

# Economical Strategies for Designing the Future Generation of Fissionable Nuclear Reactors: Unveiling Advanced Reactor Concepts (ARC)

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## Abstract

*This article delves into the critical imperative of understanding the need for innovation across various sectors and industries. Innovation is not just a buzzword but a fundamental driver of economic growth, competitiveness, and societal progress. The abstract explores the multifaceted impact of innovation on economic development, addressing global challenges, revolutionizing education, and improving overall quality of life. It emphasizes that innovation is indispensable in navigating an era of unprecedented challenges and opportunities, urging individuals and organizations to embrace a culture of innovation to shape a more resilient, sustainable, and equitable future.*

**Keywords:** Innovation, Economic Growth, Competitiveness, Global Challenges, Sustainability, Education, Quality of Life, Technology, Societal Progress, Resilience.

## Introduction

In the relentless pursuit of sustainable and low-carbon energy sources, nuclear power stands as a formidable candidate, offering the potential for a reliable and efficient energy future. As global concerns about climate change escalate and the demand for clean energy solutions intensifies, the focus on designing the next generation of fissionable nuclear reactors becomes paramount. This article delves into the intricate realm of economical methodologies that underpin the estimation of costs for the development of the Future Generation of Fissionable [1]. Nuclear Reactors, spotlighting the innovative landscape of Advanced Reactor Concepts, See Figure-1. [1-2].

The landscape of nuclear energy is poised at a critical juncture, necessitating a transformative leap in technology and design. While traditional nuclear reactors have played a crucial role in generating electricity for decades, the imperatives of safety, efficiency, and economic viability compel the exploration of novel and advanced reactor concepts. These concepts, ranging from Small Modular Reactors (SMRs) to cutting-edge designs, hold the promise of not only meeting the escalating global energy demand but also addressing the imperative need to reduce greenhouse gas emissions [3, 4, 1].

Against this backdrop, it becomes imperative to dissect the economic factors intricately woven into the fabric of designing the Future Generation of Fissionable Nuclear Reactors. The magnitude of the undertaking is underscored by the multifaceted chal-

lenges, from the need for extensive research and development to navigating complex regulatory landscapes and building specialized infrastructure. The journey toward advanced reactor technologies demands a strategic, collaborative, and economically astute approach to ensure not only technological success but also the realization of a sustainable energy future [5].

One of the fundamental drivers behind the evolution of nuclear technology is the imperative to enhance safety. The lessons learned from historical incidents underscore the necessity for robust safety features in reactor designs. Simultaneously, the economics of nuclear energy play a pivotal role in determining its feasibility as a mainstream energy source. Thus, a delicate balance must be struck between innovation, safety, and cost-effectiveness to usher in the next era of nuclear power.

As we embark on this exploration of economical methodologies, it is crucial to acknowledge the dynamic interplay between governments, research institutions, private industries, and regulatory bodies. The collaborative synergy among these entities becomes the linchpin for success, distributing financial risks, fostering innovation, and streamlining the path from conceptualization to realization.

As we stated in above, As the world grapples with the increasing demand for clean and sustainable energy sources, nuclear power continues to be a focal point in the quest for a low-carbon future. The design and development of the next generation of fis-

sionable nuclear reactors are critical steps in achieving efficient, safe, and economically viable solutions.

