SUSTAINABLE DEVELOPMENT: WHY BASIC SCIENCE HAS BEEN THE CURSE AND IS THE CURE

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Sustainable Development: Why Basic Science has been the Curse and is the Cure

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Abstract

Almost all aspects of global development, including economic, social, environmental, and even political progress, can arguably be traced back to discoveries in basic science. Basic science, originating from the curiosity and perseverance of pioneering minds, involves asking seemingly simple questions with complex answers, thereby laying the foundation for research. Scientific inquiry: the systematic search for evidence to validate or refute hypotheses, is a process that has evolved over time to incorporate structured approaches such as hypothesis testing. However, contemporary scientific research has increasingly become intertwined with considerations of potential benefits, societal impacts, and economic returns, often driving funding decisions. This trend raises questions about the commodification of scientific research and its potential impact on the pursuit of fundamental knowledge. Moreover, the decline in purely exploratory research coincides with the world's drift towards unsustainable practices. The question arises: has the methodical approach and emphasis on tangible outcomes contributed to the diminishing role of basic science? Conversely, could a resurgence in basic science research offer insights and solutions for a more sustainable future? By prioritizing curiosity-driven inquiry and revisiting the roots of scientific discovery, there is potential to unlock novel solutions and inform sustainable development strategies. Thus, a reinvigorated commitment to basic science research may hold the key to addressing the challenges of sustainability and fostering global development in innovative ways.

Keywords

Basic Science, Technology, Innovation, Global Development, Sustainable Development.

Introduction

Sustainable development stands at the forefront of global agendas, highlighting the need to balance economic growth, social equity, and environmental stewardship to meet the needs of present and future generations. As nations contend with pressing challenges such as climate change, biodiversity loss, and resource depletion, the role of basic science in shaping the trajectory of sustainable development has come under increasing scrutiny. On one hand, basic science has been criticized for fuelling unsustainable practices and exacerbating environmental degradation. On the other, it holds the promise of unlocking innovative solutions that could create transformative pathways towards a more sustainable future.

The relationship between basic science and sustainable development is multifaceted, reflecting both the opportunities and challenges inherent to scientific inquiry and technological advancement. At its core, basic science encompasses the pursuit of knowledge for its own sake, driven by curiosity, exploration, and the quest for understanding the fundamental principles of the natural world. This intrinsic curiosity has led to groundbreaking discoveries and paradigm shifts in scientific thinking, laying the foundations for technological innovations that have shaped civilization.

Unfortunately, the pursuit of knowledge through basic science has also had unforeseen and unintended consequences, contributing to environmental degradation, social inequalities, and economic disparities. Industrialization, enabled by scientific and technological developments, has led to the extraction and exploitation of natural resources on a massive scale, resulting in pollution, habitat destruction, and contributing to climate change. Furthermore, scientific and technological innovations have not always been deployed in ways that prioritize environmental sustainability or address the needs of marginalized communities, thus perpetuating patterns of inequity and injustice.

However, basic science also holds immense potential; it could catalyse sustainable development, offering insights, tools, and solutions to address the complex challenges facing society and the planet. By deepening our understanding of natural systems, basic science can provide the foundation for developing new sustainable technologies, designing resilient ecosystems, and fostering inclusive and equitable societies. More importantly, the critical thinking, creativity, and collaboration required in basic science would empower individuals and communities to engage in evidence-based decision-making and collective action for sustainability.

This paper explores the dual role of basic science as both the curse and the cure for sustainable development. Drawing on interdisciplinary perspectives from science, policy, and ethics, the historical and contemporary interactions between basic science and sustainable development are examined. Key challenges, opportunities, and pathways forward are presented. The complex dynamics that shape the relationship between basic science and sustainable development are highlighted and used to identify strategies that harness the transformative potential of science to build a more sustainable and resilient future.

The Foundations of Basic Science: Exploring Meaning, Historical Roots, and Evolution

Basic science, often referred to as fundamental or pure science, explores natural phenomena, principles, and laws through systematic observation, experimentation, and analysis. It is characterized by the pursuit of understanding without immediate practical applications or commercial objectives, aiming instead to uncover the underlying mechanisms governing the physical, biological, and social spheres. In practice, basic science expands the frontiers of knowledge and advances scientific theories, forming the foundations for applied research and technological innovation.

