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Cities – Good for the Environment?

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Graphical Abstract

This graphical abstract illustrates the evolution of the relationship between cities and the environment. It begins with the demand for agriculture, the first transformation that supported urban growth. The Industrial Revolution is shown as a turning point that intensified environmental impacts. Consumerism is represented as a driver of ecological degradation. The final stage highlights eco-cities as a pathway towards sustainability and human well-being. The central question, “*Cities – Good for the Environment?*”, emphasises that cities are both a source of environmental problems and a potential solution to climate change.



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Abstract: Cities have played a huge role in human development over millennia, shaping the environment and the earth's climate system for many years. Over the last 200 years, the rate of impact has accelerated. The Industrial Revolution changed the way we use resources, and resource use has continued to grow. We are still in the fourth phase, which is marked by emerging technology breakthroughs in a number of fields. The present economic system is based on consumerism and economic growth. The global population has continued to grow. Urbanization has increased, with now more than half of the global human population living in cities. This is forecast to grow to 70 percent of the global population by 2050. To improve the environmental performance of cities, we will need smart solutions for energy, transport and resource use. Cities must have a low environmental footprint. This will require smart solutions and a change in lifestyles. Future cities must focus on human well-being, and our environmentally (and socially) destructive consumerist lifestyle. Current generations have no right to trash the planet and deny opportunities for other species.

Keywords: Cities, Climate Change, Resources, Technology, Consumerism.

Introduction

According to Glaeser [1], cities are humanity's 'greatest invention'. Taylor *et al.* [2] argue that cities are demanding. Using Jacobs' 'city first' theory (which argues that cities effectively started organized agriculture as they required it to feed them – and that cities were driven by craft production and economic processes such as the 'export multiplier' and 'import replacement' effects [4]), Taylor *et al.* also claim that the city demanded the invention of agriculture. As cities grew it was realized that pastoralism could not provision the city, and another source of food was needed – thus agriculture was invented by city demand. Drawing on the work of Ruddiman [3], Taylor *et al.* [2] conclude that climate change is an unintended consequence of the demand of cities. In his 'early Anthropocene' hypothesis, Ruddiman [3] sees nature in control of the climate until some 8000 years ago human beings took control. Increasing deforestation along with a growing population led to an increase in carbon emissions and some 5000 years ago methane, a greenhouse gas, was being generated by rice production. Over many millennia, there is a story of a uniquely dangerous species whose material reproduction is becoming enormous, simply too big for the Earth.

Cities emerged at various times and places across the world as special settlements orchestrating local/non-local relations. According to Jacobs [4], 'in modern and historical times, no creative local economy – which is to say, no city economy – seems to have grown in isolation from other cities. A city does not grow by trading only with a rural hinterland. A city seems always to have implied a group of cities, in trade with one another.' Living in a city as part of a network of cities means a whole new world of enhanced communication, in terms of both quantity and quality. Compared to hunter-gatherer bands of some 150 people that may be in contact with other bands, city networks would show far greater numbers. It has been estimated that in Catalhoyuk (one of the earliest cities) in Anatolia, in about 7000BC residents had a human communication enhancement greater than pre-urban people by a factor of nearly 2,700, and for Uruk (in Mesopotamia, perhaps the first great city) about 4000 years later the enhancement factor was over 550,000 [5]. In other words, living in cities totally transformed the density and diversity of communications of people providing direct access to so much more information and knowledge than could ever be experienced in previous non-urban worlds.

Does this make a difference? According to Glaeser [1], all this additional communication enables city residents to become 'smarter' than their less connected country cousins; they have more and diverse people to learn from who are also smarter from being in cities. In particular, Glaeser argues that 'cities speed innovation by connecting their smart inhabitants to each other' to become very creative places. This is the reason cities have such a strong historical track record for creative change: 'cities' are

literally synonymous with ‘civilizations [6]. But being ‘smarter’ is not just about transformative innovations; living in cities can instigate collective changes in ways of living in numerous economic, social and ethical ways. Overall, urban populations did grow and continue to do so, and today another of the unintended consequences of urbanization is an increasingly elderly population in cities [7].

Social development had increasing impacts on the climate system and the physical environment. In terms of climate change there is speculation that interactions between civilizations led to the Little Ice Age. Nevle *et al.* [8] and Powell [9] claim that the early explorers of the Americas brought diseases to which the native populations had no resistance. Up to 80 million people are thought to have died. This catastrophic population drop led to the rapid regrowth of deforested areas in the Americas. This lowered the carbon concentration, and some maintain that was the cause of the Little Ice Age in the northern hemisphere. Clement *et al.* [10] argue that there is clear evidence that the Amazonian basin had a large area cleared for agriculture. Remote sensing has found remains of cities, roads and other infrastructure. This supports reports by early explorers such as conquistador Francisco de Orellana, who claimed that in 1542 he saw many large towns along the banks of the Amazon [11].

Human beings have interacted with the environment for many millennia. But, over the last 200 years we have seen a marked change in the relationship between humanity and the planet on which we depend.

The Industrial Revolution, beginning in the eighteenth century in the northern hemisphere, was a major turning point in Earth’s ecology and humanity’s relationship with the environment – compounding what the Agricultural Revolution had started with intensification. The Industrial Revolution dramatically changed every aspect of human life and lifestyles, and continues to do so with its environmental, economic, social and cultural legacy via the intensified mass-scale use of machines and fossil fuels etc. [12].

Weber’s 1904-5 work on *The Protestant Work Ethic and the Spirit of Capitalism* [13] argued that in particular Calvinist Protestantism with an emphasis on ‘hard work’, asceticism (of various degrees and depth for the industrial patrons), and reinvestment expanded capitalism in both Europe and North America. The sociologist Collins [14] considers Weber’s thesis on the ‘psychological impetus for rationalize, entrepreneurial capitalism’ as ‘only a fragment of Weber’s full theory’, and essentially an ‘idealist’ one.

Tawney [15] argued in 1926 in *Religion and the Rise of Capitalism*, that the mediaeval European Protestant Reformation, and in particular the Calvinist doctrine, made a critical contribution by

separating religious ethical or moral codes of behaviour from economic actions, in the sense of emphasizing afresh material wealth, its accumulation and self-interest connected to that.

