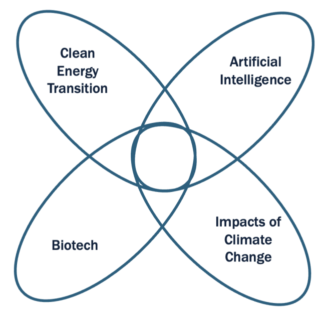
An occasional paper

Neonoesis: A New Era Defined by the Intersection of Artificial Intelligence, Biotechnology, the Clean Energy Transition, and Climate Impacts

Introduction

Over the next half-century, there are four key forces that will drastically reshape the future: the global clean energy transition, the impacts of climate change on humans and all ecosystems, the proliferation of artificial intelligence (AI), and the advancement of biotechnologies. Each of these tectonic shifts will significantly affect how we consume information, what we eat, how we live and power our lives, how the job force and global economy function, and more.

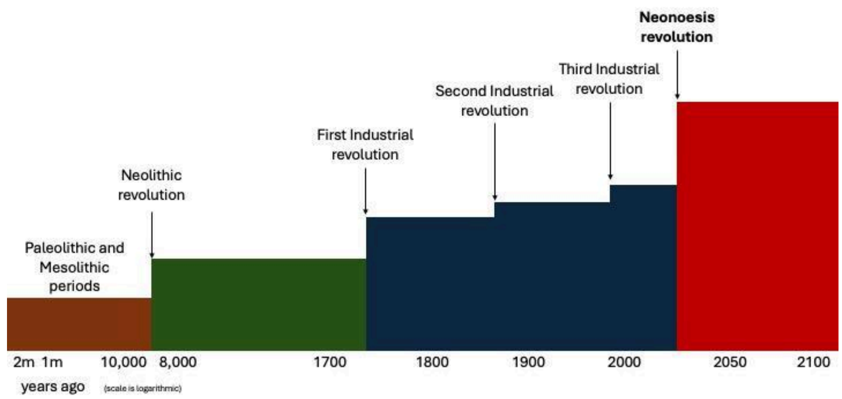


This new era, termed here as the "**Neonoesis Revolution**" (*new knowledge,)* can usher in an age of greater equity and opportunity as long as these emerging technologies are deployed with attention to one another and the solutions they offer. Alone, each of these shifts promises to create dramatic changes, but together, these shifts could be catalytic in creating a clean, equitable, and just future where negative outcomes are minimized. Some have described this new era as the 4th Industrial Revolution, but this new phase is as fundamentally different from the Industrial Revolution as the first Industrial Revolution was from the Neolithic Revolution, which is why it has been dubbed the Neonoesis Revolution.

Background

Throughout human history, massive cultural transformations have been sparked by technological innovation. Going back to the Neolithic revolution, humans transitioned from a hunter-gatherer culture to a more stable, agriculture-based society following the development of increasingly advanced agricultural tools for harvesting and irrigation systems. This shift towards technological sophistication spurred improved crop yields which allowed for the expansion of agriculture into more barren regions, the domestication of crops like wheat, corn, rice, and legumes, and of animals like cows, sheep, and pigs, all of which enabled major population growth.

The next major, technology-spurred cultural shift came in the late 18th century, with the first of three modern industrial revolutions brought on by the advent of the steam engine and power loom. A century later, in the late 19th and early 20th centuries, the intensification of industry brought the assembly line to life, the commoditization of products for a wider audience, the proliferation of electricity, steel, oil, and other fossil fuels, the passenger car, and eventually, the commercial airplane. The third industrial revolution, the digital revolution, kicked off in 1950 with large mainframe computers developed in the post-World War II scientific complex. These technologies quickly led to the creation of the ARPANET in the 1960s, personal computers in the 1970s and 80s, the mass adoption of the internet in the 1990s, and the proliferation of smartphones and other smart devices in the 2000s, putting a lifetime's worth of information into each of our pockets. The accessibility of these technologies and their reach has only continued to grow every year, affecting nearly every facet of how humans interact with one another and the world.



Each of these technology-spurred cultural transformations took place in a fraction of the time of the last. And each of the four unfolding transformations around climate, clean energy, AI, and biotechnology would be pivotal for society in its own right over the coming decades, but as catalysts with one another, they are speeding up the pace of each individually and are sure to usher in an era even more quickly transformed than anyone thinker will be able to keep pace with or predict.