At its core, basic science embodies several key characteristics: firstly, it involves exploring fundamental concepts in all scientific disciplines, including physics, chemistry, biology, mathematics, and social sciences – often within but also across disciplinary boundaries. This approach fosters a comprehensive understanding of natural phenomena and their underlying principles. Secondly, basic science is driven by curiosity and determined inquiry. Researchers embark on open-ended exploration, posing fundamental questions and pursuing novel lines of investigation without expectations, predetermined outcomes, or practical applications in mind.

Empirical methods and rigorous analysis are integral to basic science. Researchers rely on controlled experiments, data collection, and meticulous analysis to generate evidence, test hypotheses, and refine scientific theories. An extension of this aspect is collaboration and peer review: researchers may collaborate across disciplines, engage in interdisciplinary exchange, and subject their work to peer review processes ensuring the validity and reliability of scientific findings. While basic science may not result in immediate practical applications, it often leads to exciting chance discoveries, breakthroughs, and "needle-moving" innovations that have far-reaching implications for society, technology, and human knowledge over the long term.

Examples of basic science research cover a broad range of studies, including investigations into fundamental particles in physics, genetic mechanisms in biology, chemical reactions in chemistry, mathematical principles, social behaviours, and cosmic phenomena. By creating the foundations for applied research, technological development, and innovation, basic science has been and continues to be critical for advancing medicine, engineering, agriculture, environmental science, and many other fields.

The roots of basic science can be traced back to ancient civilizations, where pioneering scholars observed, experimented, and theorized about the natural world. These early inquiries, born from the intellectual curiosity of early thinkers, gradually evolved into distinct disciplines that have remained throughout the advent of modern scientific practices. Some examples of the various civilisations that have contributed to the evolution of basic science are presented.

In Ancient Mesopotamia and Egypt, significant discoveries were made in early scientific knowledge, spanning disciplines such as mathematics, astronomy, and medicine. Mesopotamian astronomers devised methods for observing celestial phenomena and tracking time (Hunger & Pingree, 1989), while the Egyptians developed medical techniques and herbal remedies (early medicines), pioneering advances that were adopted by and elaborated on by other civilizations (Nunn, 1996).

The intellectual fever of Ancient Greece birthed a pantheon of luminaries; individuals often recognised as being both philosophers and scientists, who worked across many subject fields including the natural sciences, mathematics, botany, zoology, psychology, theology, ethics, metaphysics, and literary theory. Such individuals include, Thales who developed methods to predict the weather and a solar eclipse, and theorised the origins of earthquakes postulating that they occurred when the earth is rocked on the water on which it floats (Harris, 2005); Pythagoras, who recognised that the

Earth was a sphere, that the Moon was inclined to the equator of the Earth, and that the planet Venus was both the evening star and the morning star, and famously devised the Pythagorean theorem a notable contribution to mathematics (Zhmud, 2018); and Aristotle, who conceptualised the practice of scientific analysis and is known for creating formal logic using deduction to create a pathway to a conclusion (McKeon, 1947). By embracing observation, reason, and logic as tools for understanding the natural world, these luminaries provided ground-breaking insights across disciplines and formed enduring pillars of scientific thought (Lloyd, 1970; Barnes, 2001).

