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Sustainable Society: Wellbeing and Technology—3 Case Studies in Decision Making

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Abstract: Throughout history, technology has provided many and significant improvements to the way we live, but the current pace of development now often exceeds the ability for the full potential of any technological innovation to be explored and implemented before further innovations are introduced. This pace of change results both in missed opportunities for a technology in its ability to contribute to effective solutions in addressing issues such as reducing adverse environmental impact or improving the health of society. In considering the nature of technological innovation and development, the associated engineering design processes can themselves be characterized as being associated with a highly complex, iterative problem-solving exercises, involving the integration and synthesis of a wide range of technologies. This in turn requires the design team to manage trade-offs across a range of primary constraints, as for instance embodied energy in manufacturing, energy consumption in use, capital costs and operating and resource recovery costs. Further investigation into the complexity of societal issues and means for achieving a more effective and fuller utilization of both existing resources and technologies is necessary to place sustainability as a priority of the decision making process. To support discussion and provide context, three case studies are presented. The first case study examines a strategic framework adopting metrics aligned with environmental issues used as proxies for evaluating wellbeing and common good. The second case study examines the specific contribution of eHealth to wellbeing and the balance of technological, societal and political issues in determining outcomes. The third case study considers how technology might be embedded as part of the process of obtaining meta-data from within a small rural community to demonstrate the impact of mitigation strategies associated with the reduction of its carbon footprint, and hence on climate change. In doing so, the paper seeks to bring together issues surrounding environmental problems in relation to a technology driven engineering design process while positioning them in the context of social benefits arising from sustainable decision making.

Keywords: engineering design; technology; environment; sustainability; decision making

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1. Introduction

The Brundtland Report [1] provides an authoritative approach for a global society to prioritize sustainability and address the challenges in "meeting the needs of the present without compromising the ability of future generations to meet their own needs", something now reflected in the 17 UN Sustainable Development Goals [2–4]. Taking the reduction of environmental damage as a specific priority for society, and hence sustainability and carbon reduction as objectives within such a priority, it is possible to recognize the alignment with the principles of sustainable decision making as these objectives argue for the rights of future generations to be taken into account.

One barrier to successful collective action for the community when seeking agreed decisions to achieve a shared vision of social sustainability is that it becomes increasingly difficult as the size of the community grows [5]. The factors influencing individuals to make decisions are thus critical in trusting the mechanisms by which sustainable decisions are made. Typically consultants with various specialisms are appointed on behalf of groups, such as Local Authorities and the National Health Service (NHS), to assist in capturing relevant data to help make informed decisions for the group. In 2020, new approaches to managing and delivering healthcare have arisen from the consequences of COVID-19 [6–9]. There is evidence of a shift towards prevention in areas such as obesity [10] but opportunities remain for a much greater shift from treatment to prevention. This in turn raises the complex interaction between the problems of how to engage society with sustainability solutions. Technology has the potential to enable society to develop and grow but problems remain around the purposes for which technology may be applied [11–13]. Fuller's approach [14] (Berg, 1982), indicates the potential for technology to improve human well-being, and by association the principles of sustainability in balancing societal, environmental and economic priorities.

This paper seeks to answer the research question, "Are social sustainability decision making processes sufficiently informed by data before implementing change?". Three case studies are presented that examine processes for informing decisions relating to improving social sustainability. One with a focus on a long-term major infrastructure project for social sustainability and two projects (one health care and another local community engagement) investigating the use of technology to inform the social sustainability decision making process.

2. The Design Process

2.1. Technology and Engineering Design

Throughout history, developments in technology have been associated with the provision of solutions to an identified need through a process of synthesis and integration which draws upon available knowledge from a wide variety of sources, including personal experience [15]. Technological developments are often progressed through innovators who are intrinsically motivated to learn new things while developing an individual knowledge base linked to personal experience [16], adapting their modes of practice accordingly through an iterative process of reflection [17]. The tacit or implicit knowledge generated in this way is by its nature personal, and hence extremely hard to effectively communicate with others as it encompasses subjective insights, intuitions, ideals, values and emotions [18,19]. In contrast, technological developments that arise from innovators who themselves gain a direct, personal gain from sharing their knowledge, is subject to controls such as patents that act to inhibit knowledge sharing with wider society [20]. Intuition, or a hunch, can generally be related to user experience, and hence their level of intrinsic (or tacit) knowledge. The danger is that such knowledge brings with it as a consequence a bias, unintended or otherwise, which can influence outcomes. In this context, the design process model of Figure 1 parallels that of the scientific method of Figure 2 as this emerged in the Renaissance. The main difference being that the latter emphasizes discovery and the generation of new knowledge while the former focuses on problem solving and innovation.

In most instances, what might be considered as a 'new' technology generally involves a process of synthesis in which prior technologies are adapted by and integrated with new knowledge to solve new and specific problems. This progressive development can be seen in Figure 3, which details the sequence of industrial revolutions from the 18th century to the present.

The first of these, which itself built on the development of the Scientific Method, was driven by water and steam power and characterized by increasing levels of mechanization [21]. The second industrial revolution [22] then introduced the concepts of mass production and assembly line working while the third saw the introduction of computer based automation and increased levels of system integration, as characterized by the growth of mechatronics technologies [23,24]. The current industrial revolution, the fourth, is structured around communications technologies, in particular wireless networks, and increasingly uses Artificial Intelligence (AI) structures to facilitate systems-oriented concepts such as Cyber-Physical Systems (CPS), the Internet of Things (IoT) and Cloud technologies [25–29].

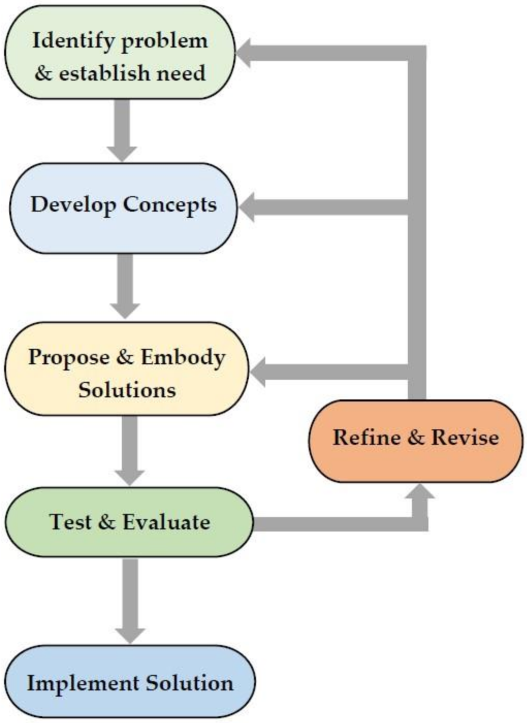


Figure 1. The Design Process.

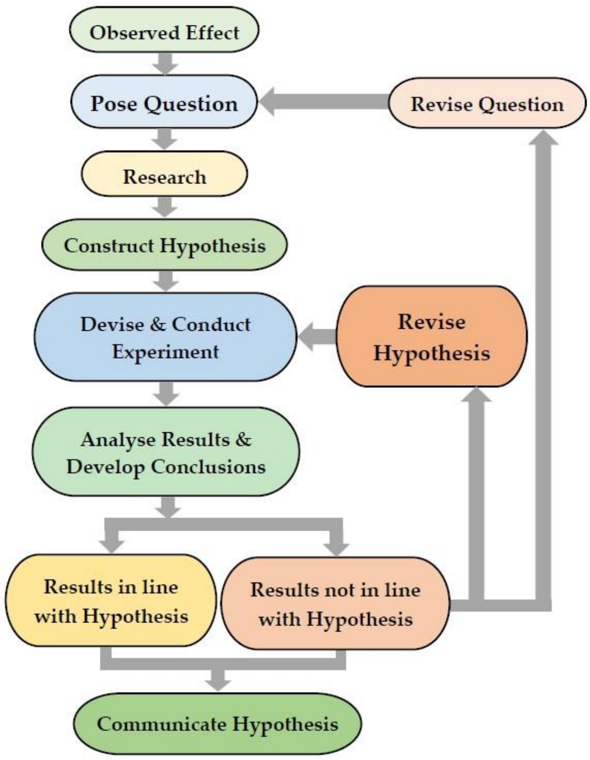


Figure 2. The Scientific Method.