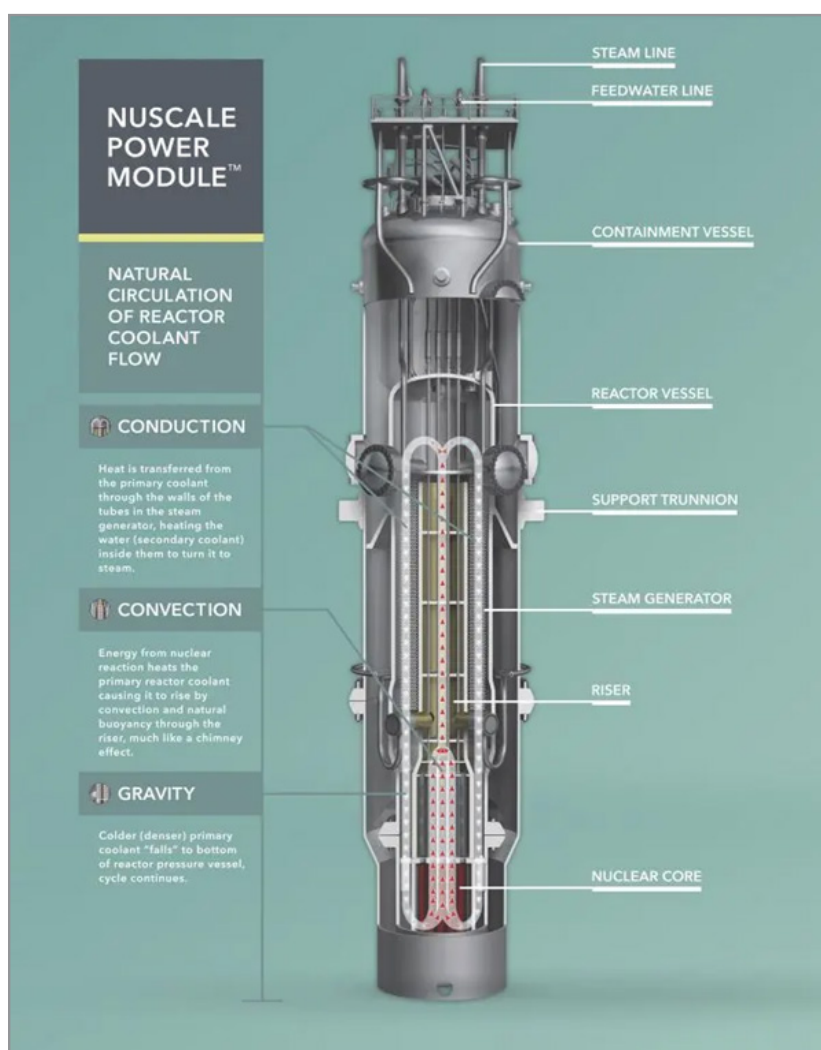
This article explores the economical methodologies behind estimating the probable cost of designing the Future Generation of Fissionable Nuclear Reactors, with a special emphasis on Advanced Reactor concepts [1, 2].

This article endeavors to unravel the intricate tapestry of factors influencing the costs of designing advanced nuclear reactors. From the early stages of research and development to the complexities of regulatory approval, construction, and operational efficiency, each facet contributes to the overall economic landscape of these transformative technologies. Moreover, the article will expound upon innovative strategies, including public-private partnerships, incentive programs, and international cooperation, which hold the potential to alleviate financial burdens and expedite the development of advanced reactor concepts [7].

In essence, the journey towards the Future Generation of Fissionable Nuclear Reactors is not merely a technological endeavor; it is a nuanced and dynamic dance between science, economics, and global collaboration. By shedding light on the economical methodologies intertwined with the development of advanced nuclear reactors, we aim to contribute to the discourse that will shape the energy landscape of tomorrow [6].

### New Generation of Fissionable Nuclear Reactor

The New Generation of Fissionable Nuclear Reactors marks a pivotal chapter in the evolution of nuclear energy, presenting a paradigm shift from conventional reactor designs to cutting-edge technologies that promise enhanced safety, efficiency, and sustainability. This transformative wave of innovation is propelled by the imperative to address the challenges posed by climate change, growing energy demands, and the necessity to transition towards low-carbon power sources.