During the Islamic Golden Age, spanning the 8th to 14th centuries, scholars in the Islamic world translated classical texts – Greek and Sanskrit – into Arabic and furthered the pursuit of knowledge, contributing to a diverse range of subject domains. Amongst others, Abu Yusuf Yaqub Ibn Ishaq Al-Kindi, Muhammad ibn Musa al-Khwarizmi, and Ḥasan Ibn al-Haytham were notable scholars of the time. Abu Yusuf Yaqub Ibn Ishaq Al-Kindi, credited as being the ‘Father of Arab philosophy’, studied the natural sciences and was a strong mathematician. He made notable contributions to many fields including mathematics with his work ‘Manuscript on Deciphering Cryptographic Messages’, which forged the field of cryptanalysis; medicine, creating the earliest known medicine dosing administration device; and, physics, establishing the theory of sound and showing how the human voice creates waves that travel through the air and are received by the cochlea in the ear (Broemeling, 2011). Muhammad ibn Musa al-Khwarizmi, the ‘Father of Algebra’, progressed the fields of mathematics. The title of his book ‘Al-Jabr’, meaning ‘reunion of broken parts’, is the etymological root of the word *algebra*, the branch of mathematics he established (Gandz, 1926). He also advanced geography, using data collected by Ptolemy, he improved the accuracy of the coordinates for the Mediterranean Sea, Asia, and Africa (Mercier, 2020); astronomy, by calculating calendrical and astronomical data for the movements of the Sun, the Moon, and the classical planets – Venus, Jupiter, Mars, Mercury, and Saturn (Marini, 2023). Ḥasan Ibn al-Haytham was a pioneer notably in the field of optics, he wrote the book ‘Kitab al-Manazir’ (‘Book of Optics’) providing the earliest explanation for how eyesight works and detailing how vision results from the brain processing information. He was also an early champion of the scientific method, advocating that a hypothesis must be tested using a systematic, methodical approach to experimental analysis or mathematical reasoning (Gorini, 2003). Their works and those of their contemporaries during the Islamic Golden Age, forged new pathways of discovery, paving the way for the European Renaissance (Lindberg, 1992; Saliba, 2007).

The European Renaissance and Enlightenment periods (c. 14th century) through to the early modern period (c. 16th century) witnessed a revival in classical knowledge and learning and a deeper exploration of the natural world, giving way to modern scientific methodologies. Leading visionaries from this period include Leonardo di ser Piero da Vinci, who advanced anatomy and physiology with his intricate drawings and dissection of the human form, as well as early engineering inventions, for example, his infamous design of a flying machine (that bears an uncanny resemblance to a modern-day helicopter); Nicolaus Copernicus, a Renaissance polymath, who devised a model placing the Sun, not the Earth, at the centre of the universe; and, Galileo di Vincenzo Bonaiuti de' Galilei, the 'father of observational astronomy', a classical physicist and progressor of the scientific method and modern science. The discoveries of this period not only built on earlier findings but also challenged widely held beliefs and advanced the skill of scientific method (Westfall, 1980; Kuhn, 1996).

These transformative historical epochs led to the establishment of modern scientific disciplines and institutions, marking the earliest stages of basic science as a systematic pursuit of knowledge about the natural world (Lindberg, 1992). From the subsequent Scientific Revolution of the 16th to 18th centuries emerged new scientific methodologies, experimental techniques, and theories, propelling humanity into the modern era of science and enlightenment (Kuhn, 2012). The institutionalization of science through scientific establishments and societies provided vital support for scientific research, collaboration, and knowledge dissemination, furthering the advancement of scientific progress (Shapin, 1996).

The Industrial Revolution of the 18th and 19th centuries ushered in a new era of rapid technological advancements and scientific discoveries, catalysed by innovations in chemistry, physics, engineering, and biology (Landes, 1969). These developments built on earlier scientific investigative findings that can be traced back to the aforementioned curiosity of ancient thinkers and scholars, whose work formed the basis for modern science.

Empowering Global Progress: The Role of Basic Science in Driving Development

The history of industrialization and global development spans centuries, marked by significant shifts in economic, social, and technological landscapes. Industrialization, characterized by the mechanization of production processes and the rise of factories, began in the 18th century in Europe before spreading globally, transforming societies and economies. The Industrial Revolution brought about rapid urbanization, increased productivity, and economic growth, leading to the formation of modern industrial societies (Mokyr, 1990).

Science and technology played pivotal roles in driving industrialization and global development. Advances in science, particularly in physics, chemistry, and engineering, led to innovations such as steam power, the mechanization of textile production, and the development of new materials and transportation systems (Landes, 1969). These technological breakthroughs revolutionized agriculture, manufacturing, and transportation, leading to increased efficiency, productivity, and economic output.