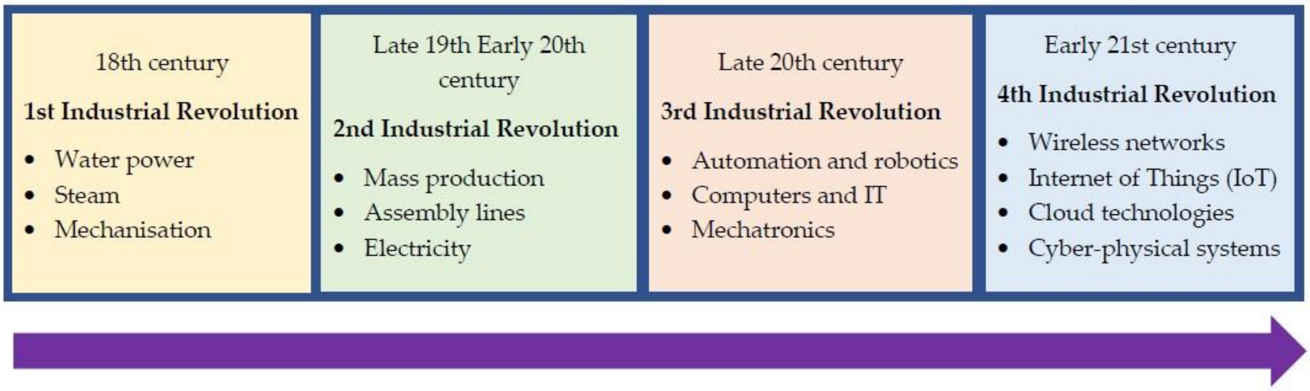


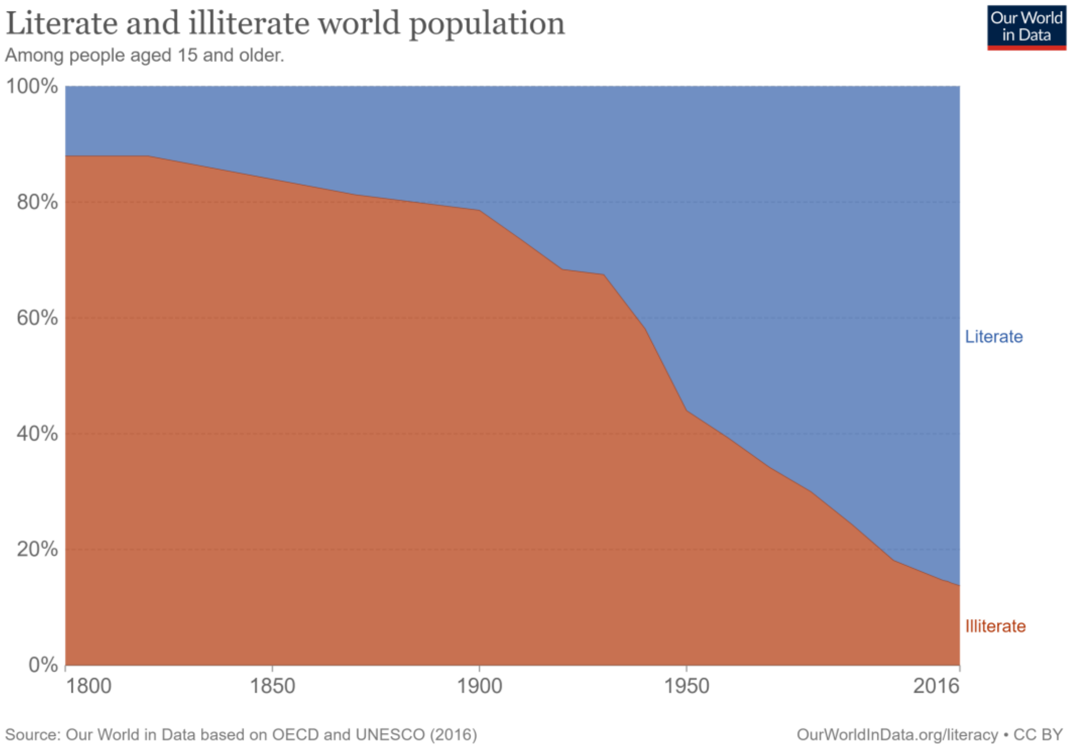
Figure 3. Timeline of Industrial Revolutions.

Each industrial revolution has in its turn impacted on the then current social norms and expectations. The first industrial revolution saw the beginning of the shift from craft-based manufacturing to factory-based manufacturing with an associated movement of population from the countryside to towns and cities. The second saw a further shift in the manufacturing skills base with work often being structured around individuals repetitively executing a single task. The third saw increasing levels of automation in manufacturing associated with a wider access to an increasing volume of consumer goods such as cars and domestic appliances, along with an increased ability to go longer distances as a result of air travel.

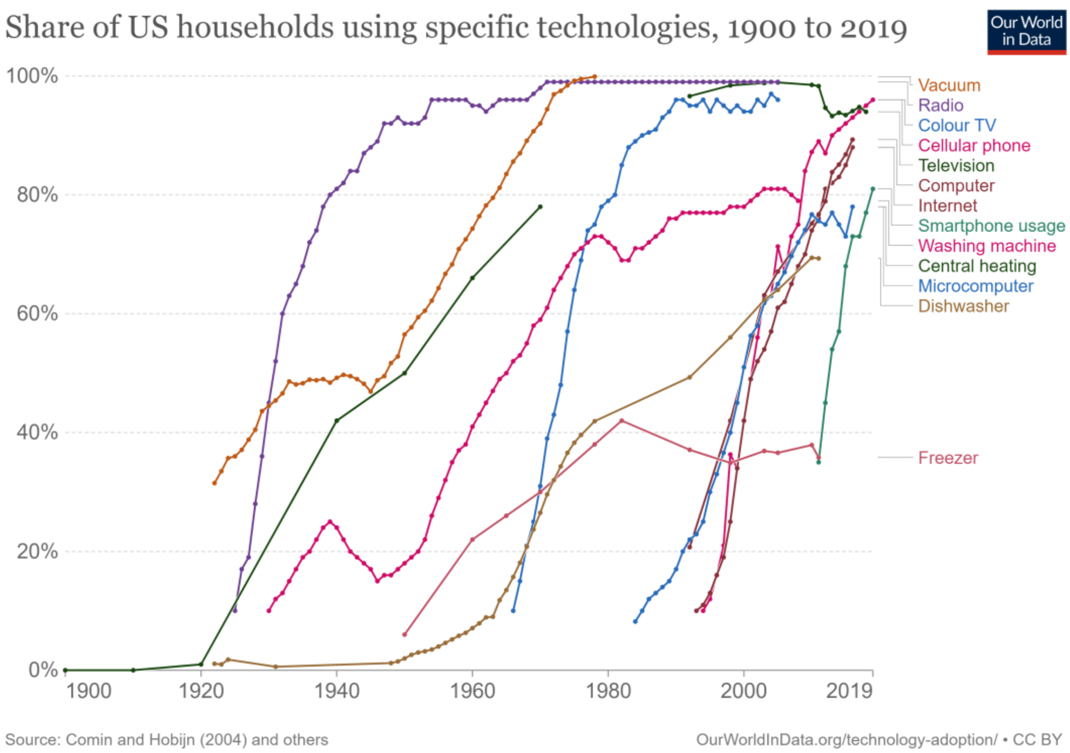
The current industrial revolution, structured as it is around 24-h access to information, and sometime to individuals, with task and activities shifted around the world in relation to the daily cycle. Such an information-based infrastructure brings with it its own range of system specific societal issues and problems, many of which are associated with the privacy of the individual [30,31]. Of particular concern is the way in which data can be used, or misused, to impact on the life of an individual [32–38]. There is also the question of dealing with the propagation of misinformation via social media, and the impact that this has on people's lives and behaviors [39–42].

The impact of changes over the course of the second, third and fourth industrial revolutions in particular can be seen by reference to Figure 4. Here, Figure 4a provides an indication of changes that have taken place in respect of the basics of education while Figure 4b illustrates the take up of domestic technologies. Figure 4c then references the use of the Internet, a technology closely related to the development of the Fourth Industrial Revolution. It should be noted that across all indicators of this type and nature, the overall trend is generally positive, however developments are not necessarily uniform across countries and societies, as can for instance be seen from Figure 4c where the least developed countries lag significantly [43] (Our World in Data).

The complexity of many modern systems is such that it is effectively impossible for a single individual to manage the necessary processes of synthesis and integration required to meet the design goals, relying instead on individuals working as a team, with associated issues and problems of communication and understanding. When teams are creating systems, there is often a choice as to whether the system is viewed as an open system or a closed system. Thus in the context of technology, within an open system a software provider would typically offer the code to a range of competing hardware developers. However, with a closed system a company would only provide and operate their software with their own hardware. Whilst an open system is ideal for enabling as wide a range of development options as possible, both political and business interests often act in ways such as to inhibit other possible solutions [44].

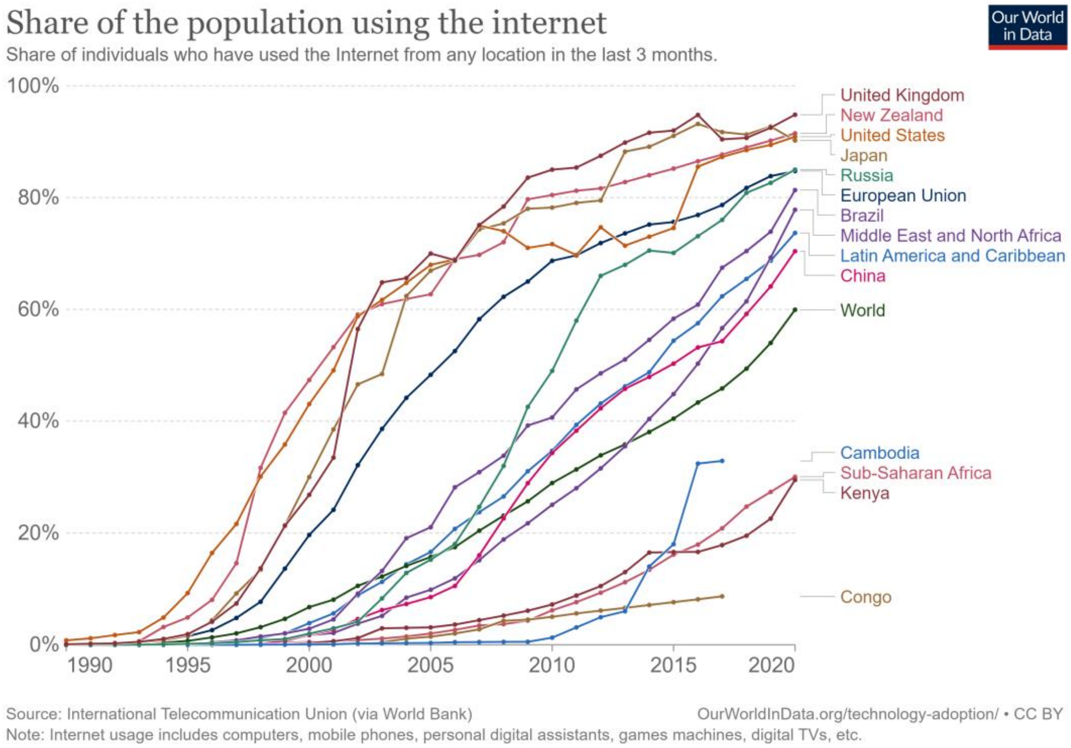


(**a**) Literacy



(**b**) Technology adoption by US households in the period 1860 to 2019

Figure 4. *Cont.*



(**c**) Share of population using internet (2020)

Figure 4. Developments over the course of the Third & Fourth Industrial Revolutions (source: Our World in Data [43]).

