink impacts on the environment by de-materializing the economy) (Bartelmus, 2001).

Industrial Ecology

Perhaps the most significant concept in recent years has been *industrial ecology* (Allenby, 1998). Variously described as a process at the level of the regional industrial system and at the societal level where the concept and routines of industrial symbiosis diffuse (Boons et al., 2011), as a collective, multi-industrial approach to improve economic and environmental performance through the use of wastes/by-products as substitutes for raw materials (Costa and Ferrão, 2010) and as an evolving framework for the analysis and design of public policy, corporate strategy, and technological systems and products (Ehrenfeld, 2000).

It has come to incorporate much of the current thinking in sustainable development. It emphasises flow of materials and energy (White, 1994), and has been described as the network of all industrial processes, much like biological ecology (Frosch, 1992). Indeed, it was Frosch and Gallopoulos (1988) who made this comparison clear when they described "an industrial ecosystem" as one where "the consumption of energy and materials is optimized and the effluents of one process ... serve as the raw material for another process". In the same year, the eponymous Winter Model laid out twenty-two clear guidelines for the application of industrial ecology for business management (Winter, 1988). Dijkema and Basson (2009) show the relevance to the three pillars of sustainability, by defining industrial ecology as interacting technical and social networks embedded in the biosphere.

The concept of industrial ecology is normally seen as working on three levels: intra-firm (within a given company), inter-firm (involving a group of companies) and regional.

Intra-firm Industrial Ecology

The application of industrial ecology at the individual firm basis incorporates clean technology, cleaner production, design for the environment (DfE), life cycle assessment and green chemistry.

Clean technology (abbreviated, often, to *Cleantech*) is an economically competitive and productive technology that aims to use less material and/or energy, to generate less waste and to cause less environmental damage than the alternatives (Clift, 1995a). The term was first used by Keith Raab and Nicholas Parker, founders of the Cleantech Venture Network (now Cleantech Group), and by the journalist, Joel Makower, in 2002, particularly referring to solar, biofuels, fuel cells, water remediation, and renewable power generation (Pernick and Wilder, 2007). The emphasis went far beyond the environmental or "green" technology of the 1970s, which was consumed with regulations and end-of-pipe issues. Rather, it incorporated new-technology business models, and defined a new investment asset class, making it relevant to business, with market economics at its heart (Bürer and Wüstenhagen, 2009). It includes processes, practices and tools and is seen as a means of uniting grassroots movements with the business sector (Horwitch and Mulloth, 2010). The term "greentech", which is often used interchangeably with cleantech, was popularized by venture capitalists John Denniston and John Doerr from Kleiner Perkins (Dikeman, 2009; Rubino, 2009).

Cleaner production was defined by UNEP in 1990 as: *"The continuous application of an integrated environmental strategy to processes, products and services to increase efficiency and reduce risks to humans and the environment"* (UNEP, 1990). It is also known as *Resource Efficient and Cleaner Production* (RECP), which has three main aims: *production efficiency* (through optimization of productive use of natural resources at all stages of the production cycle), *environmental management (*through minimization of the adverse impacts of industrial production systems on nature and the environment) and human development (through minimization of risks to people and communities, and support to their development). As can be seen, it addresses all three pillars of sustainability, the triple bottom line (UNEP, 1990, UNESCO, 1992))

Another intra-firm approach is the ***Design for the Environment Program*** (DfE). Developed as a United States Environmental Protection Agency (USEPA) program in 1992, though first coined by Branden Allenby (Allenby, 1991), it aims to prevent pollution, and the concomitant risks to humans and the environment, from services, processes and products (Allenby, 1991), from manufacture through to end-of-life (Boks, 2000). The environment helps to define the direction of design decisions (van Hemel 1998). DfE is mirrored in Europe by the concept of *ecodesign* (van Hemel, 1998).

The approach has spawned many sub-divisions, such as: Design for Supply Chain (Esterman et al. 1999), Design for Ownership Quality (Kmenta et al. 1999), Design for Assembly (Boothroyd et al. 1994, Kmenta 2000), Design for Serviceability (Gershenson et al. 1991), Design for Product Retirement (Ishii et al. 1994), Design for End-of-Life (Rose et al. 2000) Design for Recyclability (Ishii et al. 1996) and Design for Product Variety (Martin 2002).

Life Cycle Assessment (LCA) is a validation technique, and is a broad methodology for identifying environmental burdens that arise from products through the material suppliers, through manufacture, use and disposal (SETAC 1991, EPA 1993). A growing consensus is that LCA cannot appropriately separate internal and external issues, which makes the application to industry almost impossible, since cause and effect cannot be separated (Brezet et al. 1999; Stevels, 2001).

New technology to support firms became important. In the early 1990s, the US Environmental Protection Agency (Ember, 1991) coined the term ***green chemistry***, meaning the promotion of innovative chemical technologies that reduce or eliminate the use or generation of hazardous substances in the design, manufacture and use of chemical products. Twelve principles of green chemistry have been identified (Anastas and Warner, 1998): 1.Prevention; 2. Atom Economy; 3. Less hazardous synthesis; 4. Safer chemicals; 5. safer solvents; 6. Energy efficiency in production; 7. Renewable raw materials; 8. reduced derivitives; 9. increased catalysis; 10. easier degradation; 11. real time pollution monitoring; 12. safer production. The recent history of this concept is well discussed in Anastas and Kichhoff (2002).

Inter-firm Industrial Ecology

Relationships between firms are viewed as extremely important. In industrial ecology, not only should a single firm take responsibility for environmental impacts of its suppliers and consumers, but also by working in groups, firms can use waste products of other firms, thus reducing resource drain and waste production. This process is called ***industrial symbiosis***, and operates through conglomerates of firms called eco-industrial parks.

The interaction of groups of businesses, connected by waste-substrate linkage, is the domain of *industrial symbiosis*. Desrochers and Leppälä (2010) refer to some very early uses of the term *industrial symbiosis*, including Parkins (1930), Lezius (1937), Gunnell (1939), Eyre (1963) and Banerjee and Roy (1967).

The term is defined in the Dictionary of Sociology in 1944 as "*a grouping within a community of independent manufacturers, who are able to benefit by using each other's products*" (Fairchild, 1964).

Meanwhile the concept of using waste of one industry as a resource for another industry (basically the "*Waste is Food*" school of thought that underpins almost all modern economic sustainability thinking) has been around even longer. Simmonds (1862), one hundred and fifty years ago this year, discussed the fact that "*in every manufacturing process there is more or less waste of the raw material, which it is the province of others following after the original manufacturer to collect and utilize*" and, he later noted that this practice was widespread throughout Europe and America (Simmonds, 1867). Other early references to this can be found in Razous (1905), Koller (1918) and Kershaw (1928). It can clearly be seen, then, that the concepts of industrial symbiosis, and eco-industrial parks, have been around for a very long time. As Picasso is famously reported to have said, on viewing the 16000 year old cubist cave paintings in Lascaux, France, "We have invented nothing new!" (Rudgley, 1998).

Industrial symbiosis finds its practical expression in *eco-industrial parks* (Lowe, 1997, Zhu et al. 2008). Here groups of businesses are geographically located in close proximity and share each other's waste materials to use as substrates.