The second wave of industrialization, which occurred in the late 19th and early 20th centuries, saw further advancements in science and technology, including the harnessing of electricity, the mass production of goods, and the development of telecommunications and infrastructure (Landes, 1969). These innovations facilitated globalization, enabling the movement of goods, capital, and ideas across borders and continents. In the post-World War II era, science and technology continued to drive global development through innovations such as computers, telecommunications, and the internet. These advances seeded the information age, transforming industries, communication, and commerce on a global scale (Perez, 2002).

The history of industrialization and global development demonstrates the transformative power of science and technology in driving economic growth, innovation, and social progress. From the Industrial Revolution to the information age, scientific advancements have been instrumental in shaping the trajectory of human civilization and advancing global development.

The role of basic science has been pivotal in propelling global development through its expansive and enduring contributions to knowledge enrichment, innovation facilitation, and solution provision across a diverse range of industry sectors and social domains. There are many ways in which basic science has underpinned, and subsequently impacted, global advancement. These are an important consideration when reflecting on and learning from the world's pathway to the unsustainable present, assessing the ambiguity of the immediate future, and creating a vision for a long-term sustainable future.

Technological advancements are a testament to how basic science research has catalysed groundbreaking innovations in technology, engineering, and medicine. Noteworthy breakthroughs such as the transistor, laser, MRI, and DNA sequencing are exemplary of the transformative impacts of fundamental research, leading to profound shifts in industries and augmenting human well-being on a global scale (Landes, 1969; Collins & McKusick, 2001).

Healthcare and medicine have been significantly influenced by basic science research, particularly in the disciplines of biology, genetics, and biochemistry. Insights gained from such research have propelled advancements in disease understanding, pathogen characterization, and human physiology comprehension (Collins & McKusick, 2001). Consequently, the development of vaccines, antibiotics, medical treatments, and diagnostic tools has ensued, thereby lowering mortality rates, and enhancing public health outcomes, all leading to substantially improved global health (Plotkin et al., 2013).

Similarly, economic growth and innovation have depended on basic science research, which has provided the foundational knowledge and technological underpinnings that have driven productivity, competitiveness, and job creation across industries (Mazzucato, 2013). From biotechnology to information technology, materials science, and renewable energy sectors, basic science has served as an indispensable catalyst for fostering innovation, entrepreneurship, and economic prosperity on a global scale.

Education and capacity building constitute another domain wherein basic science research has an integral role, through its contribution to scientist, researcher, and innovator training. By nurturing critical thinking, problem-solving, and scientific literacy, basic science research emphasizes the imperatives of addressing global challenges and advancing sustainable development efforts, nurturing human capital which has been essential for global-scale progress (National Research Council, 2002).

Basic science research has been instrumental in driving sustainable development and environmental conservation efforts providing critical insights into ecosystem functioning, climate dynamics, and anthropogenic impacts on the environment. These insights serve as cornerstones for informing governmental policies, social practices, and industry technologies aimed at fostering environmental sustainability, biodiversity conservation, and climate resilience fortification, thereby engendering a more harmonious coexistence with the natural world (Millennium Ecosystem Assessment, 2005).

The Evolution and Significance of Sustainability: A Societal Imperative

The concept of sustainability, within the context of contemporary discourse, emerged in the 20th century and gained substantial attention and momentum, particularly in the latter half of the century. However, sustainability has a much longer, deeper-rooted past extending back to earlier philosophies and practices that have developed and evolved over time.

Early sustainability influence came from indigenous cultures: many indigenous societies worldwide have long upheld sustainable practices, acknowledging the intricate and delicate interplay between humans and the natural environment. Their ethos is to preserve natural resources for posterity, an idea rooted in an acute awareness of the interconnectedness of all life forms and the importance of preserving the ecosystem within which they live and are a part of (Berkes, 2012). Complementary to the values of indigenous cultures are those of the Ancient Greek philosopher, Aristotle. His insights, particularly those relating to the natural sciences, ethics, and natural philosophy, resonate with contemporary sustainability principles. Aristotle championed living in harmony with nature, emphasizing the need to balance the interactions of humans respectfully and sensitively with the natural world, an idea that is paralleled today by the modern concept of small-footprint living (Nelson, 2018).