The need for teams and different strategic options for technology development can also result in the creation of artificial boundaries in the design process based on interpretation of need, and hence in a separation between the designers and the user, the latter seeing the result in terms of its appearance, the aesthetics, and its functionality in respect of its effectiveness in meeting their specific needs with little concept of the underlying structures or processes. This can result in a disconnect between expectation and outcome from the user perspective when they begin to experience the system level limitations of a particular product or process; some of the causes of which can often be attributed to emotional attachment and social values [45]. The first case study presents a framework that attempts to address these problems and issues.

From the designer's perspective, the relationship with users is illustrated by the work of Rodgers and reflected in Figure 5 [46] and the Gartner Hype Cycle curve of Figure 6 [47]. The first of these shows the take up of a product by potential users while the second reflects the way in which technologies are perceived over time. Almost inevitably, most user expectations are not met!

The other major systems element associated with many modern technologies is their ability to form part of a network of devices with users then providing access to a multitude of information sources, many of which may well lack any form of verification, thus leaving them open to manipulation. Nevertheless, the ability that such networking provides both as a means of informing users and of gathering data is significant and has the potential to support the common good.

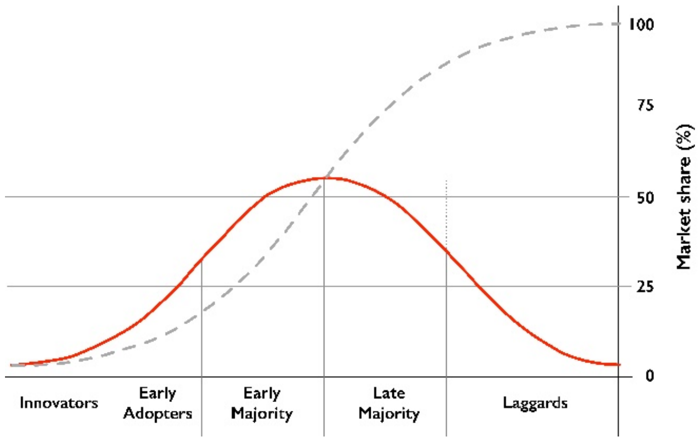


Figure 5. Rogers Technology Adoption Curve.

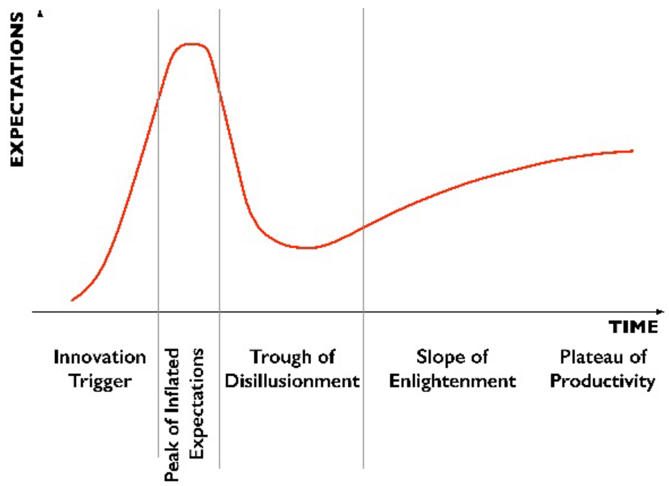


Figure 6. Gartner Hype Curve.

Thus, in the case of the environment, individuals can be provided with information specifically matched to their need while eliminating waste, as for instance through more effective environmental controls or the use of localized smart grids for energy management, thus linking the physical and information requirements. In health care, monitoring at the level of the individual would support an interventionist mode of care in which conditions are detected and treated at the earliest possible opportunity using, with appropriate privacy and other safeguards, techniques of Big Data Analysis to aggregate data over large numbers of individuals to establish markers [48–50].

The nature of large-scale, complex projects at the limits of design solutions has created opportunities for applications of technology covering uses from design through construction to the end user including smart structures, field robotics, vibration control, active maintenance and safety [51], indicating the potential for the application of technology to contribute towards sustainable project in respect of:

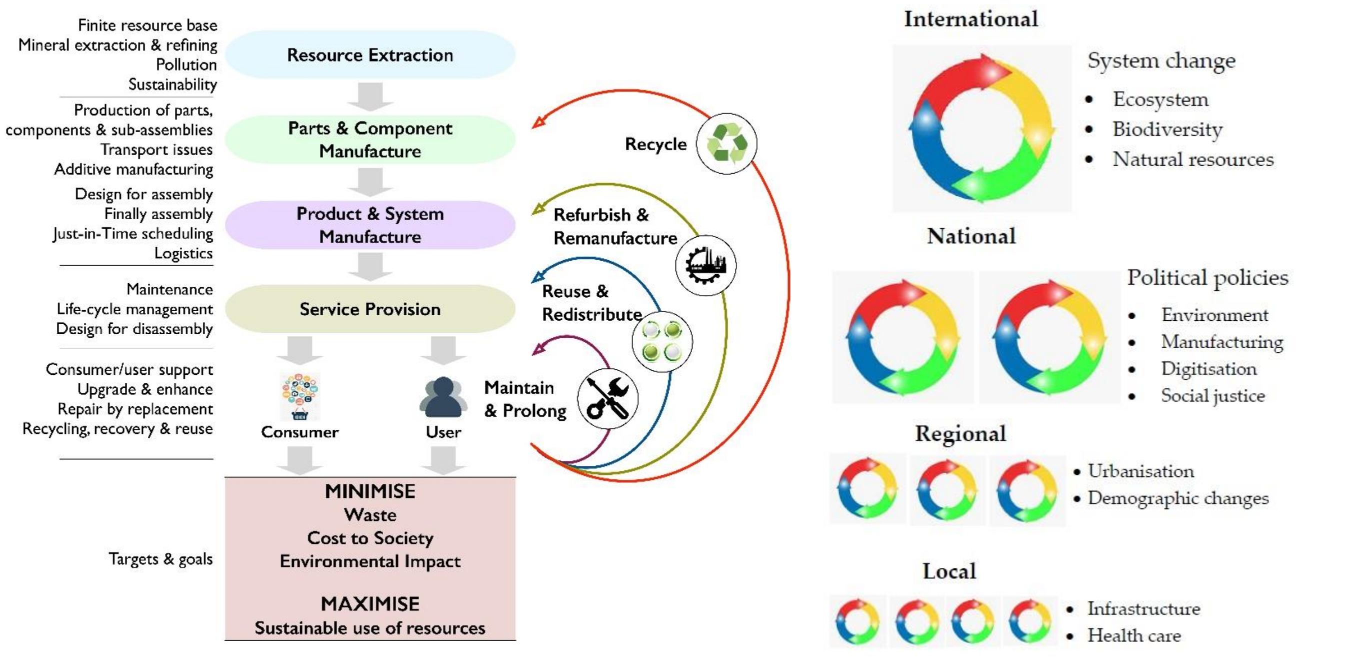
- The machinery and automation of the system being designed;
- The provision of intelligent operating systems for the users with mechatronics components or systems, such as embedded sensors, smart materials, actuators, dampers, inspecting robots and military hardware.

The balance between technology and politics is such that the political climate must inevitably be a major factor in establishing technology use. Politics influences decisions made in the design process as a result of policy decisions at government level [52], as for instance as to which areas of technologies are to receive funding support or involve business and the ways in which they control and manage their products [53,54]. In seeking approval from society any policy, advice, guidance or laws can be presented for challenge by sections or representatives of society such as political oppositions, lobbying groups and protestors, each of which can be drivers for change, even if the information presented by any group or side is knowingly inaccurate in an attempt to influence society's opinion or acceptance [41,55]. This influence can extend to impacting on longer term decisions and can create situations where solutions that are intended for longer term use might be 'locked-in' to a specific technology or closed system associated with a specific manufacturer that may not be supported over longer periods of time or has limited functionality.

In summary, technology provides opportunities to maximize solutions that promote the common good for society and individual human wellbeing whilst offering the potential to optimize resources. There are many complex factors influencing how technology can contribute, the details of which go beyond the scope of this paper, but which are associated with the underpinning knowledge of their designers and how society reacts to political and business interests influencing the pace and direction of technological change.

2.2. The Environment, Economics and a Circular Economy

The environment is linked to economics, which means that it is not possible to make an economic decision that does not, in some way, have an effect upon the environment [56]. The field of environmental economics is thus of relevance to understanding influences over the decision processes for a better society. Environmental economics provides a method whereby monetary measures can be used as a benchmark to indicate what people want, and do not want, with respect to the environment, taking into account human wellbeing as an economic effect. In this context it is possible to determine that, by certain actions (or inactions), the wellbeing of individuals may be increased or decreased through the economic effect upon the individual. A fundamental tenet of environmental economics as an open system whereby it is accepted that the materials, goods and services used in the provision of any standard of living measure are based entirely on the support of the biosphere (ecological systems of plants and animals and their interrelationships). In such a model the concept of sustainability is critical to success, and it is recognized that damage to the biosphere will ultimately inhibit society; what might be described as a model for the circular economy such as that of Figure 7 [57].