Perhaps the most studied example is at Kalundborg, in Denmark (Ehrenfeld, 1997; Jacobsen, 2006; Domenech, 2011), which began spontaneously in the early 1960s (Grann, 1997), and combines an oil refinery, a pharmaceutical company, a plasterboard plant, a power plant, a soil remediation company and a fish farm. In Kwinana, Australia, an oil refinery, inorganic chemical producer, cement producer, pig iron plant, and titanium dioxide producer form part of an EIP with a total of fifty regional synergies. This "park" also spontaneously developed over time (van Beers et al. 2009).

China is now the centre of an industrial revolution embracing sustainability at its heart. Within this context, eco-industrial parks play a significant role in delivering change. These include the Guitang group, which started out some forty years ago, where a sugar refinery (one of the largest in China), an ethanol producer, a fertilizer plant, a cement works, a pulp mill, a paper plant and a thermoelectricity plant share waste products (Zhu et al 2007). The Pingdingshan Coal Mining Group has coal mining, coal processing, building materials and a chemical plant (Long and Zhang, 2009). The Lubei Chemical Group includes aquaculture, a bromine plant, a salt refinery, a sulphuric acid plant, a cement mill, an ammonium/phosphate plant, and a turbo-generator (Fang et al., 2007). The Suzhou industrial park combines electronics manufacturers and chemical manufacturers (Zhang et al., 2009).

In Ulsan, South Korea, a large eco-park has grown, guided by the Korean National Cleaner Production Center (KNCPC). There are over seventy symbioses, involving collective utility systems, by-product exchanges, shared connections for steam, recycled industrial water, all operating together. Companies include a metals refinery, a paper mill, an oil refinery and a chemical plant (Park et al. 2008). In Kawasaki,

Japan, a paper mill, a waste water treatment plant, a steel refinery, a scrap metal plant, and a cement works operate as an EIP (van Berkel et al. 2009).

Some observations have been made on these industrial symbioses. Firstly they are, generally, not purposefully designed to begin with, but rather, evolve over decades (Mathews and Tan, 2011). China's EIPs are therefore young and will increase in complexity over time. Latecomer status has costs and benefits. State control helps ameliorate fierce competition (Gerschenkron, 1962). Certainly in the United States of America, despite a number of successes, there is a concern that "*the vast majority of these projects [were] consigned to the dustbin of history [and] vanished as soon as their funding sources dried up*" (Lowitt, 2008) and that encouraging existing symbioses has led to "*more sustainable industrial development than attempts to design and build eco-industrial parks incorporating physical exchanges*" (Chertow, 2007).

A shift in emphasis has also been encouraged, moving from a reductionist to a systems-based approach. Gibbs (2008) suggests: "*cooperation between firms as opposed to focusing on action at the level of the individual firm, seeing firms as nodal points within a networked ecosystem*".

Regional Level Industrial Ecology

Finally, at the regional level, comes the field of ***Industrial metabolism*** and the cradle-to-cradle concept. Industrial metabolism was most recently introduced by R.U. Ayres in 1989, who compared traditional industry with early life on the planet Earth, where bacteria used the iron and sulphur from hydrothermal vents to power their metabolisms (Ayres, 1989). Instead, Ayres said we needed to mimic more advanced life, where nutrients were cycled through the Biosphere, powered by the Sun. Thus the global economy should run like the modern Biosphere, interconnected and recycling material throughout the entire system.

This concept actually goes back more than one hundred and fifty years and developed from an understanding of material and energy exchange (the nineteenth century meaning of biological metabolism) rather than the functional substrate-product cycle of modern biochemistry (Fischer-Kowalski, 2003). Recent work highlights the importance of regional aspects of industrial ecology (Matsunaga, 2000; Liu et al., 2012). A number of regional studies have been recorded in the literature, such as Dalian (Geng et al., 2009) and Liaoning (Xu et al., 2008).

Some confusion in the literature exists as to whether industrial metabolism is a subset of industrial ecology, or the other way around: Korhonen (2003) wrote "The method is applied to common industrial metabolism tools of ecological footprints (EF), environmental life cycle assessment (LCA) and industrial ecology (IE)", whereas Tang et al (2011) state that "*Three methods analogous to nature systems*

are used to conduct research on industrial ecology: industrial metabolism, life cycle management and industrial symbiosis."

In addition to industrial ecology two other major fields exist in sustainable development: *environmental economics* and its younger sibling, *ecological economics.*

Environmental Economics

Environmental economics attracts economists, and stresses weak sustainability, looking at economic growth as essential, while facilitating environmental considerations through technology. The field of environmental economics emerged following the oil crisis of the early 1970s (Seneca and Taussig, 1974; Nijkamp, 1977), although the core values had been in place long before (see Cropper and Oates, 1992). Largely based on the theory of market failure, the field of environmental economics focuses on how various types of market failure create environmental damage (Cropper and Oates, 1992; Dorfman, 1993). Environmental economics approaches pollution primarily as an economic problem. Environmental economists are fundamentally concerned with the means of eradicating market failure because they believe that this will reduce environmental degradation and enhance economic and ecological sustainability. A perceived lack of input from social sciences has recently been attacked (Folmer and Johansson-Stenman, 2011).

Ecological Economics

Ecological Economics places its emphasis on ecology, and its proponents are mostly ecologists. It emerged as a response to a perceived failure of environmental economics to penetrate mainstream economic thinking into the 1980s (Spash, 2009). The history of ecological economics, and the infighting that accompanied it, has been beautifully recorded by Røpke (2004; 2005). Its emphasis is on strong sustainability economics, wherein ecosystem services should be prioritized, rather than technological mimicry (Daly and Farley, 2004). Economies are recognized as open subsystems within a closed Biosphere system (Victor, 2010). Fundamentally, ecological economics views GDP as an inappropriate measure of well being (van den Bergh, 2009). Ecological economics is more interdisciplinary than environmental economics, and both fields have a distinct group of authors and journals (Ma and Stern, 2006).

Gerber et al. (2009) and Hardy and Patterson (2012) raise concerns that while ecological economics covers two of the three pillars of sustainability (namely, the environment and the economy), there is, again, insufficient attention paid to the social implications. Indeed, a new field, called *socio-ecological economics* (Jacobs,

1996; Cameron, 2007), or *social ecological economics* (Spash, 2009), has developed to counter this (Spash, 2009).

The Circular Economy

A circular economy, or what is otherwise known as a "closed-loop" economy can be defined as a grand harmonization between industrialization and its natural limits. Germany and Japan were leaders in this field with legislation including the 1986 Abfallgesetz (AbfG: Waste Avoidance and Management Act), the 1991 Verpackungsverordnung (VerpackV: Packaging Ordinance), the 1996 Kreislaufwirtschaftgesetz (KrWG: Closed Loop Economy and Waste Management Act), and the 2005 Elektro- und Elektronikgerätegesetz (ElektroG: Electical and Electronic Equipment Act), from Germany, as well as the *The Basic Law for Establishing a Sound Material-cycle Society*, in 2000, in Japan (Triebswetter and Hitchens, 2005; Moriguchi, 2007, Bilitewski, 2007).

Tim Cooper, one of the earliest protagonists of the circular economy in the United Kingdom, comments that: "*The model of a linear economy, in which it is assumed that there is an unlimited supply of natural resources and that the environment has an unlimited capacity to absorb waste and pollution, is dismissed. Instead, a circular economy is proposed, in which the throughput of energy and raw materials is reduced"* (Cooper 1999).