In the twenty-first century, the term “sustainability” carries more weight today than ever before. The rapid rise of the sustainability movement has been two-fold, partly caused by the global population explosion; there being more people has led to more demand for natural resources, and partly the result of society’s increased awareness of environmental issues (Samways, 2022). Examples of two high-profile environmental issues include the hole in the ozone layer caused by chlorofluorocarbons (CFCs) and biodiversity loss – the result of climate change, deforestation, pesticide use, and pollution combined – that has led to the reduction and in some cases extinction of flora and fauna (Rowland, 1989; Singh & Singh, 2017).

The modern concept of sustainability began with the environmental movement in the 1960s and became established in the 1970s. It was catalysed by events such as Rachel Carson's publication of "Silent Spring" in 1962 and the inaugural Earth Day in 1970, causing environmental concerns to be thrust into the spotlight. These two decades witnessed a heightened realization of the finite nature of natural resources and the detrimental consequences of unchecked and mismanaged human activities on the environment. The period marked the onset of social awareness of there being a problem. A seminal moment came in 1987, when the Brundtland Report, 'Our Common Future' was released by the United Nations World Commission on Environment and Development. This landmark report outlined sustainable development as a crucial requirement for the security of the future. It coined the definition of "sustainable development", which still stands today: a mode of progress that satisfies present needs without compromising the ability of future generations to meet their own requirements.

The growing understanding of sustainability, not only as a concept but more importantly as a practice, has seen a host of concerns emerge across all sectors, spanning industry, government, and academia. To try and manage these, numerous strategies and frameworks have been developed such as the triple bottom line sustainability practice that incorporates economic, social, and environmental considerations into corporate social responsibility and best practice (Milne & Gray, 2013). These approaches have gained prominence and increasingly governments require businesses to adopt the principles and integrate them into their business models. For example, resource industries such as the mining industry (minerals and metals) and the petroleum industry (oil and gas) are legally required to demonstrate through audit inspections and reporting how they adhere to and implement environmentally responsible practices and sustainable operations (Böhling et al., 2019). Failure to meet environmental standards results in penalties. Such measures reflect the widespread acknowledgment of the critical need for sustainable practices.

Sustainability is by no means a new term; however, its long and established history – throughout time and across civilisations – means that its definition has evolved since its first use. It no longer solely refers to the balance between the coexistence of nature and humans but is now a fusion of environmental, social, and economic considerations and advocating for the equitable and responsible stewardship of resources to safeguard the well-being of both present and future generations.

Since its emergence as a critical concern for society, sustainability has been influenced by a myriad of factors including environmental degradation, social inequality, economic instability, and an increasing awareness of finite resources. Environmental degradation, encompassing issues such as pollution and climate change, threatens ecosystems and human health, necessitating the urgent adoption of sustainable practices (WCED, 1987). Social justice and equity are central to sustainability, realising the need to address disparities in access to resources and create opportunities to promote resilient and cohesive communities (WCED, 1987). Economic stability and long-term prosperity are contingent upon sustainable approaches that prioritize responsible resource management, innovation, and investment in renewable technologies and efficient recycling, contrasting with unsustainable practices like overconsumption (Milne & Gray, 2013). Globalization has highlighted the interconnectedness of sustainability challenges, emphasizing the need for coordinated international efforts (Sachs, 2015). Public awareness and advocacy, driven by media coverage, high-profile scientific research, and grassroots movements, have raised awareness of the urgent need for sustainable policies and practices, and more so action. Concurrently, the persistence of unsustainable practices stems from historical, economic, social, and institutional factors. Industrialization and technological advancements drive economic growth but contribute to environmental degradation. Population growth and urbanization strain ecosystems, exacerbating environmental challenges. Market-driven economies and consumer culture encourage unsustainable consumption patterns, while policy failures and cultural norms perpetuate unsustainable practices. Addressing the root causes of unsustainability demands transformative changes in governance, institutions, technologies, and societal values; these changes are essential for transitioning towards more equitable, resilient, and sustainable development pathways (Schlaile & Urmetzer, 2019).