(**a**) The Structure of a Circular Economy (**b**) The Multiple Layers

Figure 7. A Multi-Layer Circular Economy.

For a model such as that for a circular economy to work, the impact of goods and services provided for society needs to be considered in relation to the issues associated with obtaining the necessary resources from the environment, processing them into end-products and disposing of the used and no longer wanted resources back into the environment. Examination of a circular economy necessitates an understanding that materials equilibrium is essential given the unarguable fact that as more resources are used by the economy, the more waste is created and returned to the environment.

It is possible to ascertain that economic activity is limited to the capacity of the natural environment to cope with the damage from waste; a classical economic model supporting a limits concept being that of Zweig [58], although this model has been challenged in favor of scarcity [59]. In either case, it is argued that there are limits to the amount of resources that can support a population [60]. Until such time as the measure of economic output as a measure for standard of living is replaced by a different model such as The Australian Unity Wellbeing Index which provides an indicator of Australians' satisfaction with their lives, and of life in Australia [61], there will be pressures on the resources needed to support current economic growth metrics. Indeed, in the early 1970's it was found that despite absolute increases in the material standard of living, this did not necessarily equate to people feeling happier with their lives, a phenomenon described as the Easterlin Paradox [62].

In addressing environmental concerns through technology, issues such as repair by replacement, lifecycle models and the circular economy are of importance. Given the pace of change of technology and potential applications for available technologies, essential factors to identify are questions as to the knowledge of the problem and if the decisions made during the design process are leading to the right problem is being solved. As an example, it is possible to consider the issues around a simple assembly design for a push-fit pipe system that does not require any fixings or sealants. Such a system might be simple to use and put in place with minimum materials and waste, but any subsequent need to make changes presents difficulties, as for instance disassembly for repair or maintenance.

The ability to disassemble product components and the subsequent efficient recovery of both parts and materials are essential features of any design for disassembly approach, but there is clearly a balance to be established between these requirements. A methodology for Lean Design for Disassembly indicates that it is possible for engineers to make quick and robust assessment of their design choices by considering quantitative disassembly and recyclability metrics [63]. Here, the identification of the appropriate balance between incremental progression through innovation and the step change associated with disruptive innovation and technologies arises when seeking meaningful progress in reducing damage done to the environment and improving wellbeing by providing flexible and balanced solutions. Here, there is evidence that within a business model targeting over-served or unserved customers, then disruptive innovation is a requirement for change [64]. Hence, before the process of producing a solution begins, the nature and extent of the problem must first be properly and fully established and identified.

In relation to the environment, there is the need for indicators that provide for the forecasting of trends leading to the identification of causes of environmental decay in urban environments. How this may be caused by reactions to economic and political policies has been investigated by Button [65]. Evidence then supports the use of urban indicators for providing beneficial guidance in decision making as to when interventions are needed as well as where urban indicators may be the appropriate mechanism to indicate where automatic feedback may be adopted to avoid unnecessary interventions [66]. Whilst aiming to reduce adverse environmental impact by reducing carbon emissions, it is also necessary to recognize that for human wellbeing, avoiding energy poverty is also critical [67].

In ensuring human wellbeing, good health is a fundamental requirement. Current provision tends towards a model based on reactive care, responding once a condition is diagnosed or detected. The value in taking a longer-term strategic decision to shift resource use towards a proactive interventionist model aimed at prevention requires the adoption of technological solutions to collect and monitor a substantial amount of data in a way that benefits not just the individual but the whole of society.

Technological innovation can provide a mechanism to improve human wellbeing, but any solution that is technology based, as for instance in healthcare, requires the engagement of all the different stages of the design process to develop and assess the technologies and their application from a user perspective [68]. However, technological innovation is subject to organizational drivers for success, particularly within the healthcare sector [69]. Any technological solution, after a rigorous design and testing process, is still required to convince society to place trust in its intended objectives.

As an example, it is possible to examine the process for identifying, testing and producing a reliable and safe vaccine for COVID-19. On the one hand there are countries with a political desire to bypass the normal testing and regulatory processes to bring production and distribution forward. In the US, drugs manufacturers have for decades criticized the Food and Drug Administration (FDA) for being too slow and demanding too much evidence before approving new products but there is now a challenge to rushing the process given indications of the federal government considering fast-tracking release of a COVID-19 vaccine [70,71]. In addition to the balance between creating a reliable vaccine against COVID-19 and the time taken to create and test such a vaccine, there are challenges from some parts of society through the influence of groups such as the Antivaxer movement. An essential feature of trust across society is required in a respect of medical solutions, where the role of patient autonomy, greater transparency and integrity in research is required so that research and misinformation that is distorted for funding or partisan purposes is firmly refuted [72].

In such a context, where success depends on behavioral change from and by participants it has to be accepted that there are limits to obtaining the engagement of every single person in a community or population. In healthcare innovation, for example, the sustained use of technology requires a behavioral change that cannot be mandated, with no single stakeholder, organization or government able to force change on any individual [73]. How people can be encouraged and persuaded to engage with innovation for their benefit is rooted in research going back to ancient Greece, but it is reasonable to accept that tactful, systematic persuasion is a process which attitudes or beliefs can be shifted by appeals to logic and reason based in facts and science [73].

There are barriers to explain the low level of public awareness on the concept of a circular economy and lack of understanding of its principles. From an environmental viewpoint, waste management indicates limits to the use of recovered materials, identifying economically competitive but sustainable supply chains and end-of-life management as key issues [74]. In relation to a circular economy, the key product characteristics necessary to increase sustainability were identified by Chouinard et al. as modularity and robustness [75]. There is evidence that systems being designed for long-term circular strategies had a limited focus on end-of-life. It was found that some classes of device experience limitations within a circular economy model through electronics obsolescence, evolving regulations and customers who do not currently prioritize circular aspects in products thus presenting considerable barriers for designers in meeting circular principles.

In the transition towards a circular economy, political influence typically takes the form of government direction through statutory requirements as drivers for change along with tax incentives to encourage and support change. A successful circular economy model requires a systematic regulation and policy system, with effective interactions between stakeholders such as governmental institutions, policymakers, communities, and manufacturing industries to minimize environmental damage, provide cleaner, competitive, and more integrated production chains, energy-efficiency, and more sustainable buildings, promoting thermal comfort and well-being to users [76].

The adoption of user-friendly systems can reduce adverse environmental impact. Tiefenbeck et al. [77] focused on methods of reducing society's dependence on fossil fuels through changes to the energy sector using Information and Communications Technology

(ICT) based solutions. In this context, where 85% of the residential energy consumption was for space and water heating it was found that there was a gap in the application of energy informatics solutions to reducing energy demand for these purposes. In terms of sustainability and environmental protection there are benefits for society of adopting practical, user-friendly, commercially scalable options where there is clear evidence for statistically significant savings [77]. The lack of application to society of such solutions gives rise to the question as to why such benefits are not realized beyond case studies. Identifying such opportunities with gains for society is not particularly difficult given the publication of research results, therefore, why are organizations that could exploit the commercial potential not doing so?

2.3. Environmental Problems, Attitudes and Society Actions

There are complex links between cause and effect, further exacerbated when examining terminology and conceptual language, particularly around people's environmental concerns and attitudes [78]. For the purposes of this paper, environmental concern is considered as one aspect of environmental attitude. Taking this distinction into account enables the issues of environmental concern associated with environmental problems to be addressed through technological solutions. Environmental attitudes then encompass the beliefs and behavioral intentions held by an individual regarding environmentally related activities engaging with the good of society.

The historic and current environmentally destructive behavior of society in general has to be addressed through some form of intervention. The difficulty lies in identifying which behaviors can be addressed by which interventions to reduce successfully environmental damage. Whilst it is a complex area with as many as 18 different personal and social factors identified [79], there are indications that solutions addressing behavior can be correlated with knowledge, beliefs, personal responsibility, and perceived threats to personal health [80]. For some people their attitude to environmental issues is based on a purely utilitarian perspective; others are concerned about environmental sustainability and maintaining an ecological balance [81].

The social basis for environmental concern continues to challenge researchers due to the numerous and diverse policies aimed at addressing a wide range of issues, particularly when matters such as air pollution, water pollution, wildlife protection and carbon reduction are treated together under the general remit of environmental concern [82]. In addition, attitude towards the environment is only an indirect determinant of specific environmentally related behaviors [83].

With a focus on what people do as a more reliable indicator of their response to environmental policies and change in society, rather than what they state as intentions or beliefs, it is possible to value factors. The focus of a study by Poortinga et al. [84] on measuring a households' home and transport energy use identifies factors influencing environmental behavior but was limited in the amount of data that could be obtained without the use of real-time sensors and data collection for the variables under analysis. Although this issue can now be addressed through technologies such as those of the Internet of Things, there are still privacy issues associated with obtaining such data [85,86].

What is increasingly clear is that behavior and action in relation to environmental decisions and action by households is influenced by the localization of environmental issues or changes to a community and that contextual variables are an important indicator for behavior [87]. It is also necessary to appreciate that any expression of concern for the environment may not be correlated with responsible behavior in respect of the environment [88,89] visible in situations where, for example, wind turbines may be considered to be acceptable as a renewable energy solution just as long as it is someone else who has to put up with the associated visual and noise issues.