In its most basic form, a circular economy can be loosely defined as one which balances economic development with environmental and resources protection (UNEP, 2006) and in this form, it appears to be inseparable from industrial ecology, or, indeed, sustainable development. Its uniqueness comes from two interconnected ideas, the closed-loop economy and the cradle to cradle thinking.

Closed Loop Economy and Cradle-to-Cradle™

The concept of cradle-to-cradle has been disputed in terms of its origins. McDonough and Braungart say, in their book *Cradle to Cradle: Remaking the Way We Make Things* (North Point Press, 2002),"*Products can either be composed of materials that biodegrade and become food for biological cycles, or of technical (sometimes toxic) materials that stay in closed-loop technical cycles, where they continually circulate as valuable nutrients for industry."* The term 'C2C Certification' is now a protected term of the *McDonough Braungart Design Chemistry* (MBDC) consultants. However, supporters of Walter Stahel claim that he coined the term in the 1970s (Product-Life 2008). There is no doubt in the literature that Stahel first used the term "*economy in loops*" (Stahel, 1976), which is thought to have led directly to the term "*circular economy*".

Stahel founded the Product Life Institute in Geneva whose main goals were product-life extension, long-life goods, reconditioning activities and waste prevention. Kodak, DuPont, the BBC and Bosch are among its clients. The concept of delaying death of products by investing in longevity and service was very much an idea of Stahel, who said that an improved service industry could balance a loss in manufacturing, thus allowing the circular economy to be a financial success (Stahel, 2003). He also introduced the concept of a performance economy which he defined as economic actors achieving sustainable profits in the long-term without an externalization of the costs of risk and of waste (Stahel, 2006).

Braungart and McDonough went further, stressing that the long-life approach merely delayed the inevitable re-introduction of toxins back into the environment. Instead the proposed a redesign of the industrial processes altogether. This became known as the *Waste equals food* approach, where "one organism's waste is food for another, and nutrients and energy flow perpetually in closed-loop cycles of growth, decay and rebirth (McDonough and Braungart, 2003). Waste includes energy, water, material and information. However, as we have already noted, this concept has been around for at least one hundred and fifty years.

UNEP (2006) develop the definition of circular economy as featuring low consumption of energy, low emission of pollutants and high efficiency. It involves applying cleaner production in companies, eco-industrial park development and integrated, resource-based planning for development in industry, agriculture and urban areas. They further developed this definition as a generic term for an industrial economy which is, by design or intention, restorative and in which material flows are of two types – those which are biological nutrients, designed to re-enter the biosphere safely, and technical nutrients, which are designed to circulate at high quality without entering the biosphere. The aims are to 'design out' waste, return nutrients and recycle durables, using renewable energy to power the economy (UNEP, 2006). The use of the word "*restorative*" is important, as it is not merely a preventative approach, reducing pollution and arresting the decline, but seeks to move towards an improvement. In 2010, Joke Schauvliege, president of EU Environment Council stated: "*We must deal with our materials, and with our energy, more efficiently. At the end of their life we must be able to reuse materials as new raw materials. This is called completing the cycle."* (EUTRIO, 2010).

Biomimicry

Biomimicry is another concept that has become part of the thinking behind a circular economy. Janine Benyus, author of *Biomimicry: Innovation Inspired by Nature*, defines biomimicry as '*a new discipline that studies nature's best ideas and then imitates these designs and processes to solve human problems'* (Benyus, 1998).

Studying a leaf to invent a better solar cell is an example. She thinks of it as 'innovation inspired by nature'. Biomimicry relies on three key principles:

- Nature as model: Study and emulate natural forms, processes, systems and strategies to solve human problems;
- Nature as measure: Using environmental monitoring to judge the sustainability of our innovations.
- Nature as mentor: using nature as a source of information, not of material.

Biomimicry has been integrated into the circular economy literature (Spiegelhalter and Arch, 2010; Mora et al., 2011). The concept of Biomimicry has been criticised for maintaining the separation between ourselves and our environment, and it has been argued that *bio-participation* would be a better approach, wherein human activities were embedded within the Biosphere, rather than mimicking small parts of it (Skene, 2011).

Drawing on concepts such as cradle-to-cradle, biomimicry and industrial ecology, the circular economy focuses on optimising systems rather than components. It goes beyond traditional notions of sustainability by focusing on the positive restoration of the environment ((Cooper, 1997; Nakajima, 2000; Pitt, 2011). The circular economy demonstrates new concepts of system, economy, value, production and consumption (Wu, 2005), leading to sustainable development of the economy, environment and society (Shen, 2007, Wu, 2005). The ultimate objective of the CE approach is to achieve the decoupling of economic growth from natural resource depletion and environmental degradation. In many ways, the circular economy is a general term covering activities that **r**educe, **r**euse, and **r**ecycle materials (referred to as the 3R approach) in production, distribution, and, consumption processes (Cooper, 1999). Hu et al. (2011) stress that the focus of the circular economy is on resource-productivity and eco-efficiency improvement, and uses for 4R approach: **r**educe, **r**euse, **r**ecycle and **r**ecover.

Four sources of value creation have been identified within a circular economy. These are: the power of the inner circle (less cost in production), the power of circling longer (lengthening lifetime of products), the power of cascading use (waste is food) and the power of pure circles (uncontaminated material streams reduce costs) (Ellen Macarthur Foundation, 2012).

The term "circular economy" was first used in the Western literature in 1980s (Pearce and Turner 1990) to describe a closed system of economy-environment interactions. The circular economy has been framed in an almost identical way as industrial ecology, with three levels of initiatives:

1. Single enterprise, involving a firm-level study of cleaner production, such as the work of Yuan and Shi (2009) on eco-industrial initiatives at a smelter;
2. Inter-firm clusters at supply chain level, represented by eco-industrial parks (EIPs) and involving industrial symbiosis

3. Entire cities/municipalities, incorporating industrial metabolism (Chertow and Lombardi 2005; Zhang et al. 2008, 2009, 2010).

A Global Literature on the Circular Economy

The circular economy has entered the literature on many countries around the world, including Australia (Roberts, 2004; Guirco et al., 2011), Austria (Gibbs and Deutz 2007), Belgium (Maes et al., 2011), Brazil (Elbras, 2009; Michelotti, 2011), Denmark (Costa et al, 2010), Egypt (Sakret al., 2011), Finland (Korhonen, 2001; Gibbs and Deutz, 2007), Germany (Gibbs and Deutz, 2007), Indonesia (Jupesta et al., 2011), Italy (Gibbs and Deutz, 2007), India, (Bain et al., 2010), Japan (van Berkel et al., 2009), Malaysia (Mohamed et al., 2011), Mongolia (Luo and Guo, 2011), Netherlands (Baas and Korevaar, 2010), South Korea (Park and Won, 2007), Portugal (Costa et al, 2010), Sweden (Gibbs and Deutz, 2007), Switzerland (Costa et al., 2010), UK (Gibbs and Deutz, 2007, Costa et al., 2010), USA, (Gibbs and Deutz, 2007) and Vietnam (Anh et al., 2011).