**Figure 1:** Conceptual Drawing of Advanced Reactor Concept in Small Modular Reactor Structure

(Source: vase.churchrez.org)

At the heart of this technological renaissance are advanced reactor concepts that deviate from the familiar contours of traditional nuclear facilities. Small Modular Reactors (SMRs), for instance, represent a departure from the large-scale reactors of the past, offering a more flexible and scalable approach to nuclear power. Their modular design not only facilitates easier deployment but

also allows for incremental expansion, making them suitable for diverse applications, including remote areas and industrial settings [3, 4].

Beyond SMRs, there exists a spectrum of innovative designs collectively referred to as advanced reactors. These encompass

a range of technologies, such as Generation IV reactors, molten salt reactors, and high-temperature gas-cooled reactors. Each of these designs brings unique attributes to the table, whether it be inherent safety features, reduced nuclear waste production, or the ability to operate at higher temperatures, enabling diverse applications beyond electricity generation, such as hydrogen production and industrial processes.

Crucial to the allure of the New Generation of Fissionable Nuclear Reactors is their potential to redefine the safety benchmarks of nuclear energy. Advanced reactors incorporate passive safety systems and inherent design features that mitigate the risk of accidents and reduce the reliance on active safety measures. The aim is not only to enhance the protection of the public and the environment but also to instill greater confidence in the viability of nuclear power as a sustainable energy option.

Furthermore, these reactors promise advancements in fuel utilization, mitigating concerns associated with nuclear proliferation and the long-lived radioactive waste produced by traditional reactors. Some designs, like molten salt reactors, operate with different fuel cycles that not only extract more energy from nuclear fuel but also contribute to minimizing the long-term environmental impact of nuclear waste.

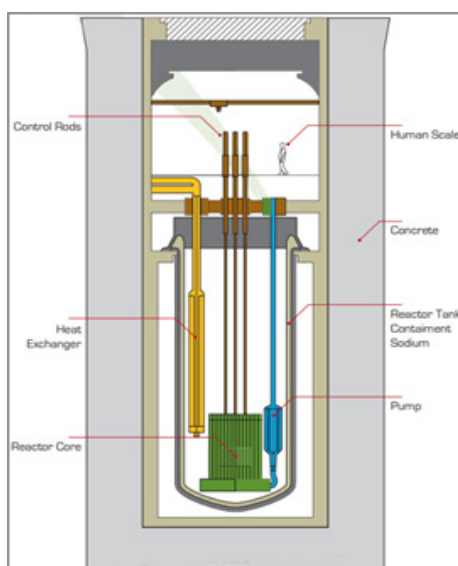
The New Generation of Fissionable Nuclear Reactors is also characterized by a heightened focus on flexibility and adaptability.

The ability to load-follow, ramp up or down quickly, and integrate with renewable energy sources positions these reactors as essential components in future energy grids. Their compatibility with intermittent renewable sources addresses the challenges of grid stability, offering a holistic and integrated approach to a diverse and resilient energy infrastructure.

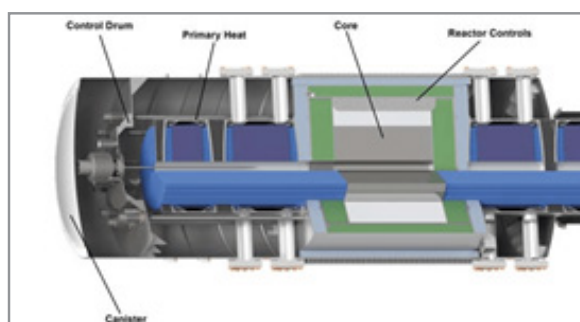
In conclusion, the New Generation of Fissionable Nuclear Reactors represents a transformative leap forward in the pursuit of sustainable and efficient energy solutions. These reactors embody a confluence of technological prowess, safety innovation, and environmental stewardship, positioning nuclear energy as a cornerstone in the global effort to combat climate change and secure a cleaner, more sustainable energy future. As research and development efforts continue to unfold, the promise of these advanced reactor concepts holds the potential to reshape the energy landscape for generations to come.