Creating a Sustainable Future

Global development aims to enhance the economic, social, and environmental well-being of individuals and communities across the globe. It encompasses a range of efforts focused on reducing poverty, promoting human rights, achieving sustainable development goals, and addressing disparities in access to resources, opportunities, and basic services. Ultimately, global development seeks to create a more equitable, prosperous, and sustainable world for present and future generations.

Economic development plays a crucial role in global development by improving the standard of living, productivity, and prosperity of individuals and societies. This involves initiatives aimed at stimulating economic growth, creating employment opportunities, enhancing infrastructure, and promoting sustainable industries (Todaro & Smith, 2011). By fostering self-sustaining economic systems and improving livelihoods, economic development seeks to reduce poverty, inequality, and dependency on external aid, thereby building greater economic resilience and self-reliance within communities (World Bank, 2021).

Social development complements economic efforts by focusing on enhancing human capabilities, well-being, and social inclusion. It encompasses initiatives to improve the availability and access to education, healthcare, housing, gender equality, and social protection. Through these systems, social development aims to empower individuals, strengthen communities, and reduce social inequalities by addressing barriers to human development and promoting equity and social justice. Through greater social cohesion and inclusivity, social development contributes to creating more resilient and cohesive societies that can better withstand and adapt to global challenges (Sen, 1999; UNDP, 2020).

Environmental sustainability, another critical dimension of global development, aims to conserve natural resources, protect ecosystems, and mitigate climate change to ensure the long-term viability of the planet. Efforts include promoting renewable energy, sustainable agriculture, biodiversity conservation, and climate resilience, while at the same time preserving natural resources and minimizing pollution and waste (United Nations, 2015; IPCC, 2018). By balancing human development with ecological integrity, environmental sustainability aims to safeguard the health and well-being of present and future generations, ensuring that future development is environmentally responsible, economically stable, and socially just (Roseland, 2000).

Sustainability and Economic Growth: Striking a Balance

The compatibility between sustainable development and economic growth is a hotly debated topic among academics, policymakers, and practitioners alike. One school of thought is that sustainable development can coexist harmoniously with economic growth, while others advocate for a re-evaluation of traditional growth models, stating the need to place greater emphasis on environmental and social welfare. The question is contentious, yet the answer may be a turn of the key to unlocking the path to truly sustainable development. Society has reached a point where sustainability, much like research, has been monetised; for example, greenwashing falsely promotes a business or product as being environmentally friendly with the aim of improving its image and marketability, thus attracting more clients or customers (Lashitew, 2021). Transparency and honesty are essential. The spectrum of perspectives includes models such as decoupling growth from resource use, emerging investment opportunities, growth limitations, and using alternative metrics to redefine and evaluate growth as being broader and more diverse than an economic success measure (Hickle & Kallis, 2020).

Decoupling economic growth from resource use proposes that it is possible to achieve economic development and prosperity without corresponding increases in resource extraction, consumption, and environmental degradation (European Environment Agency, 2011). This concept is central to sustainable development as it aims to break the traditional link between economic growth and resource depletion and promotes long-term environmental sustainability and resilience. Advances in technology, coupled with a focus on resource efficiency and the transition to a green economy, complemented by policy instruments and sustainable consumption and sustainability practices, offer pathways to economic growth that do not compromise natural resources or cause environmental harm. The model champions the concept of "green growth" or “green economics”, suggesting it presents a viable means of reconciling economic prosperity with sustainability objectives (United Nations Environment Programme, 2011; Hickle & Kallis, 2020). An offshoot from this model is the view that progressing sustainable development will create new markets and investment opportunities that arise from the adoption of sustainable practices. Advocates for this model claim that transitioning towards sustainability can catalyse innovation, foster job creation, and bolster economic resilience, consequently paving the way for sustained prosperity over the long term (Hickle & Kallis, 2020).

In contrast, critics of the conventional economic growth model argue there are limits to economic growth; a trajectory of continual economic growth, particularly as measured by metrics like Gross Domestic Product (GDP), is unfeasible, citing its inherent unsustainability within a finite global ecosystem (Rees, 2003; Washington 2021). This perspective draws attention to the ecological footprint engendered by relentless economic expansion, the disproportionate distribution of its benefits, and the hidden social and environmental tolls incurred along the way. Extending from this perspective is the idea to use alternative, arguably more meaningful metrics to gauge societal progress and well-being, beyond the confines of GDP. Suggestions such as the Genuine Progress Indicator (GPI) or the Human Development Index (HDI) offer more holistic assessments of human welfare and environmental sustainability, thus challenging the traditional approach of equating economic growth with societal progress (Berik, 2020; Sinha, 2023).