Novak [16] writes against this view to some extent, drawing on Collins' [17] work, to argue that capitalism was bound up with the mediaeval Church, which was a major landowner in Europe, with a continent-wide legal system across multiple other jurisdictions. The Church provided administrative bureaucracies at various levels and with requisite special skills to facilitate trade and investment, a highly motivated labour force. For example, the Cistercians were noted entrepreneurs separating themselves from mainstream feudalism and local settled restrictions.

There are four currently recognized phases to the Industrial Revolution. The first phase took place from the 18th to 19th centuries in Europe and (mostly Northern) America. It was a period when mostly agrarian, rural societies became industrial and urban. The iron and textile industries, along with the development of the steam engine, played central roles in the Industrial Revolution. Cities grew and urbanization increased. Today, more than half of the global population lives in cities. It is forecast to grow to close to 70 percent by 2050, with nearly 7 billion of 9 billion people projected overall in 2018 by the United Nations in their World Urbanization Prospects report [18].

During this first phase, the financial system began to change with a shift in banking practice that has now culminated in the capitalist system. The second phase, termed the Technological Revolution, took place between 1870 and 1914. This was a period of growth for pre-existing industries and expansion of new ones, such as steel, oil and electricity, and used electric power in order to create mass production. Major technological advances during this period included the telephone, the light bulb and the internal combustion engine. The third phase, known as the Digital Revolution, refers to the advances in technology from analogue electronic and mechanical devices to the digital technology available today. The era started during the 1980s and continues [19]. Advances during this phase include the personal computer, the internet and information and communications technology (ICT). The Fourth Industrial Revolution builds on the Digital Revolution, representing new ways in which technology becomes embedded within societies and even the human body. The fourth phase is marked by emerging technology breakthroughs in a number of fields, such as robotics, artificial intelligence, nanotechnology, quantum computing, biotechnology, the Internet of Things, 3D printing and autonomous vehicles [20].

Global Environmentalism

There is not a great deal of evidence that the environment was a major concern for our developing societies. Even after the Industrial Revolution there is little evidence that the environment and our impact on it was a concern. Some scientists such as Arrhenius had hypothesized that carbon dioxide could impact the climate by making it warmer [21]. But in general concerns about the environment did not really take shape until after World War II.

Three women are eminent in promoting environmentalism.

Rachel Carson, in her book *Silent Spring*, set out the dangers of chemicals on the natural environment [22]. Some commentators credit this work as being instrumental in shaping the Environmental Protection Agency (EPA) in the United States. Much of the agency's early work, such as enforcing the 1972 Federal Insecticide, Fungicide, and Rodenticide Act, was directly related to Carson's work [23].

The writings of Barbara Ward crossed so many disciplines and interest groups that different people remember her for different things. Environmentalists know her for the 'unofficial report' commissioned by the Secretary-General of the United Nations Conference on the Human Environment, 'prepared with the assistance of a 152-member committee of corresponding consultants in 58 countries', she wrote with René Dubos called *Only One Earth: The Care and Maintenance of a Small Planet* (published in 1972, republished as a book in 1983) [24]. Barbara Ward also made fundamental contributions to the UN Conference on the Human Environment in Stockholm (also in 1972), as well as to the concept of sustainable development and how it might be applied [25].

Gro Harlem Brundtland, who served as the Prime Minister of Norway, was invited in 1983 by the then United Nations' Secretary-General Javier Perez de Cuellar to establish and chair the World Commission on Environment and Development (WCED), the Brundtland Commission. This commission published its report, *Our Common Future*, in 1987 [26]. This provided the momentum for the 1992 Earth Summit / United Nations Conference of Environment and Development (UNCED), headed by Maurice Strong, who had been a prominent member of the Brundtland Commission. The Brundtland Commission also provided momentum for Agenda 21, the principal outcome of UNCED), often also known as the Rio de Janeiro conference. The United Nations describes Agenda 21 as 'a comprehensive plan of action to be [under]taken globally, nationally and locally by organizations of the United Nations System, Governments, and Major Groups in every area in which humans impact on the environment' [27].

The Brundtland Commission gave a definition for the term sustainable development: ‘Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs’ [26]. In the last 30 years most countries and many organizations and movements have adopted the Brundtland definition of sustainable development and many state that they are using this to guide policy development. Hopwood *et al.* [28] point out that many developed world nations and bodies such as the World Bank and the European Union tend to favour the status quo (see Figure 1). There is evidence of some change, but it is very incremental. It also varies between countries and other organizations.