The Circular Economy in China

The circular economy as a concept has been most clearly defined, designed and delivered in China. In 2002, the sixteenth National Congress of the Communist party pledged itself to an ambitious blueprint of sustainable development over the next twenty years, targeting both a four-fold *increase* in GDP but at a *reduced* environmental cost, the utopian target of the circular economy. The National Development and Reform Council (NDRC) ordered that a Japanese document "*The Recycling-Based Society Law"* as well as documentation from Germany, be translated. The Japanese document outlined a series of laws that had been passed from 1990 to 2003, promoting recycling. Two particular laws, one from Japan (*The Basic Law for Establishing a Sound Material-cycle Society*, passed in 2000 (Moriguchi, 2007), and the *Closed Substance Cycle and Waste Management Act*, enacted in 1996 in Germany, pointed towards a circular economy, and these are believed to have had significant influence on Chinese policy (Mathews and Tan, 2011). However China would appear to be the first country in the world to make the circular economy a national strategy of economic and social development (Mathews and Tan, 2011), with their introduction of the *Law for the Promotion of the Circular Economy*, which came into effect on 1st January 2009.

Today, most of the literature on the circular economy either relates to or emerges from China, with several hundred papers being published each year. These includes general papers on the challenges of introducing the policy (Ren, 2007; Feng and Yan, 2007), regional issues (Chen et al., 2005; Xui, 2009; Geng et al., 2009), inter-firm issues (Geng et al., 2008, Yang and Fen, 2008) and social aspects (Liu et al., 2009). The National Development and Reform Commission (NDRC) in China is

leading the Circular Economy strategy at the national level. Under the NDRC's guidance, a circular economy will be achieved through a score of legislative, political, technical and financial measures.

South American Buen Vivir

Worthy of note are the new constitutions of Ecuador and Bolivia, introduced in 2008, which emphasise the rights of nature and the subordination of economic objectives to ecological criteria, human dignity and social justice (Escobar, 2012). *Buen vivir* (Spanish for *good life*) means living as part of the natural world. The rights of nature point towards a biocentric rather than an anthropocentric framework.

Barriers to Implementing a Circular Economy

"*At every level the greatest obstacle to transforming the world is that we lack the clarity and imagination to conceive that it could be different*". Roberto Unger, Brazilian Philosopher (Smolin, 1997).

A rich literature reflects upon the barriers to implementing a circular economy. These barriers divide into two types: *generic barriers*, that apply to all or most situations, and *specific barriers*, that apply to particular sectors of the economy.

Generic Barriers

Many authors have identified three types of generic barrier (often referred to as *lock-ins*) that pervade business, holding back progress in developing sustainable approaches:

-Technological lock-ins: (Kemp, 1994; Rip and Kemp, 1998; Kemp, 2000);
-Institutional lock-ins: (North 1990; Pierson, 2000; Foxon, 2002);
-Carbon lock-ins: (Unruh 2000; Unruh 2002; Unruh and Carrillo-Hermosilla, 2006).

Another significant generic barrier relates to a lack of ***information*** and a lack of clarity relating to sustainability. Lorenzoni et al. (2007) identify a number of difficulties relating to information, including: a lack of knowledge about where to find information; a lack of desire to seek information; a perception of information over-load; a confusion revolving around conflicting information or partial evidence; a perceived lack of locally-relevant information; information that is not accessible to non-experts; a perceived lack in credibility relating to the source of information; confusion relating to links between environmental issues and their respective solutions; and information in conflict with values or experience.

At the most basic level, there is confusion over what sustainability itself means. Given the multitude of schools of thought pertaining to sustainable development, each emphasising a different set of criteria for progress, this is not surprising. These schools range from technocratic or weak positions through to ecocentric or strong positions, and evolutionary through to revolutionary ideas (Pearce *et al*., 1989; Turner, 1993; Gibbs, 1997; Pearce & Barber, 2000; Pepper, 2000).

Boons and Baas (1997) indentify a ***lack of co-ordination*** within companies as creating a significant hurdle. Political divisions, segmented responsibility and protective departmental interests can shield organizations from identifying the potential economic benefits of sustainability initiatives. These are termed *organizational silos* and form significant barriers to transition in companies (Lovins and Lovins, 1997; Alter, 2002; Doppelt, 2003; Choo, 2008; Whiteman, 2011).

Capital budgets can prevent plant managers from making wise long-term decisions, related to total lifespan costing of plant equipment. Capital planning is often designed around economic metrics that encourage actions which damage the environment or ignore social consequences (Hoffman and Bazerman, 2007). Habitual routines, fear of the unknown, resource limitations and threats to established power bases all form resistance to transition (Hoffman and Bazerman, 2007). Indeed the corporate sector has been identified as a significant barrier, due to its emphasis on economic growth. Directors are politically powerful, while growth and cost cutting lead to profits (Ritz, 2001; Hamilton 2003; McGregor, 2006). Financial markets can also present significant barriers to change (Schmidheiny, 1996).

A ***lack of a cohesive policy framework*** at a government level can be problematic. For example, in their recent report, *Seizing the Sustainability Advantage,* Consult Australia state that leading Australian firms in the built and natural environment sectors raised concerns about national and state policies inhibiting transition to a sustainable economy (Consult Australia 2011). Policy strategies have also been implicated in slowing eco-innovation (del Rio et al, 2010). Business tends to be reactive rather than proactive towards sustainable development, particularly if it is enforced by policy (Chatterton and Style, 2001). The lack of involvement of the consumer in any analysis has also been identified as problematic (Hertwich, 2005). Often, pro-environmental attitudes already exist within business, but converting this into operational changes has been identified as a key obstacle (Tilley 1999, Schaper 2002, Revell and Blackburn 2007).

Doppelt (2003) emphasised a ***patriarchal approach*** from senior management, preventing new thinking, as the most serious intra-firm barrier to transition. In addition, confusion over cause and effect (i.e. treating the symptoms rather than the underlying causes) and a failure to institutionalise sustainability, create impediments to change (Doppelt, 2003). An assumption referred to as the *mythical fixed pie of negotiation* (the belief that negotiators are fighting over a finite pool of resources and

that there can only be a win-lose outcome) is often accompanied by the belief that environmental change will always be bad for the company (Bazerman, 1983; Bazerman, Magliozzi & Neale, 1985; Pruitt & Rubin, 1986). Lorenzoni et al. (2007) highlight denial, lack of faith in alternatives, faith in technology to solve problems and being too busy to change as sticking points.

Another generic problem, in terms of it affecting all sectors of business, is the use of ***inappropriate technology*** in particular cultural contexts. Examples include large-scale hydro-electric projects, that displace thousands of people and change landscapes and ecosystems, or the introduction of mechanized straight line harvesting in areas where agriculture is small scale, community-owned and engaged in poly-culture (Black, 2007). Ryan and Vivekananda (1993) discuss a number of smaller scale inappropriate approaches including the introduction of grinders powered by bicycles into villages where, normally, women grind flour, but only men use bicycles. They also cite the promotion of smokeless cooking stoves into areas where smoke from fires plays a major role as a deterrence to malaria-carrying mosquitoes, and building solar-powered stoves in locations where, traditionally, cooking takes place after sunset. Yet the use of appropriate technology is often perceived as a "*poor person's*" technology and too difficult for a multinational company to accommodate (Zelenika and Pearce, 2011).

Another region-specific issue relates to the natural resources available. Countries with large supplies of fossil fuels and other important resources, often referred to as ***mineral-energy complexes***, such as South Africa, have low coal prices, and so it is more difficult for alternative technologies to compete economically. The low energy price means there is little incentive to develop alternative energy sources or energy efficiency (Fine and Rustomjee, 1996; Winkler and Marquand, 2009).