Whilst some people will be better at articulating environmental concerns than others, with a distinction between urban and rural contexts, behavior is dependent on direct experience with the natural world and intervention models need to take into account the needs and customs of the environment's users [90]. One area of environmental action associated with an urban population is that there is a strong correlation between home ownership and recycling behavior [91], leading to the argument that home ownership indicates a possible stronger stakeholder interest in the local environment. Therefore, it can be deduced that local communities with a higher home ownership are more likely to engage with change to make environmental improvements where they can realize not just immediate, but long-term environmental benefits.

There is sufficient evidence to acknowledge the complexity of issues surrounding the differences between attitudes and individual actions while identifiable differences across society impose considerable limitations. There are possible interventions based on a robust understanding of influential factors that may work better for local communities in seeking improvements in their environment. Such interventions are more likely to work where education to raise awareness and increase knowledge is combined with health-related improvements as a part of a strategy whereby both of these factors can be used as suitable proxies for the well-being and common good of society.

3. Sustainability, Society, Citizenship and the Common Good

For individuals to contribute to sustainability for the common good of society, an understanding of what motivates any individual in relation to environmental matters is needed to be able to support and encourage such actions. To that end it has been established that positive behavior towards the environment does not appear to be motivated just by the thought of helping the environment, and that there is an element of gaining some form of recognition from society and other tangible benefits that influence behavior [92,93]. The focus of those examining citizenship seems to be primarily towards the types and frequency of activities that people engage in, raising the question of what counts as citizenship. It has been argued that a more appropriate focus would be on how people enact citizenship and that reorienting from a question of what, to a question of how, usefully redirects attention from acts to action [94].

There is empirical support suggesting that a response to environmental issues is related to an awareness of environmental facts and information, along with beliefs and values associated with power, benevolence and universalism [95,96]. Those in society who actively seek to address environmental issues through their own actions have been described as environmental citizens [97]. These are generally individuals whose commitment is strongly influenced by contextual factors, indicating that there are diverse forms of environmental citizenship, for some of which existing public government interventions are inadequate.

There are a number of different categories of citizen with differing characteristics. Veugelers [98] describes a 'critical-democrat' citizen and Pocock et al. [99] the concept of environmental citizenship. Westheimer and Kahne [100] and Johnson and Morris [101] describe a 'justice-oriented' citizen; both descriptions identify similar characteristics for a category of citizen who is cooperative, concerned for social justice and motivated to change society. Goldman et al. [102] build on this category and its associated characteristics for the additional description of 'green citizenship'.

In terms of examining any individual's impact on the environment there are different measures, including energy use, water use, carbon footprint to name but three. One approach considers a wider description of environmental impact and has been identified as ecological footprint [103–105]. The idea of an ecological footprint has been developed and refined [106] but has been challenged on the basis that as a measure it is based on accepting flawed assumptions around issues such as energy use and which carbon reduction targets are necessary [107]. It is possible to acknowledge that there are limitations to any model and how it is used and applied to identifying and addressing environmental problems. Nevertheless, whichever model is used, as individuals all of us go about our daily activities in different ways, making individual choices and decisions, thus the extent to which we each impact on the environment will also differ.

It is a fact that Earth has a finite amount of resources. If we adopt the premise that fairness and justice for all, including intergenerational fairness and justice, according to the concept of environmental citizenship there is unfairness. It follows that a responsible environmental citizen would seek to try and make decisions and act in such a way that their impact on the environment is just and fair. However, such an approach based on social justice has to be clearly distinguished from that of charity [108]. The distinguishing aspects between an environmental citizen taking responsibility for their choices and action compared to that of charity lies in the relationship between cause and effect. For example, when a natural disaster such as an earthquake occurs, the environmental citizen is not responsible in any way; in relation to climate change and environmental impact there is some responsibility directly related to choice and actions. In these two situations an individual's obligation to respond gives rise to different issues. Responding on the basis of a charitable obligation can lead to withdrawing support somewhat more easily than on a basis of social justice that reinforces consistent behavior and action as environmental citizens know that their private actions have public implications [108]. As an environmental citizen each decision and action by an individual has implications for society, therefore the duty of an environmental citizen is to live sustainably so that they, and others, may all live well.

The descriptions of an environmental citizen and the intention of achieving a better society accept that whilst there is a characteristic of a cooperative person, there is an assumption based on accepted and unarguable evidence that indicates there is social gain. A healthy society needs unambiguous scientific evidence and a lack of conflicting expert opinions on appropriate actions but there are numerous conflicting arguments, evidence and issues in environmental matters that lead to challenge and dissent in relation to priorities that lead to compromises when setting sustainability objectives for the benefit of society.

Whilst there is evidence that people can be selective in their choice of evidence for consideration or supplied as evidence [109] in relation to an issue such as climate change, what should be sought is a clear consensus across society. In addition, there is an expectation that for the common good, individuals will act altruistically in relation to their choice of actions. Unfortunately, humans have not yet been demonstrably altruistic *en masse* [110]. A contributory factor to the limits of achieving wide-scale altruistic action across society can be associated with social media that allows for views and opinions to be presented uncritically, supported by a simple reinforcement mechanism (the 'Like' button), which reduces exposure to reasoned and critically considered conflicting views [111], including the recent phenomenon of 'fake news' contributing to the acceptance of information inadequately subjected to extensive critical review [112]. Dissent, when it arises, can be attributed to different issues but will typically be recognized as some form of unfairness to some people in society [113].

Other less confrontational forms of dissent can relate to actions in response to purchasing power. Where manufacturers take the risk of selling products with 'green credentials' to influence purchaser behavior and increase sales, any exaggerated claims leads to higher expectations from purchasers, with negative consequences when such products are found to be using misleading information [114]. For example, the fraudulent practices within the vehicle industry in making exaggerated claims for environmental performance has had a considerable adverse impact from society and consumers who believed the advertised environmental performance [115–117]. As a logical deduction, environmental citizens can be assumed to be well informed in making their choices in respect of what they choose to do and how they spend their money. Making additional efforts to increase the public's knowledge of technology and how they can engage with approaches to improve society and the common good can be expected to provide meaningful benefits, although engaging with volunteers and contributors does add complications in relation to obtaining data that is not objective and is reliant on subjective measures [118]. It has been found that, for example, where intuitive interfaces to control RC boats for collecting environmental data were used, it was considered an enjoyable way for members of the community to engage with a local site of environmental concern, improve their knowledge of environmental issues, and collect data for research [119]. There is increasing interest in how citizen engagement, connected technology and data analytics can support sustainable development with a focus on novel monitoring techniques using Internet of Things (IoT) technologies, as well as open data and citizen engagement, particularly using mobile devices, applications ("apps"), and open-source mapping platforms [120,121].

4. Methodology

Three case studies have been selected for the purposes of answering the research question. The first case study examines, through the assessment and monitoring process of more than a decade, the efficacy of applying knowledge mapping techniques to the decision making process for a major urban infrastructure project. The Local Authority enabled research to be conducted through observation. Whilst it is accepted that the presence of observers may influence the activities under observation, as this was a long term project it is believed that regular collaboration and engagement has limited the potential for such bias to influence the process. During the establishment of sustainability criteria for the project 3 key individuals were selected, based on their roles, as representative of the three strands of the Waterfront Partnership delivery team namely, urban planner, engineer and enterprise agency. The output of the decision making process resulted in a number of different benchmark indicators, with 9 social sustainable benchmark indictors identified that were expected to meet the expectations of the different stakeholder groups.

The second case study is chosen as an area of importance to society as an indicator for human wellbeing as part of social sustainability, with the purpose of supporting individual decisions on independent living. For the purposes of this case study an examination of existing literature was used to examine an eHealth model of healthcare. The recent events of the pandemic and pressures on healthcare provision across the globe produced considerable pressure on existing models of healthcare provision requiring a new way of thinking about access to, and provision of healthcare. This case study identifies the flexibility of deploying appropriate technology is an essential part of a new eHealth model. Most of the investment in healthcare is allocated towards care as a response, whereas prevention would be better for society and individuals. Successful implementation of this different approach as a standard for some healthcare provision requires some change within society itself to be ready to adopt greater use of eHealth technology. Whilst there are advantages to this approach for society there are also concerns. Amongst the problem areas is the ability of an eHealth model to gather extensive personal data that may also contribute to healthcare research for the good of society. At the same time, data security and access to those with a legitimate interest are reported areas as barriers to adoption.

The third case study covers the issues around individual decision making in the context of a rural community. Community groups were observed at 3 meetings in which open discussions around sustainable priorities for the community. From these observations the themes of individual choice, healthcare provision, energy reduction and transportation infrastructure were identified. It was noted that some compromise would be needed at individual level if change were to happen. Whilst there was support and willingness to engage with change that may support sustainable objectives, at this stage the actions could not be confirmed to support the intention. Some factors have to be driven by the decision process at regional or national level to achieve change with which local communities and individuals can readily engage.

5. Applications of Solutions

5.1. Case Study 1—Major Waterfront Refurbishment Strategic Framework

Major urban infrastructure construction projects need to create mechanisms to encourage resource utilization consistent with the aims of a sustainable society (the common good) by using sound governance to share net benefits [122]. Whilst different sustainability indices are available that can be applied to city sustainability such as the following: Ecological Footprint (EF), Environmental Sustainability Index (ESI), Welfare Index, Genuine Progress Indicator (GPI), Index of Sustainable Economic Welfare, City Development Index, Environmental Vulnerability Index (EVI), Environmental Policy Index (EPI), Living Planet Index (LPI), and the Environmentally adjusted Domestic Product (EDP), each method has limitations when seeking to address certain specific city requirements to assess social sustainability achievement [123]. This case study used a knowledge mapping technique from key stakeholders to inform the original decision making process to set social sustainability objectives. Suitable indicators were identified and aligned with the expected Single Outcome Agreement (SOA) obligations expected by the Scottish government. These indicators could be assessed for progress during the implementation of the project for impact. The metrics used were easily obtained but, after about 10 years it became apparent that the data upon which the original social sustainability benchmarks had been established showed gaps for achievement of aspects relating to wellbeing. For example, one metric for social sustainability used the number of city-wide travel journeys by public transport and the percentage increase in number of journeys was taken as an indicator of progress. Data that was easy to collect but could not be reliably correlated with wellbeing improvement. The information behind the increase was not recorded as part of the review of progress towards sustainability objectives and therefore gaps in determining the extent of impact was limited. To address the gaps it was necessary to consider the possibility of identifying suitable proxies to indicate, for example, where these targets aligned with improvements in wellbeing. In the context of this case study the concept of the common good is adopted to provide suitable proxies for the sustainable society priorities for the citizens of Dundee.