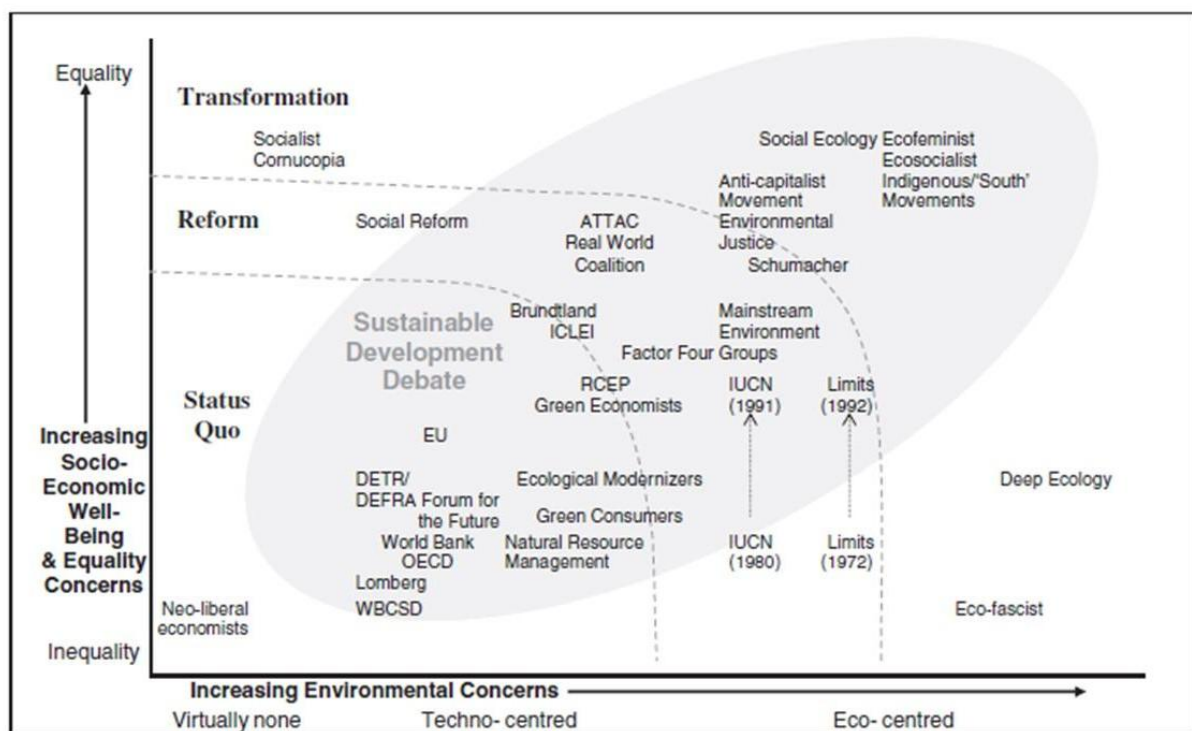


Figure 1. Mapping Sustainable Development (Source: [28])

O'Brien and O'Keefe [29] use the Kyoto Protocol as a means of showing the difference between countries. When the United Nations Framework Convention for Climate Change (UNFCCC) was formed in 1992 [ratified in 1994 by 50 signatory states], most countries became signatories. It was quickly realized that a more formal and flexible agreement was needed. This was realized in the Kyoto Protocol, adopted in 1997 and coming into force in 2005. Although its targets were modest, there were different responses. The USA left the Protocol under the first Presidency of Trump,

claiming that its terms would damage its economy. The European Union took a (net reduction) flexible approach with some Member States, such as Germany and the UK, having relatively higher targets to meet, and others, such as Portugal, being allowed to increase greenhouse gas emissions. The Kyoto Protocol was successful, but as stated earlier its target was very modest. The international community has continued to look for ways to develop an international agreement to limit greenhouse gas emissions. The latest agreement, the Paris Agreement, adopted in 2015, came into force in 2016. The United States became a signatory in 2016, and U.S. President Obama signed an Executive Order to ratify it, committing US\$3 billion to the Green Climate Fund. In 2017, U.S. President Trump announced that the United States would cease all participation (although it later stated that the U.S. would abide by the 4-year exit process). Trump's view was that the Paris Agreement would "undermine" the U.S. economy and put the U.S. "at a permanent disadvantage". In 2019, the first Trump Administration gave formal notice of the intention to withdraw, which it did formally in November 2020. The U.S. rejoined in 2021 under President Biden, through an Executive Order, and withdrew again in January 2025 shortly after President Trump's second inauguration (again by an Executive Order).

Sustainable Cities

Cities themselves can promote good environmental performance. Meyer [30] points out that, using New York as an example, cities appear to be very resource-extravagant. An analysis of the city as a whole shows that city-centre areas, where resident density is high, vehicle ownership is below the norm and public transport is well planned, have a lower resource consumption per capita than corresponding suburban areas [30].

UNEP and Habitat maintain that cities have historically constituted efficient settlement patterns because of the correlation between higher density and lower per-capita rates of resource use and emissions [31]. They manage to accommodate more than 50% of the earth's people on just 3% of its surface area and generate some 80 percent of its wealth. In theory, the concentration of resources and talent should also make cities more resilient since city structures allow decision-makers to plan resource use and the consolidated wealth in cities should be able to buffer socio-economic shocks. UNEP and Habitat have stated that cities and urban areas now consume 75 percent of the earth's natural resources and produce 60 percent of its greenhouse gas emissions and 50 percent of its waste. Because of urban sprawl and bad or no planning, cities are losing the efficiency advantages they have historically possessed.

Clearly, the problems of sustainability will have to be addressed at the city-level. There have been a number of initiatives to reduce the environmental impacts of cities.

One of them, 'The Garden City' concept, was initiated in 1898 by Ebenezer Howard. Garden cities were intended to be planned, self-contained communities surrounded by greenbelts, containing proportionate areas of residences, industry, and agriculture. The ideal garden city would house 32,000 people on a site of 6,000 acres (2,400 ha), planned on a concentric pattern with open spaces, public parks and six radial boulevards, 120 feet (37 metres) wide, extending from the centre. The garden city would be self-sufficient and when it reached full population, another garden city would be developed nearby. Howard envisaged a cluster of several garden cities as satellites of a central city of 58,000 people, linked by road and rail. Research suggests that the Garden City concept can have many benefits such as improved health and social cohesion [32]. These ideas were promoted by British town planners, but the British 'New Towns' were mainly built to accommodate the larger (and often homeless) populations of postwar Britain, and to end slums. Coping with bomb damage with a huge national debt did not produce the most imaginative examples of Howard's hopes. There are examples where only certain aspects of the concept have been selected, which mitigates the positive effects. Further, there is evidence that it is the wealthier areas of the city that gain the most [32].

Urbanization and Future Cities

Ritchie *et al.* [18] show with data that 'more than half of the world's population now [after 2007] live in urban areas — increasingly in highly dense cities.' This is uneven between high-income and low-income countries: 'Across most high-income countries – across Western Europe, the Americas, Australia, Japan, and the Middle East – more than 80% of the population lives in urban areas. Across most upper-middle-income countries – in Eastern Europe, East Asia, North and Southern Africa, and South America – between 50% to 80% of people do. In many low to lower-middle-income countries, the majority still live in rural areas. But this is changing quickly.' The UN World Urbanization Prospects projected estimates of "urban" shares of population world-wide through to 2050 in 2018. With projected population growth being based on the UN's medium fertility scenario, the global human population is estimated to be about 9.8 billion in 2050, with close to 7 billion – that is more than 2/3 – to be forecast to live in urban areas then. That does not mean they will live well, as quality of living standards should be considered in the urban context also. According to Ritchie *et al.* [18], 'one metric of living standards is the share of the urban population living in slum households. A slum household is defined as a group of individuals living under the same roof lacking one or more of the following conditions: access to improved water, access to improved sanitation, sufficient living area,

and durability of housing. The most recent global estimates [available since 2000] suggest just under 1-in-4 people in urban areas live in slum households ... [where] most countries across Asia and Latin America had between 10 to 50% of urban populations living in slum households. Slum households are most prevalent across Sub-Saharan Africa; in most countries, more than half of the urban populations live in slum households, and in some (such as Chad) around 8 in 10 people live in slum households.'