In Europe, small and medium enterprises (SMEs) account for sixty-four percent of environmental damage (Calogirou et al., 2010). In the UK alone, forty-five per cent of total UK business energy use is by SMEs, broadly in proportion to their share of the economy (Vickers et al. 2009). SMEs are responsible for some forty three per cent of the serious industrial pollution incidents and generate sixty per cent of the commercial waste in England and Wales (Blundel et al., 2011).

Important ***differences in scale*** emerge, and small and medium enterprises (SMEs) can have very different obstacles compared to large businesses (Calogirou, 2010; Burch et al., 2011). In surveys, most SMEs recognized the importance of environmental issues, but few could envisage remaining as competitive (Taylor et al., 2003). Unless there were regulatory and political checks, market-led actors are under pressure to externalize social and environmental costs (Stern 2009). Also environmental legislation was not clear to many SMEs (Vickers, 2009).

Willard (2005) indentified the three most significant barriers for SMEs when undergoing transition as perceived/actual costs, lack of awareness of business

benefits, and resources (time, money and knowledge). Barriers such as cost implications, management time, and other priorities have been listed as significant obstacles to sustainability in a survey of eight hundred businesses in New Zealand (Lawrence et al., 2006).

The obstacles to sustainability become increasingly important when companies, operating globally, have to deal with the added factors of international legalities and the need to cater to different cultures, because these can require a different suite of corporate responsibility activities (Vidal & Kozak, 2008).

Sector-specific Barriers

In addition to these generic issues, each business sector has specific barriers relating to their particular situations.

In ***agriculture***, federal farm programs and environmental constraints were highlighted as the primary barriers to sustainable practice (Drost et al., 1996). In addition, significant heterogeneity between farms, in terms of landscape, soil and practice, make any generalized policy difficult to implement (Drost et al., 1996).

Roberts and Lighthall (1993) developed a three tiered model used to outline some of the challenges farmers face in adapting to traditional agriculture. The three tiers are separated into market and policy imperatives that include competition and innovations in markets, the system of production and accumulation including land, labour, and capital, and the climate, soil, and topography that makes up the agro-ecological environment.

For many of today's farmers, the increased labour requirements of most traditional farming practices present a significant barrier to change. With the average age of farmers being above fifty years of age, and the increasing numbers of young people migrating to the cities in order to find better paid jobs, the farm labour problem is significant (Northwest Area Foundation 1994; Netting 1993)

The concept of manure exchange (as a means of forming an industrial symbiosis in farming) was seen as being hindered by neighbour complaints relating to odour, representing a significant barrier to manure exchange (Battel and Krueger, 2005). Disagreement over who should spread the delivered manure, giver or receiver and concerns about spreading weed seeds within the manure were also were raised (Battel and Krueger, 2005)

Social barriers, infrastructure, land tenure and incompatibility and irrelevance of government support programs are identified as significant issues (Rodriguez et al., 2009). Of these, land tenure is a particularly difficult issue. Half of all farmland in the USA is rented, and so the complexities of landlord, tenant and agricultural agency

professionals, each with their own targets and motivations, makes it very difficult to produce change on the ground (Carolan, 2005). Furthermore, the benefits of sustainable agricultural practice are less tangible to the farmer than the benefits of conventional farming, while the costs of sustainable practice are more visible than the costs of conventional practice (Carolan, 2006). Allen et al. (1991) stress that social inequality, in terms of both hunger and poverty, must be addressed within any agricultural sustainability policy, and that, at present, the social pillar of sustainability is under-emphasized in comparison to economy and the environment.

Import tariffs and sustainability certification system remain significant ***barriers to biofuel expansion*** (Junginger et al., 2011). Planning consent is extremely slow for alternative energy technology. It takes two years, on average, to gain planning permission for wind turbine in UK and 25 months for gas storage projects. (BERR, 2007).

The ***construction industry*** is dominated by the cement industry, which is the largest user of natural resources and one of the largest consumers of energy, yet much more environmentally friendly concrete is available, which lasts much longer, thus not requiring replacement. However, it takes longer to install. Significant barriers relate to the need for speed in construction projects, out-of-date building codes, and profitability of short-lived buildings (Mehta, 2002).

Procurement of services by governments represents a huge global market, and one where the circular economy has the potential of having a huge impact (Taylor, 2006; Sustainable Procurement Task Force, 2006). However a number of barriers exist. Economies of scale put pressure on procurement in terms of buying in bulk, rather than in small parcels, the latter considered to be more expensive. This forms both a barrier and a lock-in, preventing sustainable development (Morgan, 2008). EU procurement rules mean it is illegal to specify “local” food in public catering contracts (Morgan, 2008). Through creative procurement policies, public bodies in Italy and France are able to purchase local food without specifying it as such (Morgan and Morley, 2002; Morgan and Sonnino, 2007).

There is a supply and demand problem, where small organic producers are unable to meet large contracts, or to expand quickly enough, such as with organic produce. Other barriers to localism include EU hygiene regulations which have made small local abbatoirs uneconomic (Morgan, 2008), preventing localism from developing.

The National Audit Office (2005) considers cost, knowledge, awareness, risk, legal issues, regulatory ambiguity, and leadership inertia to be key obstacles in the implementation of sustainable procurement. In one of the most comprehensive studies of sustainable procurement in the UK, the Sustainable Procurement Task Force (2006): added two further barriers: a lack of whole life costing and a lack of sustainable procurement skills.

A number of ***tourism barriers*** exist. Political issues impact upon sustainable tourism efforts, in that the 4-5 year electoral cycle is not sufficient to allow long-term policies to be activated (Yasarata et al., 2010). It has been suggested that sustainable tourism programmes require at least ten years (Dodds and Butler, 2010). Given the many parts of government that tourism impacts upon, there is a lack of co-ordination between government departments (Lickorish, 1991).

Tourism is judged by the numbers of visitors and cash input, rather than the net benefit to the destination, at all three levels (economy, society and environment) (Godfrey, 1996; Tosun, 2001), and is understood in a nested system model (Nitsch and Straaten, 1995) rather than an overlapping systems model (three pillars model).

The *tragedy of the commons* (Hardin, 1968), where each person takes what he wants from a given region without reference to the total exploitation occurring, is a system-level consequence of individual level attitude, values and behaviour, which is particularly relevant to tourism. Thus the failure to address issues at the personal and individual level of stakeholders, by promoting an altruistic attitude towards the environment, and a comprehension of the benefits for individuals within a society, have been a significant barrier to change (Parlato, 2004). Other barriers include: greater investment in marketing rather than sustainability, lack of stakeholder involvement, lack of a clear structure for roles and responsibilities, lack of integration of sustainable tourism into wider policy, and a lack of integration/coordination with other sectors (such as transport, etc) (Nitsch and Straaten, 1995; Dodds and Butler, 2010).

Inclusion of sustainability teaching, particularly in economics and business courses, is recognized as a crucial step if transition to a circular economy is to be realized. However, many barriers exist within ***tertiary education***, blocking this process. Moore (2005) listed a number of these obstacles, which include distinct hierarchies, competition between faculties for funding, too many pre-requisites within degree programmes (meaning students cannot take courses outwith their subject area), lack of policy implementation, and disagreement over course content (with each faculty demanding its own content).