### Advanced Reactor Concept (ARC) by Definition

By Definition, Advanced Reactor Concept (ARC) is considered as a Sustainable, Cost-Effective and Design driven an innovative Energy Solution for the 22nd Century in different infrastructural form, such as ARC-100 (i.e., Figure-2) suggested by some startup companies in field of advanced nuclear reactor design to Nuclear Micro Reactors, such as Westinghouse eVinci Micro-Reactor as illustrated in Figure-3 [9, 10, 8].



**Figure 2:** The ARC-100 Reactor Conceptual Design  
(Source ARC LLC Corporation)



**Figure 3:** eVinci Micro-Reactor  
(Source: Westinghouse Corporation)

There are existing globally, other companies who are involved with Miro-Reactor designs of their own concept as well.

With worldwide demand for electrical power expected to double over the next 25 years, the world faces a daunting new challenge: provide affordable electricity to an expanding population with a rapidly increasing per-capita energy consumption rate without exacerbating climate change or fostering nuclear proliferation. Companies involved with conceptual and innovative design of Advanced Reactor Concepts (ARC) will address and resolve this challenge. ARC is developing a distinctive new technology for green power generation: an exportable, factory-produced, small-scale (50 MWe – 100 MWe) nuclear reactor with fixed fuel costs for 20+ years.

In case of conceptual idea of behind ARC-100 Reactor, due to its proposed long-life and proliferation-resistant fuel cycle, the ARC-100 reactor represents a significant enhancement in proven fast-reactor design that will open new markets to nuclear energy. It offers a new model for nuclear power that is based on the factory fabrication of modular components that can be shipped for rapid site assembly thereby promoting the prompt start of a revenue stream.

Key features suggested by the above concept (i.e., ARC-100) are considered as:

- Small Size.
- Highly Secure Deployment – Below Ground.
- Passive Safety Features – Proven Safety Record Through Experimental Breeder Reactor-II (EBR-II), which is an unmoderated, Sodium-Cooled Fast Reactor (FSR) with design power of 62.5 MWt.
- Advanced Monitoring & Control.
- Infrequent Fuel Handling & Shipment.

The Advanced Reactor Concept (ARC) stands as a testament to the forefront of nuclear innovation, embodying a suite of cutting-edge technologies designed to redefine the landscape of nuclear energy. Born from the imperative to address the limitations of traditional nuclear reactors, the ARC represents a leap forward in terms of safety, efficiency, and versatility.

At the core of the ARC lies a commitment to inherent safety features, leveraging advanced engineering principles to minimize the risk of accidents and enhance the resilience of the reactor. This includes the incorporation of passive safety systems, which operate without the need for active control mechanisms, ensuring a robust and fail-safe design. By prioritizing safety in the reactor's fundamental architecture, the ARC aims to set new benchmarks for the nuclear industry, fostering public confidence in the viability of nuclear energy.

One of the distinctive features of the ARC is its ability to operate at high temperatures, surpassing the capabilities of conventional reactors. This characteristic opens the door to a myriad of applications beyond electricity generation, such as industrial processes and hydrogen production. The high-temperature operation enhances the efficiency of the reactor and allows for the utilization of advanced materials, contributing to increased overall performance.

Moreover, the ARC showcases advancements in fuel utilization, seeking to optimize the extraction of energy from nuclear fuel while minimizing the production of long-lived radioactive waste. This emphasis on sustainability and reduced environmental impact aligns with the global goal of creating a more responsible and efficient nuclear energy sector.

In terms of design, the ARC often explores novel reactor configurations, such as molten salt reactors or fast neutron reactors. These alternative designs bring unique advantages, ranging from improved fuel efficiency to reduced proliferation risks. Molten salt reactors, for instance, operate with a liquid fuel mixture that not only enhances safety but also contributes to the efficient use of nuclear fuel and the reduction of nuclear waste.