According to the Worldwatch Institute [33], there are now more than 1.7 billion members of "the consumer class" - nearly half of them in the developing world. A lifestyle and culture that became common in Europe, North America, Japan, and a few other pockets of the world in the twentieth century is going global in the twenty-first. The Institute gives a frightening array of statistics. Worldwide, private consumption expenditures- the amount spent on goods and services at the household level - topped \$40 trillion in 2015. As incomes rise, people are gaining access to a multitude of consumer items associated with greater prosperity; for example, 1.4 billion of the 1.9 households have a television set and some 3.2 billion people have internet access. The Institute concludes that we must find ways of curbing excessive consumption.

This explains why a number of cities have opted to become 'ecocities'. There are other terms such as 'sustainable cities' and 'green cities'. For our purposes, we will use the eco-city term that was coined by Richard Register in 1987 [34]. An eco-city is a city designed with consideration of environmental impact, inhabited by people dedicated towards minimization of required inputs of energy, water and food, and waste outputs such air pollution and greenhouse gases.

According to Joss [35], there is no complete agreement about what a sustainable city should be or what its components should be. But, a sustainable city should meet the needs of the present without sacrificing the ability of future generations to meet their own needs. There is likely to be a great deal of variation in terms of how cities carry out their attempts to become sustainable. Ideally, a sustainable city creates an enduring way of life across the four domains of ecology, economics, politics and culture. A sustainable city should at least firstly be able to feed itself with a sustainable reliance on the surrounding countryside. Secondly, it should be able to power itself with renewable sources of energy. The aim is to create the smallest possible ecological footprint, and to produce the lowest quantity of pollution possible, to use land efficiently; compost used materials, recycle or convert waste to energy, and so the city's overall contribution to climate change will be minimal.

But as Taylor *et al.* [36] point out, the increase in the number of large cities that we see through the Industrial Revolution coincides with very rapid increases in greenhouse gases. They make clear that the key environmental trigger is immensely heightened urban demand. Traditional bourgeois thrift

has been transformed into bourgeois conspicuous consumption, making modern cities ultra-demanding. It is this toxic urban process which we have inherited today. A technocratic approach to 'smart cities' may well imply that city development has a technological focus as opposed to a people focus - and this is still the case today, even within the eco-city movement [37]. Other authors, such as Shao and Min [38], consider the 'smart sustainable cities' concept to be 'human-centered, involving the multidimensional integration of people and digitization'.

Amongst environmentalists, the role of respective technologies – including sources of energy – has been discussed, e.g. by O'Brien [39] and O'Keefe *et al.* [40], and will continue to be discussed [41] - including with controversial advocacy by Lovelock [42] and Brand [43] (e.g., on the role of civilian nuclear energy [44], forms of hydrogen generation, carbon capture, and genetically modified intensive agriculture for global food provision). There has been a change of tone and emphasis from the popular thinkers more aligned to an anti-urban outlook – because of 'ecological carrying capacity concerns' – e.g., views of Giradet [45].

One other direction, connected to the Garden City movement, is the 'co-cities' urban governance framework, or locally adaptable design principles, proposition by Foster and Iaione [46], which – like the UK Transition Town movement [47-48] - argues that 'cities also often harbour the solutions to the inequalities they create'. '... [The] majority of the world's inhabitants live in cities, but even with the vast wealth and resources these cities generate, their most vulnerable populations live without adequate or affordable housing, safe water, healthy food, and other essentials.' 'Practices, laws, and policies (for the production, delivery and management of urban assets or local resources) that are ... fostering innovation in the provision of urban services, spurring collaborative economies as a driver of local sustainable development, and promoting inclusive and equitable regeneration of blighted urban areas.'

This paper will argue that the eco-city should be about human well-being. It will also reflect on the impacts of continued consumerism.

Can we develop cities that provide human well-being? First of all, we need to understand what we mean by well-being. According to Dodge *et al.* [49], well-being is difficult to define. The authors evaluate the debates on well-being from Aristotle onwards. They propose a new definition of well-being as the balance point between an individual's resource pool and the challenges faced as shown in Figure 2.

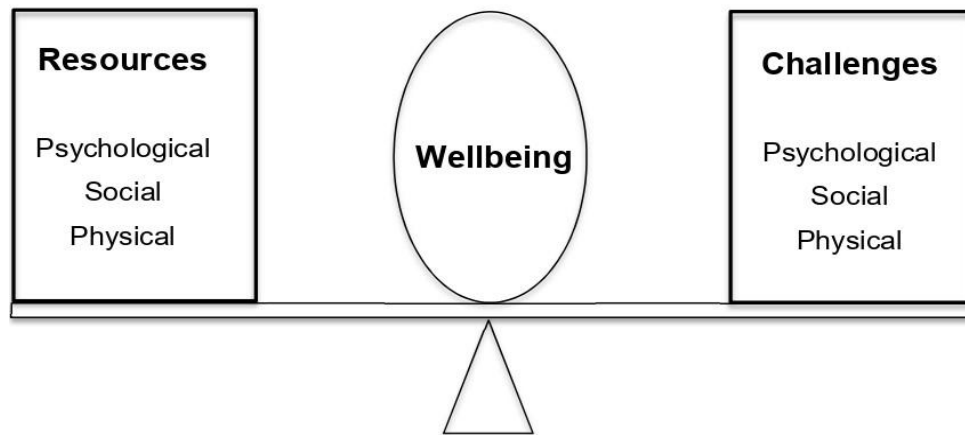


Figure 2. Balance Point (Source: [49])

In order to address well-being we need to address human needs. Two scholars, Maslow [50] and Max-Neef [51], offer solutions. Both argue that in order to address human well-being we must look at both our physiological and psychological needs. McLeod [52] discusses Maslow's approach by looking at his hierarchy of needs that is usually illustrated as a pyramid, as shown in Figure 3.