Despite some inviting arguments and evidence supporting the alignment of sustainable development with economic growth, critics contend that conventional growth frameworks warrant scrutiny and review. The approach proposed; to reframe the narrative of progress and encourage the adoption of inclusive and environmentally responsible models of prosperity, offers a different way to measure growth and success. Navigating these tensions and charting a course toward sustainable development requires a candid review of traditional economic systems and current policies, and prioritising environmental stewardship, social equity, and human well-being above all else. That said, it would be shortsighted to entirely overlook the economics of sustainability.

Exploring how sustainable development can offer opportunities for innovation, efficiency gains, market expansion, and creating long-term value (which could fuel economic prosperity) allows any potential benefits of the traditional economic model to be leveraged. Several sustainable development pathways offer economic advantages.

The pursuit of sustainable development is a catalyst for innovation across all sectors. Developing and using clean technologies, renewable energy, resource-efficient products, and sustainable business models all offer benefits. These innovations cultivate new markets and industries, as well as unlock new avenues for investment, fuelling economic growth and generating employment opportunities (Mazzucato & Perez, 2015). Sustainable practices, such as energy efficiency measures, waste reduction initiatives, and resource optimization strategies, could lead to substantial cost savings for both businesses and households. The rewards are realised by reduced energy bills, diminished waste disposal expenditures, and increased operational efficiency (DeSimone & Popoff, 2000).

Adopting sustainable development practices equips businesses and communities with the knowledge and means to strengthen their position against a range of environmental, social, and economic risks. From climate change impacts to supply chain disruptions, sustainable initiatives facilitate risk mitigation by encouraging diversification of revenue streams, reducing dependencies on finite resources, and bolstering social license to operate. Through these measures, enterprises can enhance their resilience and withstand uncertainties more effectively (Fiksel & Fiksel, 2015). Furthermore, by implementing sustainable practices companies strengthen their brand reputation and gain a competitive edge. Demonstrating environmental and social responsibility, businesses can garner greater consumer trust, attract a broader clientele base, and recruit top-tier talent. This consequently enhances sales figures, augments market share, and bolsters shareholder value, positioning sustainable enterprises as leaders within their respective industry sectors (Maignan et al., 1999).

Governmental policies, regulations, and incentives aimed at promoting sustainable development play an important role in nurturing the business environment. Measures such as carbon pricing mechanisms, subsidies for renewable energy sources, green procurement practices, and sustainability standards encourage the private sector to invest in sustainable solutions (Abdmouleh et al., 2015). By aligning regulatory frameworks with sustainability goals, policymakers pave the way for enhanced economic opportunities and societal well-being.

When rethinking the sustainability-growth model, prioritising environmental stewardship, social equity, and human well-being need to be balanced with economics. Sustainable development offers economic prospects for businesses, investors, and societies, inviting a future shaped by innovation, efficiency, resilience, and competitive advantage amidst a dynamically evolving global landscape.

Science as a Pathway to Sustainable Development

Basic science is a cornerstone in the pursuit of sustainable development, providing an avenue to fundamental insights, innovative technologies, and evidence-based policies. Science is currently the catalyst for sustainable development across all sectors and disciplines offering alternatives to unsustainable practices and informing remediation, mitigation, and adaptation strategies when managing sustainability issues. To highlight this, some examples of advances made in the fields of environmental systems, technology development, agriculture, and policy and decision-making are presented.

Disciplines underpinned by the study of natural processes typically strongly depend on basic science; research driven by the desire to broaden and deepen our knowledge of the natural world. Understanding systems such as geological, ecological, climatological, and oceanographical systems, provide valuable and original insights into the processes and mechanisms that govern the natural world. Practical examples include how findings from mapping ecosystem dynamics, deciphering climate patterns, and modelling natural resource systems, have been used to inform and assess environmental risks, predict future changes, and develop sustainable resource management and responsible conservation strategies (Tallis & Polasky, 2009).