Questions have been raised concerning the very ***concept of sustainable development***, in terms of its efficacy for achieving change, compared to other topics such as corporate social responsibility (Norman and MacDonald, 2003). Others question the extent to which the sustainability agenda could be injurious to corporate survival (Murray, 2005). So ambiguous and contentious is the concept that some have suggested that the term sustainable development should be scrapped, as it is more of a hindrance than a facilitator of change (Goodman, 2000).

Transition to a Circular Economy: Policies, Politics, Participation and Prospects

There is a growing literature on transition, and this addresses a most important issue: how best should the Circular Economy be implemented, given the barriers that exist. Based on the findings and results from a World Bank-supported circular economy study (Xie et al., 2009), four areas were viewed as being crucial to transition: a balanced mix of *policy* instruments, the appropriate participation of the government (*politics*) and the *participation* by both industry and the public in the CE approach. There is a significant literature on policy, politics and participation.

Policy

Transition policy plays an important role in facilitating the transition to a circular economy, influencing the speed and direction of change. Crucially, it targets societal transition (Hoffman, 2003). Transition policy acts best as an overarching policy goal that helps to align all other policies. Innovation policy, industry policy, energy policy, environmental policy and economic policy are then designed within a transition context. Foxon and Pearson, 2008; Alkemade et al., 2011)

A range of policy tools are viewed as important (European Environmental Agency, 2010a; 2010b), including financial incentives (DEFRA, 2009), information and advice (ETAP, 2011). It has been found that information and advice had much better outcomes than financial incentives. Once a financial incentive was stopped, uptake of sustainable technology stopped (Loorbach and Rotmans, 2010, NRC, 2011).

The importance choosing the most suitable types of policy for transition has been demonstrated by research into *community-based social marketing* (CBSM). This approach determines the significant barriers in a community, then design a programme specifically tailored to overcome these obstacles, pilots it and evaluates the results (McKenzie-Mohr, 1996; McKenzie-Mohr & Smith, 1999). Thus, CBSM designs environmental programmes based on psychological expertise, rather than information-rich marketing, which has been shown to fail (Geller, Erickson, & Buttram, 1983; Finger, 1994). In a case study in Durham Region, Ontario, Canada, CBSM reduced water use of lawns by 54%, while an information-rich approach led to a 15% *increase* in use. The approach had significant financial implications for the local authority, as it saved them almost one million Canadian dollars because it didn't need to build a new water treatment plant (McKenzie-Mohr, 2000).

Politics

The role of government is considered as central for the implementation of any transition to sustainability. Adger and Jordan (2009) have stated that the crisis of unsustainability is, above all, a crisis of governance. As Tim O'Riordan (2009) notes, governance for sustainability needs to foster conditions and incentives for civic virtue and comprehensive wellbeing. However, the political philosophy underpinning a particular government will have a significant impact upon how that government approaches facilitating the transition to a circular economy (Hess, 2009).

Welfare State Liberalism (social democracy) emphasises increased government intervention in the economy, incorporating the Keynesian belief that the economy could achieve equilibrium at undesirable levels of output and employment. Thus liberalism stresses *government intervention* to bring the economy to a socially desirable equilibrium (Wissenburg, 2001a; 2001b; Paton, 2004; Paton, 2011). F.D. Roosevelt's four freedoms speech, on 6th Jan, 1941 (freedom of speech, freedom of worship, freedom from want, freedom from fear), emphasised freedom from want as an important basis for intervention (Hess, 2009). One such liberal approach is the World Energy Modernization Plan. A tax on international currency transactions (the Tobin Tax) would allow redistribution of wealth for technology innovation in poorer countries, thus aiding equality (Patomäki, 2001).

Neoliberalism changes this emphasis, believing, as Adam Smith did (Smith, 1994), that freedom from want can be derived from market freedom, rather than welfare or labour politics. Trade liberalization and deregulation, less regulation, decreased government spending and the reliance on markets to solve social and environmental problems are all held as important for progress to be made. As global economy became more efficient and local ownership declined, manufacturing would move to poorer countries, and the *innovation economy* would replace it in richer countries.

The economy will become green in response to marketplace signals. As a commodity, such as oil, becomes scarce, then prices would rise, driving industry to develop alternative energy technology. Thus the neo-liberal approach would be to leave the market alone, because the market would naturally adjust without interference from government (Hartwick and Peet, 2003; McCarthy, 2005, Raco, 2005). Indeed, profitability would drive greening (Hawken et al., 1999).

State-centred socialism emphasises government ownership and control of large corporations for the benefit of all. This is the strongest form of government regulation and intervention. Here, government intervention is both essential and necessary, as government actually manages industry (Leff, 1993; Angus, 2001; Winson, 2006). In China, the government have played the role of leadership in promoting and facilitating the transition to a central economy (Yong, 2007).

Edward Goldsmith, former editor of The Ecologist magazine, claimed that "*The problems facing the world today can only be solved by restoring the functioning of those natural systems which once satisfied our needs, i.e. by fully exploiting those incomparable resources which are individual people, families, communities and ecosystems, which together make up the biosphere or real world*" (Goldsmith, 1988). E.F. Schumacher emphasised that sustainability would not work under neo-liberal, socialism nor liberal approaches, but rather required a new economy, stressing appropriate technology, ownership and national self-sufficiency (Schumacher, 1973). Hopkins (2008) and Estill (2008) go further, saying that small is not only possible, but inevitable. The ***decentralized communalist approach,*** an anarchic movement, emphasises local, communal organization using sustainable technologies and local sharing of wealth. It is fundamentally a form of anarchism. Here, a national government is unnecessary and unwanted. Instead local communities worked together to produce what the community needed (Gallopin, 2001; Meadowcroft, 2001; Raskin, 2008; Foster, 2009).

The fifth political school, ***Localism,*** also is an anarchic movement, but separates itself from the decentralized communalist approach, stressing community and sustainability over appropriate technology, and targeting the middle class rather than working class. It incorporates some neoliberal values of the market (albeit locally applied), and of decentralized government. It can be seen as liberal in that it calls for government support. Local ownership is socialist and local food networks are communalist but, importantly, it is built from grassroots, hence diversity plays a key role. It targets the large corporation-society interaction. Its focus is on restoring community-based sovereignty in order to find social justice and equality, empowering individuals and communities. Localism also allows escape from the global economy and its drivers (O'Riordan, 2001; Brenner, 2002; Curtis, 2003; Parnwell, 2006; Hildreth, 2011; McIntyre and Rondeau, 2011).

Governments rely on ***legislation*** in order to have influence upon economics, society and the environment. The principle driver for environmental protection is government regulation, or sometimes the threat of legislation (Dummett, 2006; Henrichs, 1992).

The Porter hypothesis (Porter and van der Linde, 1995) states that properly designed and enforced regulations can trigger innovative responses by firms, resulting in both more environment-friendly practices and more profits. However, although Germany has been one of the most active leaders in legislating towards a circular economy, 74% of German ID consultancies showed no environmental awareness, compared to 55% of Australian companies, who had much fewer laws (Behrisch et al., 2010). Mayers (2007) concludes that the European legislative framework largely fails to encourage the inclusion of extended producer responsibility considerations into product design. Murray et al. (2006) when analysing environmental disclosure in financial markets found a "*convincing relationship between consistently high(low) returns and the predilection to high(low) disclosure*" pointing to success breeding environmental responsibility and compliance.