As a key player in the landscape of advanced reactors, the ARC contributes to the broader narrative of nuclear energy's resurgence. It serves as a catalyst for research and development initiatives, prompting collaboration between governments, research institutions, and private entities. The ultimate goal is to not only overcome the challenges of the current nuclear energy paradigm but also to position advanced reactors like the ARC as cornerstones in a sustainable and diversified energy portfolio.

In conclusion, the Advanced Reactor Concept (ARC) represents a beacon of innovation in the nuclear energy sector. Its commitment to safety, efficiency, and versatility reflects a paradigm shift that promises to redefine the narrative surrounding nuclear power. As research progresses and prototypes are developed, the ARC stands poised to play a pivotal role in shaping the future of clean, reliable, and sustainable energy with an innovative design idea such as Combined Cycle Driven Efficiency [11].

### Understanding the Need for Innovation

In the ever-evolving landscape of technology and industry, the imperative for innovation has become more than a buzzword; it is a fundamental necessity for progress, sustainability, and societal advancement. The need for innovation spans across diverse sectors, from healthcare to energy, finance to education, driving a relentless quest for creative solutions to complex challenges.

Firstly, innovation is the driving force behind economic growth. In a globally interconnected world, nations and businesses must continuously seek novel ways to enhance productivity, create new markets, and stimulate economic activity. Innovation fosters competitiveness, allowing entities to stay ahead in a dynamic and competitive marketplace. By introducing groundbreaking products, services, or processes, innovators not only capture market share but also propel entire industries into new realms of possibility.

Moreover, innovation is the linchpin for addressing pressing global challenges, such as climate change, resource depletion, and public health crises. As societies grapple with the consequences of industrialization and population growth, innovative solutions are critical for mitigating environmental impact, developing sustainable practices, and ensuring the well-being of populations. Whether through breakthroughs in renewable energy, advancements in medical research, or the creation of resilient infrastructure, innovation provides the tools to confront and overcome these challenges.



In the realm of education and knowledge dissemination, innovation is indispensable. As technology reshapes the way we learn and acquire information, innovative approaches to education are paramount. From online learning platforms to interactive teaching methods, innovation in education not only democratizes access to knowledge but also adapts to the diverse learning styles of an increasingly interconnected and multicultural world.

Furthermore, the need for innovation is underscored by its capacity to improve the quality of life. Innovations in healthcare, for example, result in new treatments, diagnostic tools, and medical technologies that extend and enhance human life. Similarly, technological advancements in communication, transportation, and urban planning contribute to the creation of smarter, more efficient cities that elevate the standard of living for their inhabitants.

In essence, understanding the need for innovation requires a holistic perspective that recognizes its multifaceted impact on economic, social, and environmental dimensions. It is the driving force that propels societies forward, enabling adaptation to an ever-changing world. Embracing a culture of innovation involves fostering creativity, encouraging risk-taking, and providing the necessary support structures for individuals and organizations to experiment and iterate.

As we navigate an era characterized by unprecedented challenges and opportunities, the need for innovation is not merely a luxury but a strategic imperative. Those who understand and actively engage in innovation are poised to shape the future, unraveling new possibilities and charting a course towards a more resilient, sustainable, and equitable world.

In summary, the existing fleet of nuclear reactors has served humanity well, but there is a growing need for innovation to address safety concerns, enhance efficiency, and reduce costs. Advanced Reactor concepts, including small modular reactors (SMRs) and next-generation designs, offer promising solutions to these challenges. However, designing and implementing these advanced technologies require careful consideration of economic factors to ensure their viability.

### **Key Factors Influencing Costs**

#### **Research and Development (R&D)**

The initial phase involves substantial R&D investments to explore new materials, reactor designs, and safety features. A collaborative approach between governments, research institutions, and industry players can help distribute the financial burden and accelerate progress.

#### **Licensing and Regulatory Approval**

The regulatory landscape significantly impacts the cost and timeline of reactor development. Streamlining regulatory processes and fostering open communication between regulators and industry stakeholders can contribute to cost reduction.