The Dundee waterfront refurbishment project is part of the Local Authority Regeneration Masterplan, overseen by a governance group representing the citizens of Dundee for the project accountability and delivery. The purpose of creating an accountable body to oversee and deliver the project was to serve the needs of society while seeking a measure of gain for society. As the accountable body, the intention was to make suitable decisions that improved the social sustainability priorities of its citizens. Within the project evaluation process drivers that could be measured objectively were aligned with social sustainability issues.

The framework for evaluating the outcomes from the Regeneration Masterplan needed to establish metrics that satisfied accountability of the governing body while post-project checks were also required to assess the extent to which these metrics were achieved. A regular reporting process was established to indicate progress of achievement towards the sustainability objectives. The Regeneration Masterplan provided an agreed method for evaluating project impact and enabled comparison between the original decisions and sustainability objectives with consensus on well-being indicators. Table 1 presents a mapping of the strategic outcomes from the post-project review process of the waterfront refurbishment to the three-level structure of the political common good model of Sison and Fontrodona [124]. The levels present the actions of the governing body in delivering the Regeneration Masterplan, which appear to be suitable proxies for the common good. Level 1 covers material well-being: profits, financial capital, equipment, and other material conditions that affect economic viability and sustainability. Level 2 covers peace and concord: good governance or management practices, to the right rules and procedures. Level 3 covers cultural values: encompassing not only different forms of technical expertise and artistic skills, but also ethical and spiritual meaning and values.

The Regeneration Monitoring Framework was established in 2010, supported by a set of Sustainability Benchmark Indicators, designed to utilize Single Outcome Agreement (SOA) metadata to populate indicators in post baseline data compilation and reporting. The indicators were designed to monitor the direct activities on the regeneration project and the city-wide/regional impact of the regeneration activities. They were designed to align as closely as possible with Scottish Government indicators to provide a basis for tangible reporting to the Scottish Government whilst providing clear and easily understandable indicators for internal monitoring at the strategic level.

Table 1. Dundee Regeneration Masterplan Social Sustainability Indicators [125].

Title 1	Title 2
Level 1 Material wellbeing	• More and better employment opportunities • Increase education and training opportunities • Strong, popular and attractive communities • Strong, popular and attractive communities • High quality and accessible local services and facilities • Low carbon, sustainable city data
Level 2 Peace and concord	• Environment where children will be safe, healthy, achieving, nurtured, active, respected, responsible and included • Care support where people will have improved physical health and mental well-being and will experience fewer health inequalities • People in Dundee are able to live independently and access support when they need it • Communities where people will be safe and feel safe • Dundee will be a fair and socially inclusive city
Level 3 Cultural values	• Dundee will be an internationally recognized city at the heart of a vibrant region • A city renowned for learning and culture data

10 years after establishment, the indicators were published and the majority of issues provide positive results in relation to the achievement of the vision for the regeneration project as monitored through the regular reporting process [126]. In particular, social sustainability indicators, which encompass the societal and political objectives of the redevelopment, align closely with common good aspirations in general and human wellbeing indicators in waterfront redevelopments in particular [127].

5.2. Case Study 2: Health Care and Innovation

The underlying technologies of eHealth have been under development for over 20 years [128,129]. Hence, it is suggested that the next stage of eHealth development, including elements such as tele-care and tele-health, should not be technology oriented but must emphasis the establishment of need-led systems within which technologies are able to be deployed effectively in relation to the requirements and needs of each individual. Emphasis will thus be on developing evidence-based decisions on policy formation that meet a wide and comprehensive range of need encompassing all aspects of social wellbeing as well as health issues [130,131]. This in turn implies:

- Increasingly 'joined up thinking' on the integration of social and health care, removing any artificial, barriers that may exist between the two [132,133];
- Privacy must of necessity be a key element operating at the level of the individual and of the system [134,135];
- The requirement for a user led approach based on system integration rather than a technology led approach focused on technological development. The intent must be to parallel the development of the technology and its application largely through a process of sequential, and parallel, progression as suggested by Figure 8;
- Technology must be considered as being on a par with, and in some cases an alternative to, medication;
- The ultimate goal is a shift away from a responsive mode of dealing with need to a predictive and proactive interventionist mode aimed at prevention rather than cure.

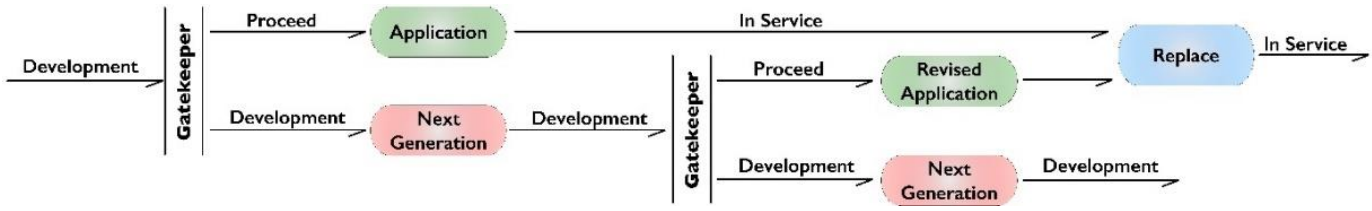


Figure 8. Technology application and innovation model.

To achieve these goals, it must be recognized that political and professional interests need to be overcome; the pharmaceutical industry, medical profession, national and international bodies all tend, intentionally or not, to favor the status quo. For instance, in the case of the universities there is evidence that they are tending to be conservative in their approach, at least in respect of larger research groups with smaller, more agile and disruptive groups being marginalized or excluded [136,137]. This results in a tendency towards an incremental approach to development aimed at doing 'more of the same' rather than the adoption of a more radical viewpoint and disruptive stance [138–140]. Current financial and political risk management methodologies also tend to act to underpin this academic conservatism.

More of the same is thus not likely to make significant progress towards wide scale adoption. What is needed is a systems led strategy, informed by data to determine suitable policy changes, which seeks to integrate technologies with individual need, which will differ from person to person. This means that technologies will need to be prescribed to the individual in a manner similar to that in which drugs are currently dispensed [141]. Consider then the following issues and questions:

- The requirement for a universal home 'clinical hub' with which all social care and medical technologies can be integrated as the core of a home based system. This could eventually be built-in to any home in the same manner as, say, lighting and heating systems;
- Privacy is key to reassuring the individual that their personal status is hidden from all apart from those to whom they have granted some level of access. Thus, a model where only such agreed data is transmitted on a schedule, which itself will be determined by the user in consultation with the appropriate social and health care providers in the same manner in which a doctor advises a patient on the pros and cons of particular treatments prior to prescribing, is advocated. Access to real-time data in emergency situations would also be provided for authorized individuals and primary care providers;
- Social care technologies are as important as healthcare technologies in an integrated needs based system, and need to be configured to deal with issues ranging from social isolation to access to information. Here, it needs to be recognized that not all individuals may have the necessary technical, cognitive or motor skills to have unlimited access to current technologies;
- Clinical sensors, which can be remote, worn or implanted, will form the basis of the eHealth system [142–146]. However, the research emphasis should not necessarily be on the technologies per se, though these will continue to be developed and enhanced, but on the protocols for their use and the associated standards. The current situation is perhaps somewhat analogous with that associated with home systems development in the late 1980s, where the absence of agreed protocols meant that manufacturers introduced their own system structures and configurations, often with a primary aim of preventing competitor's technology being integrated with it;
- Development of the relevant 'participatory systems' modes, structured around and configurable by the user, as the basis for system integration;

- Methods and techniques for in-service data validation;
- Relevant Big Data analytics, along with technologies such as AI, machine learning for data analytics, cloud computing for data services and IoT for healthcare, needs to be further developed, while incorporating precautions against factors such as algorithmic discrimination, to promote knowledge sharing and a shift to a pro-active and preventative approach to well-being.

5.2.1. State of the Art

There is already a significant investment in related areas of eHealth and related technologies, but the financial model for many healthcare providers remains that of a 'centralized, for profit' structure rather than one focused on meeting individual need. This can result in an emphasis on areas perceived as 'profitable', such as the sale of patented drugs, rather than a move towards interventionist and preventative strategies [147,148]. Even within integrated and unified systems there is often a disconnect between the provision of social care and health, resulting in budgetary competition rather than facilitating the provision of a shared spectrum of services. There is also significant work in areas such as cognitive therapy and the use of AI pets and robotic carers [149–154]. However, these remain relatively isolated and need to be integrated within more conventional approaches.

While acknowledging that access to large volumes of related data is a powerful diagnostic and predictive tool in relation to Big Data analytics, there are critical issues of data ownership, control and privacy that need to be addressed. At present, the lack of availability of dedicated long term data sets limits capabilities and possibilities, with minimal data integration and sharing even with supposedly integrated or unified services. This needs to be balanced against the requirement to prevent algorithmic discrimination based on the analysis of an individual's data, and the issues around 'ownership' of that data, which must be with the individual to whom it relates.