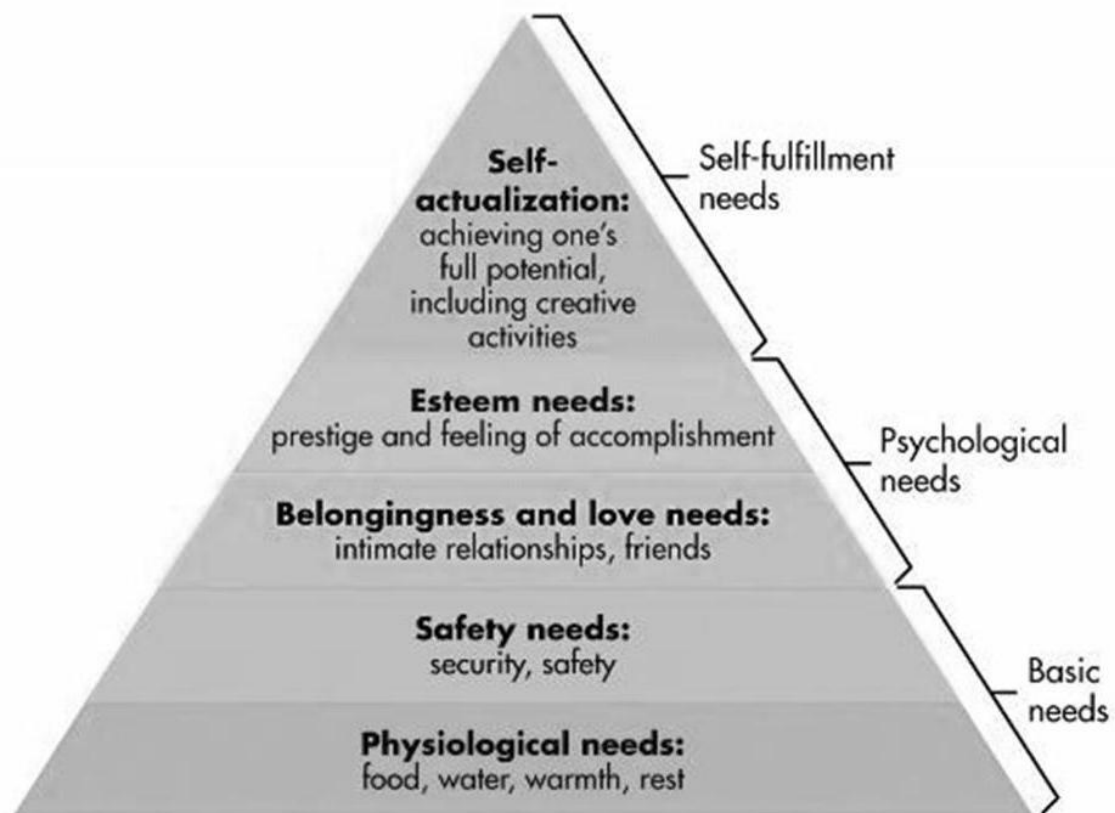


Figure 3. Maslow's Hierarchy of Needs (Source: [52])

McLeod [52] argues that negative events in meeting physiological needs such as losing a job or a divorce can impact the journey to meeting people's psychological needs.

Human needs are seen by Max-Neef *et al.* [53] as being ontological (stemming from the condition of being human), are few, finite and classifiable (as distinct from the conventional notion of conventional economic "wants" that are infinite and insatiable). They are also constant through all human cultures and across historical time periods. What changes over time and between cultures are the strategies by which these needs (and created desires) are satisfied. Human needs can be understood as a system - i.e., they are interrelated and interactive. In this system, there is no hierarchy of needs (apart from the basic need for subsistence or survival) as postulated by Western psychologists such as Maslow. Rather, simultaneity, complementarity and trade-offs are features of the process of needs satisfaction.

Doyal and Gough's [54] theory of human need is also worth noting here. This is to do with social participation as a process and outcome, and grounded in two fundamental or basic needs: the autonomy of an individual and physical health. Further to this, their theory speaks of a number of intermediate needs, namely food, clean water, economic security, protective housing, non-hazardous work environment, healthcare, physical security, pre-natal security and childhood security. These in turn are said to be linked to 'universal satisfier characteristics' applying across cultural contexts. These universal satisfier characteristics, e.g. goods, activities, services, and relationships, are argued to enhance the prospect of meeting intermediate needs. They differ from so-called 'need satisfiers' specific to time, place, and culture.

In essence then, the eco-city has to meet two needs. The first is physiological needs:-

A sustainable city must have clean water and air and access to secure high quality food supplies. Good quality and affordable accommodation is also required. It is important that citizens feel that their physical needs are met where there are physical places for leisure and interaction. This will contribute to a sense of security. There is a need also for connectivity through transport and multi-media communications systems along with a variety of sustainable livelihood options.

In short, a sustainable city has to meet our physical needs.

The second is psychological needs:-

Meeting human needs starts at birth where the relationship with parents is so important. Throughout life relationships will be important and the sustainable city will need to devise ways of ensuring we have a range of relationships that build a sense of belonging and togetherness. Underpinning this will

be education and life-long learning as well as leisure time that will help people to express themselves in different ways.

The challenge for the eco-city movement is to retrofit or redevelop cities that promote human well-being. But as Monbiot [55] suggests, since the collapse of the Soviet Union the predominant economic system is neoliberal market economics that has led to conspicuous consumption. The current dominant economic paradigm requires that we produce more and more products (e.g., mobile phones) and that we purchase new upgraded models in a relatively short time so that producers can keep making phones. The reality is that we do not consume – we use, and then discard.