#### **Construction and Infrastructure**

Building advanced nuclear reactors demands specialized infrastructure. Optimizing construction techniques, leveraging modularization, and selecting suitable sites can contribute to cost-effectiveness.

### **Supply Chain and Manufacturing**

Developing a robust and competitive supply chain is crucial for controlling costs. Standardizing components, fostering innovation in manufacturing processes, and promoting economies of scale are key strategies.

### **Operational Efficiency**

Advanced reactors often come with improved operational efficiency and enhanced safety features. These factors can contribute to long-term cost savings, making it essential to consider the entire lifecycle cost of a reactor.

### **Economical Methodologies**

#### **Public-Private Partnerships**

Collaborative efforts between governments, private companies, and research institutions can help distribute financial risks, attract investment, and expedite the development of advanced reactor technologies.

#### **Incentive Programs**

Governments can implement incentive programs such as tax credits, subsidies, or research grants to encourage private sector investment in advanced reactor development.

### **International Cooperation**

Collaborating on an international scale allows for shared resources, knowledge, and regulatory frameworks. Initiatives like the International Atomic Energy Agency (IAEA) can facilitate cooperation and cost-sharing among nations.

### **Streamlined Regulatory Processes**

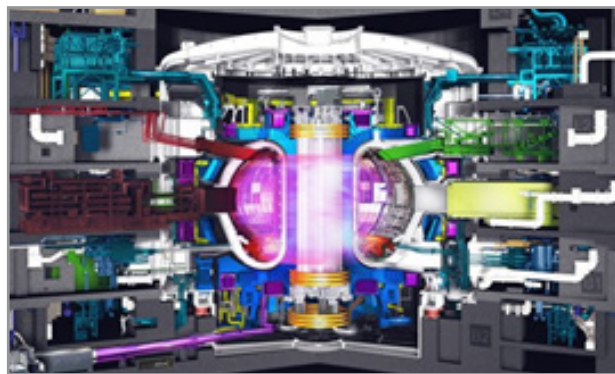
Governments and regulatory bodies should work collaboratively with industry stakeholders to establish efficient and transparent regulatory processes. This not only reduces delays but also provides certainty to investors and developers.

### **Fusion Nuclear Driven Energy Source Concept**

The future of fusion nuclear reactor concepts holds the promise of unlocking an almost limitless and sustainable source of energy, mimicking the very process that powers the sun. Fusion, the process of combining light atomic nuclei to release energy, presents an alternative to traditional fission reactors by offering numerous advantages, including reduced nuclear waste, enhanced safety features, and a nearly boundless fuel supply.

At the heart of fusion reactor concepts is the ambition to replicate the conditions found in the sun, where intense heat and pressure force hydrogen isotopes to fuse into helium, releasing a tremendous amount of energy in the process. The challenge lies in recreating these extreme conditions on Earth in a controlled and sustained manner [12-14].

One of the leading fusion reactor concepts is the tokamak, a torus-shaped device that uses powerful magnetic fields to confine and compress a plasma of hydrogen isotopes to induce fusion. ITER (International Thermonuclear Experimental Reactor) as illustrated in Figure-4, a collaborative global effort, represents a significant milestone in tokamak research, aiming to demonstrate the feasibility of sustained fusion reactions and pave the way for future commercial fusion power plants.



**Figure 4: ITER Fusion Reactor Tokmak Concept**

(Source: International Scientific Collaboration)

Other innovative fusion reactor concepts include stellarators, which use a more complex magnetic field configuration, and inertial confinement devices, which involve rapidly compressing and heating a small pellet of fusion fuel to induce a burst of fusion reactions [13].

The idea behind these fusion reactor concepts is to harness the immense energy released during fusion to generate electricity in a clean and sustainable manner. Unlike traditional fission reactors, fusion does not produce long-lived radioactive waste, and the fuel source—primarily isotopes of hydrogen—is abundant and widely available [12].