5.2.2. Goal

Based on the foregoing, the goal is to better support the right of an individual to enjoy a happy, fulfilled and independent life for as long as possible. To achieve this, the structural considerations presented above must be considered in relation to factors currently preventing this goal from being attained. These potentially include:

- Loss of purpose by an individual;
- Isolation and exclusion resulting from factors such as a lack of mobility or limited access to communications in preventing the close engagement with others in social activities;
- Loneliness associated with an individual's ability to access others;
- Anxiety resulting from an individual's lack of understanding of their position, and of the steps being taken to mitigate this;
- Deterioration of physical and/or mental health restricting the ability of an individual to be independent
- To take things forward it is suggested that what is needed is:
- A shift away from technology-led to user-led design methods and strategies that focus on overall need;
- The embedding of the concepts and constructs of privacy by design [155–157] throughout health and social care;
- The prevention of algorithmic discrimination in health and social care through appropriate embedded safeguards and constructs operating to defined and agreed standards;
- New economic models for wellness that focus on prevention and achieving an enhanced utilization of resources;
- Technology standards to support interchangeability and interoperability;
- The creation of long term, integrated, open-source data bases to support research and development;
- Strategic policy coordination for social care and health.

The facilitation and development of targeted research projects based on identified need to develop appropriate and relevant solutions would include both technology-oriented research and systems-oriented programmes focused on application and data management. Emphasis for those making policy decisions for healthcare provision would thus of necessity be on 'making this work' rather than on incremental development.

5.3. Case Study 3: Cupar Angus

Carbon footprint and its link to climate change presents a wide range of challenges and issues as to how to respond, both at the level of society and of the individual. In this context, the linking of the physical and information environments is seen as a key element in managing a wide and diverse range of strategies associated with transport, housing, social networking and the individual as well as to technologies such as those increasingly associated with Cyber-Physical Systems and the Internet of Things.

For even the reasonably well-educated non-expert, understanding the issues around lowering the carbon footprint of the general population, not to mention reducing one's personal footprint, is surrounded by complexities which can easily lead to inertia. One of the simplest questions as an individual is whether it is better to buy an electric car, to at least reduce local emissions, or continue to use an older, non-electric vehicle, since the embodied energy of a new car is so high. Consider another travel issue, in rural areas is it best to commute by bus, even if the bus is old and diesel, use a park and ride or set up a car commuter pool to ensure maximum occupancy of the car? Furthermore, where do electric cars fit into all of this [158–160]? So, how to integrate public transport systems and increase flexibility, a key issue in rural environments where public transport is inevitably expensive and often inconvenient unless supported by significant subsidies?

Physical context brings in another level of complexity. While it is in cities where many of the efforts to reduce carbon footprints are directed, rural communities also have their part to play in decarbonization [161–163]. The issues in the two types of community are in some ways similar, but in others very different. Thus, travel is important as a CO_2 producer in both contexts. In the city there are many potential short term wins, cycle and walking paths, restriction of vehicular traffic, parking charges, public transport and so forth [164–166]. In a rural environment things are more difficult. Commuting by bicycle is only realistic for the average person over relatively short distances, public transport costs are often high and commuting numbers may well be limited so buses are underused. Park and ride using electric vehicles might offer a solution, as might vehicle sharing and autonomous vehicles. However, are electric cars really as carbon neutral as they might be [167]?

Perhaps what is primarily needed is behavioral change across all levels of society? Currently it is all too easy to jump in the car to travel, and this ease of use is heightened by the introduction of electric cars. No carbon footprint guilt, cheap to run and service and becoming very acceptable socially. The introduction of autonomous driverless vehicles could mean an increase in the numbers of cars on the road, but is that what is wanted in already congested cities?

Systems based on car sharing or short-term, potentially of only a few hours, hire would need a significant change in individual perceptions and behavior. With a sufficient number of cars available on request linked to information systems indicating where there are available vehicles, their levels of charge and traffic conditions, there is the potential for significant impact. These changes are, however, predicated on a change in the perception and acceptability of personal car ownership. This is not an easy change to make, particularly when car ownership and specific marques remain as powerful status symbols.

Within both rural and urban complexities there is the potential to use information technology based solutions and methods available to support optimization. At the macro level, mapping energy flows, optimizing grid connections, predicting renewable energy gaps and ensuring back up are areas where IT based solutions have made an impact [168]. Smart mechatronic systems and Cyber Physical Systems (CPS), enhanced by 5G technology, will increase both the capacity and scope of Internet of Things (IoT) and Cloud-based technologies as a means of system integration [169,170]. At the micro or personal level the IoT is already bringing about changes in home energy systems, a major contributor to personal carbon footprints except perhaps for that of frequent flyers!

As can be seen from Figure 9, for a country such as Scotland the major energy use is for heating rather than transport, something which significantly impacts on the housing stock. Here, while there is a sensible concentration on improving the energy efficiency of new build, the real problem is more likely to be how to ensure more effective insulation in old build.

In illustration of the issues involved with such changes, a major shift to electric vehicles across Scotland would have significant implications with regard to the generation of the required electricity. Referring to Figure 9, a replacement of the current transport energy use in Scotland by electric vehicles essentially implies an increase in electricity generation equivalent to the total current generation [171].

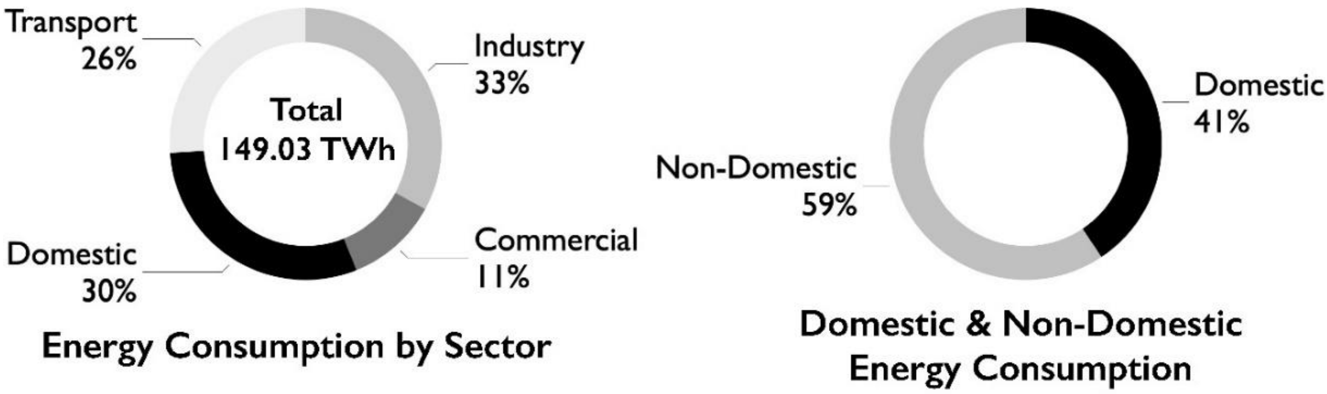


Figure 9. Energy use in Scotland in 2018 (Mathews & Scherr, 2020) [172].

In this respect, the Scottish Government has expressed its intent to move to a position where all electricity generated within Scotland is from renewable sources. There are a number of major issues associated with this. First is the irregular nature of many renewables, particularly wind, and hence the need for an increased storage capacity along with access to alternative sources to make up any deficiencies, in Scotland's case this is currently through the interconnectors to England and Wales. Second is the difficulty of delivering electricity from the major, and regular, ocean renewable energy sources, tidal currents and deep sea currents where, though developments continue, no large scale commercially proven devices as yet exist [173,174]. Finally, there is the need to restock with new, primarily electric, vehicles and the associated carbon costs of doing this (Scotland is being used here as an exemplar and the rest of the UK has indicated a similar shift but with variations in target dates).

These objectives are placed into the context of the present situation by Figure 10, which shows that fossil fuels have effectively been replaced for electricity production in Scotland. In England and Wales meanwhile, gas remains as the main primary energy source for electricity generation.

Which returns discussion to the original question, how to pick a way through the extensive conflicting evidence to decide at a personal, regional or national level what are the best ways of reducing carbon footprint?

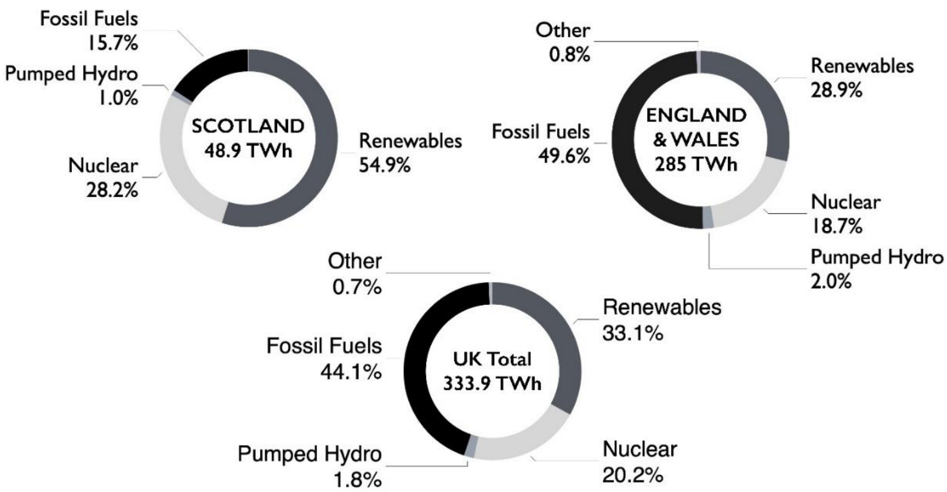


Figure 10. Electricity generation in Scotland and the UK in 2018 [175].