The Forthcoming Reality

Many governments appear to be committed to a low-carbon (emissions) future, in part by existing domestic legislation or international agreements. Many governments are apparently committed to addressing climate change and other environmental problems, including reducing poverty. But, there is no real fundamental change. The rhetoric is focused on growth – neoliberalism is the driving force. Neoliberalism sees competition as the defining characteristic of human relations. It redefines citizens as consumers, whose democratic choices are best exercised by buying and selling, a process that rewards merit and punishes inefficiency. It maintains that “the market” delivers benefits that could never be achieved by planning [56].

There appears to be a contradiction about what many say at the national level (e.g., in the UK) about sustainability and prevailing economic policy. So, what are the implications? Will a low-carbon approach really boost sustainability? The following thematic case studies try to address this.

Energy

Energy is clearly important to society. There is extensive literature about the adverse impacts of fossil fuel usage to produce energy. There is considerable interest in shifting to more renewable sources such as photovoltaics, wind, nuclear and hydropower. One of the problems is the amount of subsidy that is being given to the fossil industry as compared to the renewable sector. Kavanagh [57], reporting on data from the International Energy Agency (IEA), states that the global subsidy bill for fossil fuels stood at about \$490bn in 2014. Subsidies to aid the deployment of renewable energy technologies were \$112bn in 2014, with another \$23bn spent on supporting biofuels. So, while many developed countries are increasing financial backing for the expansion of green energy supplies, total

subsidy support for “dirty” fuels across the world still exceeded that for renewables by a considerable margin in 2015/6. Coady *et al.* [58] calculated that subsidies for fossil fuels were US\$ 4.9 trillion worldwide in 2013, and US\$5.3 trillion in 2015 (6.5% of global GDP in both years). They claim this is because of the undercharging, e.g., of the costs of climate change. They calculated that eliminating subsidies would have reduced global carbon emissions in 2013 by 21% and fossil fuel air pollution deaths by 55%, while raising revenue by 4 percent and social welfare by 2.2 percent of global GDP.

The figures have been changing, but with fluctuations owing to economic and political election cycles very notably in the USA (but not just there) – and also pressures of state/government public budgets and some hedging from the private sector too (including major global energy companies). According to Gunay *et al.* [59], a 2022 International Energy Agency report stated that up to 2030, more than US\$ 50 billion of public funds could be levied for pilot-projects of large-scale low-carbon energy technologies in order to drive the green transition, but noted that it is not very clear how the public energy R&D spending would evolve following the pressure on government budgets after the Covid-19 pandemic. The report also argued that the private/corporate sector has a leading role in supporting public policies concerning both clean energy and energy efficiency.

The International Energy Agency’s Global Energy Review 2025 [60], including the years 2022, 2023 and 2024 with world-aggregated data for total energy supply, electricity generation, technology deployment and CO₂ emissions, provides a rounded depiction of recent trends in the energy sector with data on fuels, technologies, world regions and key countries, as well as associated CO₂ emissions. In 2024, world-wide energy demand rose faster than before, across all energy sources such as oil, natural gas, coal, renewables and nuclear power. This was principally down to the power (electricity) sector, because of higher demand for cooling, rising consumption by industry, electrification of transport as well as the growth of data centres and artificial intelligence. Almost all of this extra demand was satisfied by low-carbon energy production, led by solar photovoltaic production as well as other renewables and nuclear power. But gas demand rose also substantially, in contrast to oil and coal. Overall for 2024, this meant an increase in energy-associated CO₂ emissions – of which about half was caused by higher temperatures - but still less so than in 2023. The good news according to the IEA [60] is that ‘the continued rapid adoption of clean energy technologies is limiting emissions growth, according to new analysis – avoiding 2.6 billion tonnes of additional CO₂ emissions per year.’

According to Cubitt [61], the amount of energy being used by the information and communication technologies, which were seen as one of the drivers of a low-carbon economy [62], is rising rapidly. There seems to be a contradiction between the need for low-carbon technology and the developments

needed to achieve it, e.g., data centres. As a sector, these talk about ‘sustainable or responsible procurement’, including from civilian nuclear power plants, which the European Commission in 2022 classified as ‘sustainable and ‘clean‘ and thus as ‘eligible green investment’ in its Sustainable Finance Taxonomy for investment purposes alongside gas if certain conditions such as being fitted with carbon capture, use and storage technology are met [63]. Yet data centres are likely to be the fastest growing contributors to greenhouse emissions as their demand for electricity will increase leading to further greenhouse gas emissions, as pointed out in a recent study published by the lobby-group Beyond Fossil Fuels [64].

Organizations such as Google tend to site facilities close to hydroelectric dams (which does not address concerns of water needed for cooling of major data centres) and more recently wind farms and Apple builds biomass generators at their new sites. And most global ‘big data’ and internet search companies have invested greatly in nuclear energy expansion in recent years. Worthy though this is, Carr [65] argues that the main driver is energy costs – and also electricity availability arguably - as opposed to sustainability in its own right. Private sector white papers are now emerging for ‘driving data centres from environmental liability to sustainable powerhouse’, e.g. by Partington and Mark at IQ-EQ [66], which emphasizes advanced energy procurement strategies, closed-loop cooling systems, waste heat recovery, sustainable construction methods, etc. There is also a focus on management, and the need for monitoring with comprehensive reporting.

Zie [67] argues that ‘the time has come to start focusing on reducing the energy consumption of digital and the technological infrastructures, which underpin nearly all of our daily activities.’ Zie thinks it can be done, if matters are taken seriously and there is necessary investment. Ertugrul [68] makes the case for the low-carbon transformation of the power grid through the scaled-up integration of renewable energy, storage, and grid modernization.

This moral and practical engagement, collective action and (‘just’ / ‘fair’) transformation action programme across sectors can also be stimulated at regional level, including in the historic heartlands of the Industrial Revolution [69].

Semiconductors

Semiconductors are the basis of the electronics industry. Semiconductors are used to manufacture the electronic components that are used in all sorts of devices such as personal computers and mobile phones. Although the industry produces waste, many of its products become waste. There has been a history of outsourcing and offshoring in the industry, often in very harsh conditions for the workforce.