Desrochers (2008) argues that market-driven actions to mitigate environmental harm, in particular the development of closed loops among firms that use one member's wastes as another's input, would be supported by enhanced private property rights.

Benson and Garmestani (2011) identify environmental law as a major player in shaping policy for sustainability of social-ecological systems. They identify types of legal instruments and the response of law to inherent variability as essential for successful transition.

While the environment and society form important pillars in the sustainability paradigm, the economy cannot be forgotten. Much literature is dedicated to addressing one significant question: ***can sustainable development be profitable***? Sustainability is now linked to long-term competitive advantage (Porter and Kramer, 2006; Franklin, 2008; Ferraro and Sands, 2009; Lubin and Esty, 2010) and an organization's increased ability to attract high quality employees (Hargroves and Smith, 2005). Companies find sustainability economically viable (Lovins, Lovins and Hawken, 2009; Stubbs and Cocklin, 2008). However to some, a positive relationship between sustainability and profitability remain to be proven (Hamschmidt and Dyllick, 2006; Bonini and Oppenheim, 2008; Sharfman and Fernando, 2008). This is counteracted by a significant literature that indicates sustainable development will lead to profitability (Roe, 1984; Moore and Miller, 1994; Laszlo, 2008; Esty & Winston, 2009; Kiernan, 2009; Unruh, 2010; Korten, 2010 Dee, N. 2011).

Seidel et al (2010) propose that ***information technology*** is a key enabler of transition towards a circular economy. Watson et al. (2008; 2010) argue that green IS can contribute to sustainable business processes by reducing logistics costs through fleet, delivery, and vehicle routing management systems that minimize traffic congestion and energy consumption. They also highlight facilitating virtual collaboration between distributed teams, thereby reducing the impact of travel and supporting remote working through systems that enable virtual collaboration.

Further applications include monitoring and analysis of environmental information, assisting the management of a firm's operational emissions and waste products, and providing information to end users and consumers to facilitate decision-making under consideration of "green" choices (Watson et al., 2010). Finally, Arunachalam (2002) points to information technology as a means of empowering the poor through knowledge sharing.

While the use of inappropriate technology has been identified as a barrier to transition, ***appropriate technology*** **(AT)** for sustainable development is an important area of research (Buitenhuis et al., 2010). Appropriate technology can be defined as technology that fits local conditions and is easily and economically utilized from readily available resources by local communities, to meet their needs (Sawhney et al., 2002; Buitenhuis et al., 2010). Appropriate technology was first conceptualized

as *intermediate technology* by the economist E.F. Schumacher in the 1970s in his influential book *Small is Beautiful: Economics as if People Mattered* (Schumacher, 1973).

Rotmans *et al.* (2000) argue that for a transition to a circular economy to occur, it will require a structural change of the system, in terms of technology, economy, culture, ecology and organization, and a central aspect of this is ***transition management.*** Firms still focus more on *reducing* unsustainable behaviour rather than on increasing the sustainability of the system via radical change across actors and levels (Ehrenfeld, 2005; Korhonen and Seager, 2008).

Stemming from the assumption that sustainability issues are too interconnected and complex to be solved by individual firms and agencies, several researchers have developed network and systems management approaches to enable transition (Boons and Roome, 2005; Svendsen and Laberge, 2005; Westley and Vredenburg, 1997; Wheeler *et al.*, 2005; Murray et al., 2010).

Transition management embraces the concept that society is a patchwork of complex and adaptive systems, with three stages: strategic, tactical and operational (Loorbach, 2007). Loorbach (2007) further states that "*The basic steering philosophy underlying transition management is that of anticipation and adaptation, starting from a macro-vision on sustainability, building upon (micro) initiatives, meanwhile influencing the meso-regime*."

Escobar (2012) develops a concept of the *Pluriverse* – a world where many worlds fit in. Moving away from the dualism of the twentieth century, and from globalization, which relies on a homogenization of human activity, the Pluriverse allows for the co-existence of many different ways of doing things, what he calls *planetarization*. This is more akin to the natural world, wherin different ecosytems co-exist within the Biosphere.

Panarchy

Another approach taken to facilitate transition to a circular economy has been to examine *ecological transition.* Ecological studies of food webs have been used to understand resilience of systems, and it has been discovered that the circularity of nutrient and energy flow within the group is enhanced as the number of connections between the organisms increases. This has been adopted as part of the circular economy model, where links between firms leads to greater resilience These interconnections can be quantified in terms of "connectedness" or "connectance" of the group (Van Berkel, 2009), by analogy with connectance of food webs (Hardy and Graedel 2002; Dai, 2010).

The most famous example of this is the concept of *panarchy*, developed by Gunderson and Holling (2002). They studied why management of natural ecosystems often fails, leading to the collapse of the system, they identified four stages in natural transitions: *exploitation*, characterized by rapid unlimited growth; *conservation*, characterized by the slow accumulation of energy and increasingly limited resources; release, characterized by rapid change due to environmental perturbation; reorganization, characterized by often rapid response to new opportunities. Panarchy is a process of cyclic succession, akin to that found in heathlands (Watt, 1947; Gimmingham, 1972; Bokdam, 2001), where different species arrive and depart in a cyclic manner.

The word *panarchy* is deliberately set in opposition to hierarchy, and uses the stem –*pan* (meaning *all*) as a reference to the holistic nature of the process. It is the complex interaction of all levels of organization, coming together as a balance between resilience and change, rather than the reductionist, hierarchical approach of traditional management. The core principles of panarchy are potential, connectedness and resilience, and these determine the dynamics of the system (Petrosillo et al., 2010; Benson and Garmestani, 2011; Cooke, 2011). Thus, management practice must be holistic, and systems-based, rather than linear. Gunderson and Holling (2002) describe sustainability as the capacity to create, and development as the process of creation.

Participation

While focus at regional (territorialism and industrial metabolism) inter-firm (industrial symbiosis) and intra-firm (cleaner production) are well developed, it is recognized that, ultimately, the greatest challenge to the circular economy is at the level of individual people. Ultimately, decision making is at the ***individual level***, and much literature addresses this. Yet at the organizational level, organizational theory views individuals as part of larger systems of organizations and institutions (Hoffman, 1999), based on the hierarchical model of management. At the individual level, behavioural decision research offers insights into how the social perception and enactment of issues occurs (Cordano and Frieze, 2000)

A new emphasis has been placed on *stakeholder participation* in sustainability modelling and evaluation, in order to facilitate an inclusive dialogue on possible futures (Steurer et al., 2005; Reed, 2008). Stakeholder participation aims both to incorporate information on what people want to be sustained and also, through a common ownership of the decision-making process, to boost incentives for behavioural change (Reed, 2008; Hermans et al., 2011). Both approaches have been developed with a view to enabling citizens to learn about the social and environmental consequences of multiple future scenarios (Bäckstrand 2006).

Finally, a more radical approach to management, called distributed intelligence, has been suggested by Pascale et al., 1997), defined as "l*eadership from a different place*." Here, leadership comes from individuals from every level of the company, and allows fast response at appropriate locations within the structure. Employees become stakeholders, designers, managers and planners.

Importance of Appropriate Indicators

The Stiglitz commission (Stiglitz, Sen and Fitoussi (2009)) puts forward the need to develop a better measure of performance in a complex economy. The emphasis on the Millennium Development Goals (MDGs) has created the requirement for some means to measure change in sustainable development. Transition must be measureable in order to assess how various approaches are working. New indicators that measure sustainability have been developed, that try to measure more than merely economic growth.