Advances made in fields like materials science, chemistry, and biotechnology have seeded new ideas and possibilities for sustainable technology development. Sustainable technologies have helped improve the efficiency, reliability, and scalability of renewable energy systems, efficient energy storage devices, clean water technologies, and eco-friendly materials, helping improve environmental footprints, enhance resource efficiency, and support sustainable development (Chu, 2022).

In agricultural science, research into agronomy, genetics, and soil science formed the platform for sustainable farming practices, developing resilient crop varieties and eco-friendly cultivation techniques. This has led to many benefits such as enhancing food security, bolstering soil health, curbing agricultural inputs, and mitigating some of the environmentally negative impacts associated with conventional farming practices. Such developments have and continue to contribute to the transition toward agricultural sustainability (Mrabet, 2023).

Evidence-based policies, regulations, and decision-making processes are informed and developed by research findings. By using scientific evidence and empirical data relevant to environmental protection, public health, energy transition, and natural resource management, the application of basic science bridges the gap between scientific knowledge and policy implementation. This contributes to identifying and constraining sustainability objectives and helps with developing mitigation methods and strategies to address global challenges (Sarewitz et al., 2000).

Science has been and continues to be an indispensable tool informing and aiding the progress of sustainable development. However, the vast majority of science currently being done is applied research – transforming basic science knowledge into practical outputs – since science has become an investment that must guarantee returns if it is to be funded. Yet through the development of innovative technologies, and the implementation of empirically grounded solutions, the environmental, social, and economic challenges faced by humanity are being recognised, managed, and resolved, albeit slowly.

Radical Transformation: Let History Repeat Itself

History has shown clearly, the evidence is irrefutable that basic science is essential for driving scientific progress and innovation, yet numerous challenges and barriers are faced that impede its advancement and hamper the pursuit of new knowledge. These challenges, ranging from funding constraints to ethical considerations, shape the landscape of scientific research and require concerted unified efforts to address them effectively. Key challenges include securing sufficient funding amidst competing priorities and budgetary limitations, lack of support due to risk aversion, and the bias towards short-term, applied research over long-term, curiosity-driven investigations. Additionally, engrained disciplinary boundaries and institutional silos hinder interdisciplinary collaboration, while concerns about reproducibility, replicability, and ethical implications reinforce the need for rigorous research standards and practices. Science communication – the effective dissemination of results and engaging the public in scientific discourse – is another critical challenge since it is the means of maximising the value of research and realising its full potential. Addressing these challenges requires collaborative efforts from stakeholders across sectors to create an environment conducive to curiosity-driven inquiry, interdisciplinary collaboration, scientific integrity, and equitable access to scientific opportunities. Achieving such an environment would advance the frontiers of basic science and facilitate transformative discoveries.

The critical need for sustainable development comes after being on an unsustainable trajectory for too long; the planet is no longer able to naturally reestablish equanimity: intervention is needed. The pursuit of basic science led to the wealth of original knowledge discovered before the 18th century and formed the platform for the technological advances of the Industrial

Revolution. The exponential rate of industrialisation and global development propagated seismic shifts resulting in strong economic growth and rapid urbanisation. Governments have sought to maintain continued growth, particularly economic growth, for more than three centuries, seemingly at any cost; the cost is the future. Globally, governance is helping to raise awareness across industry and society, but the effects of their efforts are incremental step-changes and improvement is slow. Currently, many of the greatest impacts of research come from applied science and are often linked to improving sustainability: the transformational change urgently required is not being achieved. It seems reasonable, even logical, to assume that greater investment in basic science would result in revolutionary, groundbreaking discoveries, as it has historically revolutionary, groundbreaking discoveries. The greatest barrier to new discoveries and transformational scientific breakthroughs is money, ironically at the most prosperous time in history; this must change. It is unquestionable that to create and maintain a sustainable world a multitargeted approach is necessary, yet a promising component to the solution is continuously being overlooked, which given the stakes – an unsustainable future – requires serious consideration: basic science.

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