However, significant scientific and engineering challenges remain to be addressed before fusion can become a practical and economically viable energy source. These challenges include achieving and maintaining the extreme conditions required for sustained fusion, developing advanced materials that can withstand the harsh environment inside a fusion reactor, and optimizing the energy input-output ratio to ensure that the energy produced exceeds the energy invested.

Despite these challenges, the idea behind the future of fusion nuclear reactor concepts represents a beacon of hope for a world grappling with the urgent need for clean and abundant energy sources. Success in developing practical fusion power would not only revolutionize the energy landscape but also contribute to mitigating climate change and ensuring a sustainable future for generations to come [13,14].

#### **Cost to Design Concept**

The cost to design, particularly in the context of technological innovations such as advanced nuclear reactors, is a critical consideration that profoundly influences the feasibility and success of a project. Designing novel and sophisticated technologies requires substantial financial investments in research and development, engineering expertise, and prototyping. The complexity of advanced reactor concepts, such as the Advanced Reactor Concept (ARC), necessitates meticulous planning and robust design methodologies, contributing to the overall cost. However, it is crucial to view these costs not merely as financial expenditures but as strategic investments in the pursuit of safer, more efficient, and sustainable energy solutions. Effective cost management strategies, collaboration between public and

private entities, and a focus on long-term benefits contribute to mitigating the economic challenges associated with designing the next generation of fissionable nuclear reactors.

#### **Conclusion**

In conclusion, the exploration of the imperative for innovation reveals its profound and far-reaching impact across diverse facets of our global landscape. From driving economic growth and enhancing competitiveness to addressing pressing global challenges and reshaping education, innovation emerges as a cornerstone of progress. This journey through the multifaceted nature of innovation underscores its indispensable role in fostering societal advancement and sustainability.

Economically, innovation is not just a catalyst but a fundamental driver of growth. Businesses and nations that cultivate a culture of innovation are better positioned to adapt to dynamic market conditions, introduce groundbreaking products and services, and carve out a competitive edge in an interconnected world. The symbiotic relationship between innovation and economic development becomes evident as new markets emerge, productivity increases, and job opportunities expand.

Moreover, in the face of global challenges, innovation emerges as a powerful tool for transformative change. Climate change, resource depletion, and public health crises demand creative solutions, and it is through innovation that we can forge a path toward sustainability. Breakthroughs in renewable energy, sustainable practices, and environmentally conscious technologies offer hope for a future where humanity coexists harmoniously with the planet.

Education, a cornerstone of societal progress, is undergoing a revolution propelled by innovation. From digital learning platforms to interactive educational tools, innovation is reshaping the way knowledge is acquired and disseminated. This transformative approach not only makes education more accessible but also adapts to the diverse learning needs of a global and multicultural society.

The quality of life is profoundly influenced by innovation, particularly in healthcare and technology. Medical breakthroughs, advanced treatments, and improved diagnostic tools contribute to longer and healthier lives. Meanwhile, technological advance-

ments in communication, transportation, and urban planning create smarter, more efficient cities, enriching the lives of their inhabitants.

As we navigate an era characterized by unprecedented challenges and opportunities, the need for innovation is not just a strategic imperative; it is an ethical responsibility. Cultivating a culture of innovation involves fostering creativity, encouraging risk-taking, and providing the necessary support structures for individuals and organizations to experiment and iterate. Those who actively engage in innovation are not merely shaping the future; they are architects of a more resilient, sustainable, and equitable world.

In essence, the imperative for innovation is not confined to a single domain; it permeates every aspect of our existence. Understanding this imperative equips us with the tools to confront challenges, seize opportunities, and chart a course toward a future where innovation is not just a means to an end but an inherent part of our collective ethos. As we stand at the nexus of possibility and progress, embracing the spirit of innovation becomes a beacon guiding us toward a brighter and more promising tomorrow.

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