The ***Environmental Sustainability Index*** incorporates twenty-one elements of environmental sustainability covering natural resource endowments, past and present pollution levels, environmental management efforts, contributions to protection of the global commons, and a society's capacity to improve its environmental performance over time (Sands et al., 2000; Jha and Murthy, 2003; Sutton, 2003; Cui et al., 2004, Esty et al., 2005).

The ***Environmental Performance Index*** ranks countries on performance indicators tracked across policy categories that cover both environmental, public health and ecosystem vitality (Färe et al., 2004; Munksgaard et al., 2007; Clarkson et al., 2008; Zhou et al. 2008).

The ***Environmental Vulnerability Index (EVI)*** was developed by UNEP and SOPAC (South Pacific Applied Geoscience Commission) The EVI uses fifty biophysical or natural environment indicators grouped into three sub-indices (hazards; resistance; damage) and then applies these to the following issues or threats: climate change, biodiversity, water, agriculture and fisheries, human health, desertification, and exposure to natural disasters (Kaly et al., 1999; Villa and McLeod, 2002; Gowrie, 2003; Li et al., 2006).

The ***Human Development Index*** was developed by the United Nations Development programme, starting in 1990, in an effort to go beyond income as a measure of well-being. It combines measures of health, education and income in a single index (Trabold-Nübler, 1991; Neumayer, 2001; Crafts, 2002; Burd-Sharps et al. 2008).

The ***Human Well-being Index*** also includes measures of community (political rights, crime, internet users, and peace and order), and social equity (gender and income) (Prescott-Allen 2001; Vemuri and Costanza, 2006).

The ***Prevalent Vulnerability Index*** (PVI) is a social vulnerability index that concentrates on social, economic, institutional, and infrastructural capacity to recover from natural hazards, focusing on socioeconomic fragility and social resilience. It was developed by the Inter-American Development Bank (Cardona 2005).

Energy Performance Index (EPI) indicates the specific energy usage of a building. It is basically the ratio of total energy used to the total built-up area. This total energy used includes both purchased electricity as well as that generated on-site, but excludes renewable sources like solar photovoltaic etc. The total built-up area excludes basement and parking areas (Boussauw and Witlox, 2009).

The ***Genuine Progress Indicator*** (GPI) takes everything the GDP uses into account, but also adds other figures that represent the cost of the negative effects related to economic activity (such as the cost of crime, cost of ozone depletion and cost of resource depletion, among others) (Hamilton, 1999; Lawn, 2003; Wen et al., 2007; Harris, 2008).

Adjusted Net Saving was developed by the World Bank in the late nineteen nineties, and measures the true rate of savings in an economy after taking into account investments in human capital, depletion of natural resources and damage caused by pollution (Gnègnè, 2009).

The ***Ecological Footprint*** is measure that combines all environmental costs to indicate the cost of externals (Rees, 1992; Wackernagel and Rees, 1997; van den Berg and Verbruggen, 1999)

Organization-level measures of sustainability are also being developed (Eccles, 2011; Kates et al., 2005; Henriques, 2010). *Environmental benchmarking,* wherein businesses achieve good environmental performance by learning from 'best-in-class' companies, is become more widespread, with awards for good practice contributing to its influence (Matthews, 2003; Wever, 2007; Iribarren et al., 2011).

The role of Design in the Transition to a Circular Economy

It has been written that the ecological crisis can be viewed as a design crisis as it largely emerges from the properties of our designed, material world (Fry, 2008). Thus, design can be viewed as one of the most important elements of any transition to a sustainable age (Brown, 2009). Concerns about the relationship between design and resource management go back at least to the beginning of the twentieth century.

In the inaugural yearbook of the *Deutscher Werkbund* (the German Work Federation) Karl Schmidt-Hellerau (1912), one of the forefathers of German design, called for a resource-cautious approach to design.

Good design is concerned with the environment (Rams, 1995). Design must contribute towards a stable environment and a sensible use of raw materials. This means considering not only actual pollution, but also the visual pollution and destruction of our environment (Rams, 1995).

Recent literature discusses *design thinking* as the next frontier in competitive advantage (see Boland and Collopy 2004; Martin 2009) and is rapidly emerging as a catalyst for unexpected, disruptive business innovation (Laszlo 2008). Martin (2007) defined design thinking as "*a discipline that uses the designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity."* Design thinking uses solution-based thinking, rather than problem based thinking. Scientific problem solving is done by analysis, while designers solve problems through synthesis (Ehrenfeld, 2008).

Design thinking is considered, by its advocates, as creating better things, while traditional analytic thinking is about choosing between things (Martin, 2009; Dewberry, 2011). The prominent anthropologist and systems thinker, Gregory Bateson, notably said that the world partly becomes how it is imagined, emphasising the importance of our thinking as the basis of design (Bateson, 1979).

Designing our urban environments for transition is an important concept. Cities pose many problems, not only in terms of their high energy use and pollution production, but also because they contain a large part of the human population and the industries at the centre of sustainable development. However they also offer great opportunities in terms of sustainable development. There is a growing literature addressing how urban space can be designed to contribute to the transition to a circular economy.

Salat and Nowacki (2011) discuss the design of Mediterranean towns as providing two fundamental lessons in sustainable development: on the one hand, that the town is a centre for people to exchange and meet, a veritable *polis,* and, on the other hand, that it should become a living organism sculpted by the forces of the environment, "*in symbiosis with its bioclimatic setting*".

The Territorialist school, founded by Alberto Magnaghi, explores the concept of localism within a city, dividing it into a number of villages that interact with each other and with the rural surroundings, bringing connectedness and therefore resilience but maintaining diversity (Magnaghi, 2005a). This is set out as a local, self-sustaining model (Magnaghi, 2005b).

In Conclusion

There is a rich literature that provides a clear picture of the inter-relatedness of society, environment and economics. A number of approaches have been developed to redress the damage done by our activities, and the circular economy is the most applied, thanks, mostly, to the progressive thinking of the Chinese government, who have set out to transform their economy over the next decade. There are significant barriers, both generic and specific, that face any transition to a circular economy, but there is also a significant literature reflecting transitional thinking, spanning across policy, politics and participation. Appropriate indicators, combining all three pillars of sustainability (economics, society and the environment) allow us to be more accountable in terms of the price of our existence.

Speth (1992) sums up the essential elements of a successful transition to sustainability: (i) a demographic transition, (ii) a technology transition that includes the "green" automobile, (iii) an economic transition to one in which prices reflect full environmental costs, (iv) a transition in social equity, and (v) an institutional transition to different arrangements among governments, businesses, and peoples. Satterfield et al. (2009) stress the need to establish clear definitions of the terminology, to create and disseminate better information for better decision-making, to present sustainability as an opportunity and investment, so that it becomes a top priority, to tear down organizational silos within and among organizations and to develop forward-thinking, collaborative regulations.

Sustainability advocates across the world have, as their challenge, to impress on their governments and fellow citizens the conviction that long-term global security and prosperity rests not on political and social division, but a principled multilateralism informed by shared ideas of sustainability (UNEP, 2007). And the Circular Economy, born out of a long history of sustainability philosophy, is set to become the most significant concept in the field, given the commitment of China to its implementation.

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