5.3.1. Exemplar—Cupar Angus

Coupar Angus is a former market town in central Scotland (Figure 11) around 20 km from the cities of Dundee (pop. ~150,000) and Perth (pop. ~47,000). A large proportion of the inhabitants of working age commute to one or other of these larger centers on a daily basis. There is little industry within the town and a grid substation located slightly to the south has been proposed as a site for a battery storage installation. The demographic breakdown for 2016 (Figure 11) shows that 28.2% of the residents are aged 60 or over, many of whom will rely on public transport.

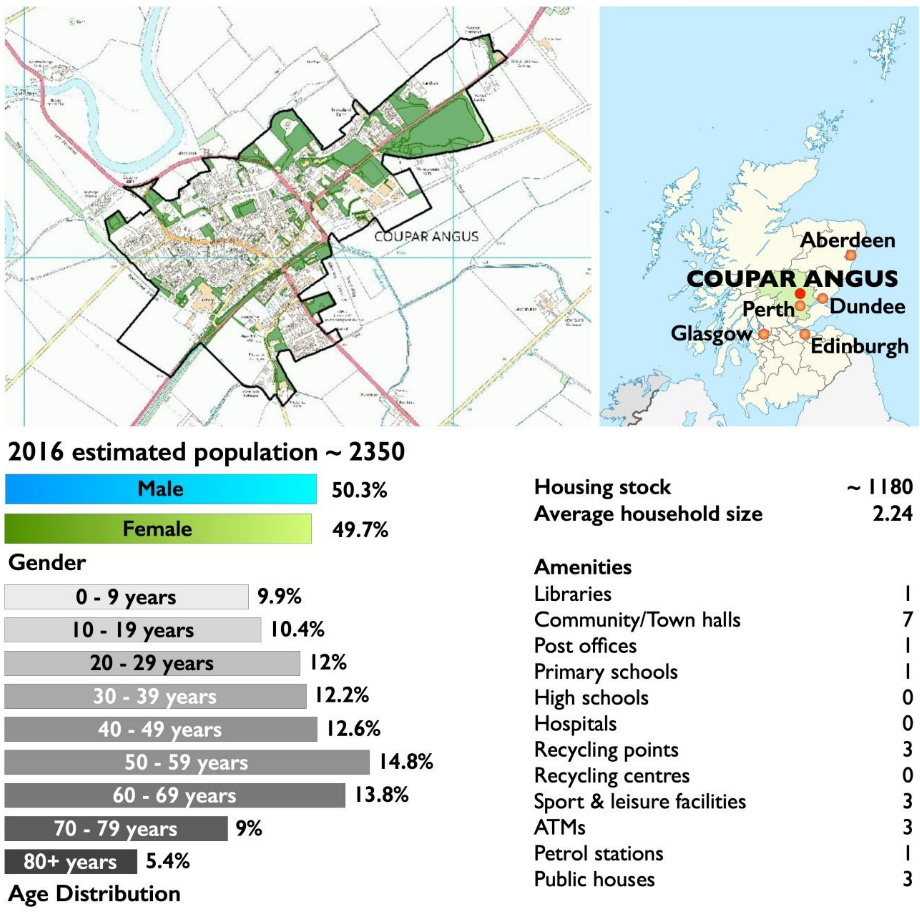


Figure 11. Coupar Angus location and demographics [176,177].

Transport links—The town is served by a series of bus links to Perth and Dundee as well as to other small towns in its immediate vicinity. Busses tend to service a number of local communities, increasing journey times to the larger population centers and residents have only a very limited say as to the timing of services. The nearest rail stations are those at Dundee and Perth, but there is little or no coordination of train arrival and departure times with bus services.

Housing—The housing stock consists of a mix of old and new build, while new build will conform with current standards for levels of insulation, this presents issues of refurbishment in order to reduce the overall heating load if the town is to move towards becoming carbon (CO_2) neutral [178].

How does a small rural community, such as Coupar Angus, pursue a strategy that will lead, ultimately to carbon neutrality? Not all of the topics discussed in the following sections, following engagement with the local community to obtain indicators of areas of priority for engagement with sustainable objectives, can be confronted directly, some require pressure and influence on the decision makers.

5.3.2. It Is Not Just about the Technology

While technology has a major role in reducing CO_2 levels, in a practical sense this can only be achieved with a corresponding societal change associated with relevant political actions [179]. In illustration, while a managed transition to electric vehicle technologies may well support a reduction in CO_2 emissions, it only solves some of the issues. In terms of infrastructure, more accessible charging points would be required to support an increased number of electric vehicles along with the ability to generate the additional power required. Further, the green aspects of such vehicles may persuade people to use them more, increasing levels of congestion while parking will become ever more challenging. Technology, for instance in the form of autonomous vehicles integrated with real-time traffic management, could potentially support an increase in capacity [180].

An alternative approach based on behavioral change questions why it is necessary for individuals to own their own cars, which sit idle for most of their lives, when a library of autonomous vehicles linked to much improved, public transport and information systems could result in a reduction in the numbers of vehicles on the roads. When considering cost and convenience, as soon as the ability to obtain access at a time that suits and a cost below current expenditure, it would appear there is little resistance to this concept.

What is clear is that global warming and climate change present a major threat to the Earth and hence to society, requiring a range of technical responses along with societal change, this later being determined by a mixture of command-and-control, market-based and voluntary approaches to the management of change leading to improvements in carbon literacy levels throughout society [181]. Hence, solutions leading to the reduction of C02 levels, and indeed those of all greenhouse gases, requires a cooperative effort and while actions taken at the level of small communities such as Coupar Angus are commendable, they need to be integrated as part of a larger series of actions aimed at increasing integration and shared use of resources.

6. Looking to the Future

Throughout history, technology has been a driver for change, and that dynamic is undoubtedly going to continue for the foreseeable future. The outcomes of such changes are difficult, if not impossible to predict, and remains so despite the introduction of AI based decision making aids and other methods [182]. In illustration, in 2018, the World Economic Forum published its report "Shaping the Future of Construction—Future Scenarios and Implications for the Industry" [183] which presented the following three scenarios.

6.1. Building in a Virtual World

Economic conditions and research collaborations generate advances in robotics and artificial intelligence. Cloud technologies dominate while highly interconnected and intelligent systems along with robots replace most manual labor. People shop and go to school virtually and spend their abundant free time on leisure activities such as travel, creating the need for large passenger transportation hubs structured around the integration of aircraft, drones, robot taxis, hyperloops and other transport technologies. Governments and private companies are required to channel resources into cybersecurity to keep systems free of intruders. There is a slight reduction in the use of natural resources, leading to lower emissions per capita. Global cooperation is high and cultures move closer together. Key features include:

- More resources required for passenger transport;
- Interconnected and intelligent systems run the majority of systems;
- Software developers gain power;
- Businesses emerge configured around data and services.

6.2. Factories Run the World

After a major global financial crisis, cybercriminals launch attacks on public and private data networks, resulting in an erosion of trust. Private industry then assumes tasks once associated with the public sector including infrastructure, defense and education. The prioritization of profit and efficiency leads to the adoption of lean principles as well as technological advances, particularly for manufacturing. The result is increased global prosperity, but with a negative impact on the environment and some social groups. Resources are further depleted and unskilled workers lose their jobs to automation. Information is exchanged only through closed data systems isolated from the internet, limiting cooperation and increasing regional and cultural differences. Key features include:

- Construction boom for industrial and commercial buildings as well as for infrastructure;
- The value chain adopts prefabrication, lean processes and mass customization;
- Suppliers benefit the most;
- Business opportunities in integrated system and logistics.

6.3. A Green Reboot

Neglect of climate change and dwindling natural resources cause devastation until a group of countries takes action to halt overuse of scarce resources, react to climate change and rebuild the environment. This leads to innovations in materials and new production methods supported by taxes on CO_2 emissions, waste and other industrial by-products harmful to the environment. Society becomes more eco-friendly, moving closer to a circular economy. Recycling and reuse is mandatory and strong sharing economy emerges. Online platforms let people share housing, workspaces and vehicles supported by e-mobility and battery storage. However, the economy stagnates, but citizens are in general pleased with the outcomes. Key features include:

- Sustainability becomes the primary decision-making criterion;
- Innovative technologies, new materials and sensor-based systems ensure low environmental impact;
- Organizations with a deep knowledge of materials and brownfield portfolios thrive
- Business opportunities develop around environmental-focused services and material recycling.

All of the above is not to suggest that any of these scenarios will actually come to pass, they are included here as an indication of the potential nature of technology driven change, and the potential outcomes for society [184–189]. In the context of the common good, what the above scenarios do however make abundantly clear is that society, at all levels and through all agencies, needs to be aware of the potential impact of decisions relating to the use of technologies, and to direct their choices accordingly.

7. Conclusions

This paper sought to address the question of whether social sustainability decision making processes sufficiently informed by data before implementing change. Whilst the case studies indicate that the decision making process intends making informed decisions, where a system-led technology approach can better inform the process. Technological innovations as part of a system-wide design can be more fully explored, implemented and exploited before being rendered technologically, although not functionally, obsolete. It is essential that, for the common good and human wellbeing, we understand and appreciate the function of system-wide design. Within the system design the role for technology based solutions and their deployment can be more fully exploited in support of objectives structured around the common good and aligning decisions with priorities for a sustainable society. The developments in technology in relation to Cyber-Physical Systems and Internet of Things, provide considerable potential for further collection and use of data necessary to make more informed and evidence based social sustainability decisions. Whilst seeking progress towards a better society through improved wellbeing and the benefits for the common good the problems of preserving individual freedoms and rights such as privacy remain problematical barriers.

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