Despite efforts in the last 5 to 10 years to clean up atmospheric emissions, waste dumping and water pollution there are historic emissions of perfluorinated chemicals that will persist in the atmosphere for many thousands of years and have twenty thousand times more impact than carbon on the greenhouse effect [70].

The latest and fourth (2024) UN's fourth Global E-waste Monitor (a report by the International Telecommunication Union and the United Nations Institute for Training and Research [71]) revealed that the world's e-waste is in fact rising five-fold in comparison to documented recycling thereof. In 2022, less than a quarter of e-waste was reported to be properly collected and recycled – with 'US\$ 62 billion worth of recoverable natural resources unaccounted for and increasing pollution risks to communities worldwide'. Recycling of rare earth elements is stated to satisfy only 1% of the demand for them. The trend is alarming: 'A record 62 million tonnes (Mt) of e-waste was produced in 2022, up 82% from 2010, and on track to rise another 32%, to 82 million tonnes, in 2030. Worldwide, the annual generation of e-waste is rising by 2.6 million tonnes annually, on track to reach 82 million tonnes by 2030, a further 33% increase from the 2022 figure.'

Cubitt [61] argues that many wastes of these semiconductor-producing plants are composed of carcinogenic materials and others of unknown effects will persist in the vicinity of these plants for many years. There is clear evidence that employees in these plants are contaminated. It is very likely that female employees that have families will contaminate their children. Some 2,200 gallons of water is needed to make the average integrated circuit. Some 1500 gallons of that has to be Ultrapure Water (UPW). It takes 1,400 gallons of water to make 1000 gallons of UPW, and the US regards the removed minerals as toxic waste. Much of the digital waste is disposed of illegally and much of it has yet to enter the waste cycle. We have no idea what are the long impacts of many of these technologies.

On the other hand, there is little doubt that electronics have had a significant effect on industrial development. The introduction of new electronic products has had a significant impact on society. Many workers can now work from home, relying on advanced means of communication to speak with and see people without the energy costs and financial costs of long-distance travel. There have been improvements to manufacturing processes, and this is welcome. But, the massive growth of demand for electronic products is likely to outstrip any gains made in improved environmental performance of individual processes.

Electric Vehicles (EVs)

EVs are increasingly popular, and commentators such as Seba have stated that the internal combustion engine (ICE) is likely to be obsolete by 2025 [72]. This has not happened yet, although in many

countries pure ICE-powered road light-duty vehicles (cars and vans at least) are scheduled for prohibition in terms of new registrations from either 2035 or 2040 or at least 2050. Various (often financial) levels of incentives for (especially pure) EVs are in place and are now being modified and extended in many jurisdictions. And the state-of-the-art in electric vehicles [73] is changing continuously also – with the next level of developments likely to concern common standards for charging, Vehicle-to-X (including Vehicle-to-Grid bidirectional charging) expansion across more models and perhaps new EV battery technologies. But the major question is what can electrical vehicles and electric batteries do for us in a more holistic sense?, e.g., EVs for energy services, including with temporary stationary storage for energy services and also vehicle-to-building bidirectional charging [74]. This needs multi-stakeholder business and societal models, with acceptance and supporting regulation from both the public but crucially also from the private sector (investment, insurance etc.) [75].

Hawkins *et al.* [76], assessing the environmental life cycles of both electric and conventional vehicles over a decade ago, found out that EVs powered by the present European electricity mix offer a 10 percent to 24 percent decrease in global warming potential (GWP) relative to conventional diesel or petrol vehicles assuming lifetimes of 150,000 km. But, they noted that EVs exhibit the potential for significant increases in human toxicity, freshwater eco-toxicity, freshwater eutrophication, and metal depletion impacts, largely emanating from the vehicle supply chain if the demand for EVs increases rapidly. Hawkins *et al.* [76] pointed out that in regions where fossil fuels are the main sources of power, electric cars/vehicles offer no benefits and may even cause more harm.

Magill [77] reported on a study undertaken, again over a decade ago, by the University of Minnesota that the environmental and human health costs of operating an electric vehicle using electricity generated from coal may be as much as 80 percent greater than driving a gasoline-powered vehicle. But, the study showed that the environmental health cost of driving an electric vehicle using electricity from solar or wind generators could be as much as 50 percent less than the environmental and health toll of using gasoline. It is clear that EVs offer real environmental benefits, but it should be noted that any innovations in transport may also have some adverse impacts.

The Union of Concerned Scientists has made this point for some time - but crucially noting also that grid transformations regionally produce clear both net use and life-cycle environmental benefits for EVs in regions turning away from coal and gas, and by adding solar and wind power, as an energy source [78].

Batteries

EVs rely on batteries for energy storage. Lithium is currently used in the manufacture of batteries used in EVs. According to Wanger [79] about 75 percent of the global reserves of lithium are found in the salt lakes of Uyuni in Bolivia, Atacama in Chile and Hombre Muerto in Argentina: the “lithium triangle.” This desert expanse in the high Andes provides the raw material that moves the world of information technology and communications. The salt lakes do not have much flora or fauna, but they do provide a home for flamingos. Wanger points out that the flamingos feed on cyanobacteria - food for the birds but lethal to human beings, animals and plants [80]. The impact of mining lithium is devastating, particularly on water supplies. Although lakes exist despite low rainfall there is concern that more mining will disrupt water supplies for people and agriculture. In addition, crops can be affected by runoff saline solution from which the lithium salts are gathered. Traditionally, gathering salt has been part of local livelihoods. This becomes impossible as the salt ponds are contaminated by lithium mining [80-81].

Investing in alternative battery technologies is essential to achieving sustainability. Improving lithium recycling is crucial for advancing sustainable practices. Developing more environment-friendly mining methods is necessary to achieve sustainability goals. We must balance the benefits of lithium-based technologies with their environmental costs [82].

There is also concern that regulation designed to minimize the adverse environmental impacts of lithium mining will not be effectively enforced. None of the governments of the lithium triangle have a good history of environmental regulation and there is evidence that poorly paid officials often take bribes [81,83]. There are fears that in the long run lithium mining will make the area unfit for its indigenous inhabitants. The demand for lithium is increasingly driven by the push for EVs. These should solve the urban air quality issue (especially if fully battery electric), but their batteries are causing environmental degradation in both their production and disposal. This will continue with more ‘rare earth’ metal extraction – although this can be made more sustainable [84] - and also more second-life use and recycling of end-of-life batteries should certainly occur [85-86].

There are 2 types of batteries used for electric and hybrid vehicles. Hybrid vehicles initially used nickel-metal hydride batteries. EVs use lithium-ion batteries. EV batteries often contain other useful metals such as high-grade copper and aluminium - in addition to depending on the active material, metals such as cobalt and nickel as well as ‘rare’ earths. To prevent a future shortage of cobalt, nickel, and lithium and to enable a sustainable life cycle of these technologies, recycling of lithium batteries must be improved [87,88].

In line with the objectives of the European Green Deal, the European Union (EU) has adopted increasingly strict measures to ensure that the entire life cycle of batteries – from production to recycling – is sustainable, efficient and compliant with the most advanced environmental standards. To ensure a uniform and binding application of the new rules, the previous EU Directive 2006/66/EC was replaced with European Regulation 2023/1542 [89-91]. Recycling electric car batteries includes separating out the valuable materials, e.g. cobalt, lithium salts, stainless steel, copper, aluminium and plastic. All these can be recycled. Cobalt, as a ‘conflict-associated’ metal in the Democratic Republic of Congo, is also an ethical supply chain issue – though regulatory intervention is far from straightforward globally and also in-country [92-95].

When EVs started to become more popular, the price of elements such as lithium was still low and supplies were plentiful. Re-use as storage capacity as a solution for dealing with batteries from EVs is of course one option [96]. But stationary batteries may also be newly-produced.

According to Kühnbach *et al.*'s Fraunhofer ISE & Fraunhofer ISI study [97], the wider introduction of vehicle-to-grid (bidirectional) charging in both AC and DC connection modes, where EV batteries are accessed for power to offset peaks on the power grid, may bring very substantial benefits e.g. for Europe's more integrated energy system in the decades to come. The AC-mode is less hard-ware intensive and suitable for residential and slow charging, but the DC-mode is more expensive with more hardware requirements and used mainly for fast charging, although it is currently leading in both hardware and communication ISO protocols. Most new EV models focus on vehicle-to-load, thus enabling vehicles to charge electric appliances and vehicle-to-home applications rather than vehicle-to-grid (V2G). Furthermore, the availability of supporting infrastructure such as bidirectional wallboxes for EV charging is still limited. However, Kühnbach *et al.* [97] conclude, ‘despite technical, regulatory and acceptance barriers, vehicle-to-X offers socio-technical-economic benefits such as CO₂ emission reductions, integration of renewable energy and grid relief. Compared to smart charging alone, bidirectional charging offers additional advantages, such as decreasing the need for backup capacity from gas and hydrogen power plants and lowering the use of power generation from these sources. The opportunity to integrate PV capacity more effectively is seen as the biggest value of the charging flexibility provided by electric cars, especially when they are connected during the day.’

In the longer term a technological development may offer an even better solution. Nickel metal hydride batteries are not currently used in EVs. But, research by BASF suggests that the capacity of these batteries could be considerably higher than that of lithium-ion batteries. Nickel metal hydride batteries are considerably lighter than lithium-ion batteries which means that there will be a price

advantage [98]. Sodium-ion batteries, currently with lower energy density than lithium-ion, are the other promising alternative [99].

Concluding Thoughts

Cities have played a significant role in human development, with a significant impact on the environment. Early cities demanded the invention of agriculture in order to feed growing populations. The next major transformation was the Industrial Revolution. Cities demanded labour to operate the increasingly complex industrial processes. Simultaneously cities demanded that we become consumers. Today, we have become conspicuous consumers. Neoliberalism, the predominant economic system, demands that we consume more and more products. In reality, we do not consume products but discard them in order to get the latest version. This has distanced us from the sustaining environment: our one home.

The Industrial Revolution has enclosed the commons of everyday skills. Databases and most databanks have enclosed knowledge. In short, we have become divorced from the commons that we all shared. The social change driven by the Industrial Revolution, and the rise of capitalism, has moved into an era of passive consumption. The problem is that we live on a finite planet, and that there are insufficient resources to meet the growing needs of our global population, if we retain the same neoliberal approach. Capitalism is untroubled by seeing poverty in other parts of the world. We have become separate from the environment we need – we should always remember that the environment does not need us. The problem lies in the neoliberal economic system. It assumes that trading is ‘perfectly informed’ and ‘rational’, and that there is an infinite amount of resources and carbon / emissions / pollution sinks. Economics assumes markets can find solutions. But this is not always the case. Now and in the future, adapting to the consequences of accelerated climate change and increasing variability with more extreme weather events/periods will be a considerable, and for poorer countries and regions a huge, challenge. Human societal climate adaptation urgently requires rebuilding the resilience of communities in order to ensure that they can cope with climatic disturbances. We can no longer separate risk and development. We need holistic and continuing approaches to adapting to climate change [100].

The majority of the global human population now live in cities, and will do so in the future. The solutions to the problems we face will have to be found in cities. History suggests that cities innovate. The neoliberal market-based system is at the root of the problem. Political leaders must make a huge effort to innovate in their adaptations to our reality. Perhaps a moral revolution is in order! We have

had an Industrial Revolution. Perhaps it is time for an Economic Revolution (for human-wellbeing, social and environmental reasons) as we may well be at the turn where we need protection from the environment, rather than the environment from us. The demands we are making on nature by living in cities have reached a crisis point and unless we make significant changes the prognosis is terminal consumption. We need a radically new integrated global understanding of nature and cities. The challenge of urban stewardship to tackle the climate emergency crisis needs to be at the very centre of our thinking [101]. Climate Change is now key for Disaster Management [102]. Poverty and community disaster risk reduction, both urban and rural, can be said to be in a 'double bind' [103]. Community participation in disaster risk reduction is critical [104]. And we should develop strategies for building resilience for cultural heritage, too [105]. Locally, as much as nationally, we need to produce equitable energy systems [106].

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