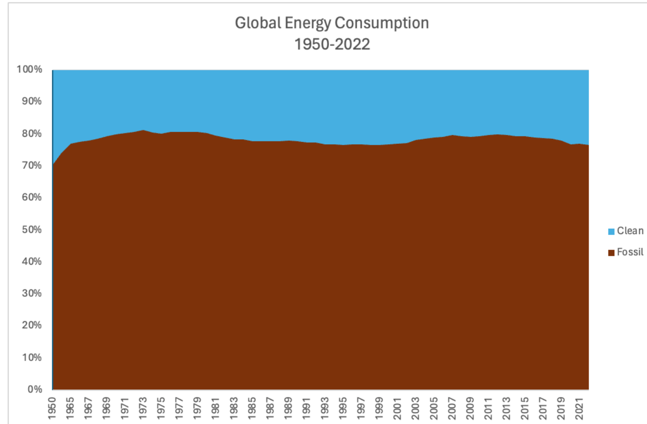
Which leads to the questions underlying this concept: *How can we work together to not only better predict what lies ahead, but shape what lies ahead? How can we deploy these technologies to act on and shape our world rather than letting them shape us*? *How can they amplify one another's positive impacts, minimize the negative, and create a more equitable future for all?*

The global clean energy transition

Since the 19th century, the global economy has been run almost exclusively on coal, oil, and methane gas (natural gas), with the industrialization and globalization of society demanding these fuels to heat our homes and buildings and power the electricity grid, cars, ships, trains, planes, and factories.

Even with decades of investment into cleaner energy sources, 80% of the global energy supply still comes from fossil fuels. The reason behind this is simple - as the world continues to build more clean energy, it almost always adds clean energy to existing sources rather than taking any existing capacity away. Today, nearly 800 million people globally still need access to reliable electricity, and the impacts of climate change are limiting the reliability of the grid in many places. In many countries like India, Indonesia, and Nigeria, the demand for fossil fuels continues to grow, and with rapidly growing and young populations, energy demand is only growing.

The next 15 years will be pivotal in determining whether nations can bend the curve on energy sector greenhouse emissions and near the goals set in the Paris Climate Agreement in 2015. New laws in the U.S. (the Inflation Reduction Act and Bipartisan Infrastructure Law), a rededication to deploying clean energy in Europe in reaction to the Russian invasion of Ukraine, and more and more funding for building clean energy in South Asia, Africa, and across Latin America are steps in the right direction but remain insufficient in the scheme of what is necessary.



In the years to come, deploying technologies, like wind, solar, advanced nuclear, carbon capture and storage, electricity storage, as well as electric vehicles and critical minerals, at the speed and scale necessary will continue to bring their own geopolitical risks and considerations to be managed. Critical minerals, for example, like lithium and cobalt are not rare per se, but the mining and processing of many of these minerals are concentrated in just a few countries, with China being the primary processor of most critical minerals today. Other challenges around community opposition to certain clean energy projects, workforce re-training and mobilization for these new projects, and slow permitting and insufficient transmission reform, among other hurdles, will characterize the clean energy transition's rapid efforts to mitigate emissions in the decades to come.

Impacts of climate change on humans

The second major force at play is the increasing impact of climate change on people and the planet. The world is already 1.18ºC warmer than a century ago, and we will likely breach the 1.5ºC barrier in the next five years. These increasing temperatures have brought more extreme weather, including more intense flooding, wildfires, heat waves (think – three weeks above 110ºF in Texas or 130ºF in Tehran), hurricanes, and more.

These climate impacts will drastically reshape how communities live and are built over the next century and beyond. More than sixty thousand people died in Europe in 2022, in areas that once did not need cooling infrastructure, because of climate-induced heat waves, and across the world, communities are rethinking how they build heat resilience to withstand these temperatures. Similarly, extreme weather has and will continue to lead to climate migration, affect national security, increase political unrest, affect food security, reshape housing and how we build resilience into infrastructure, and undoubtedly touch nearly every facet of modern society.

The rise of AI

AI development began in the 1950s, pioneered by Alan Turing's observations that machines could exhibit intelligent behavior indistinguishable from humans. In 1956, at a Dartmouth College conference that brought together researchers to discuss AI, Logic Theorist (considered the first AI program) was introduced by Allen Newell, Cliff Shaw, and Herbert Simon, and the term "artificial intelligence" was coined by John McCarthy. Through the 1960s and 1970s, the field underwent a rollercoaster of successes and disappointments, but a resurgence of interest in the 1980s and 1990s and the shift from rule-based systems to machine learning set the stage for commercial applications and the growth of machine learning that has exploded today.

Weak AI is the only form of AI that exists today but it has different forms and capabilities. Weak AI is designed to perform specific tasks under a defined range of conditions, as seen in virtual assistants like Siri or Alexa or in a recommendation system like Spotify, where AI suggests music based on pattern recognition. Generative AI, like ChatGPT, depends on the limited memory of the data the tool is trained on to generate human-like text and code based on prompts provided by users on wide-ranging topics, allowing humans to automate tasks and accelerate content creation.

AI introduced an era in which machines can now learn, adapt, and think autonomously. Since its emergence, AI has permeated many sectors. Its ability to automate tedious tasks allows people to focus on more creative, complex, and significant interactions across agriculture, technology, and climate industries, demonstrating itself as an effective and productive tool. However, this new technology has also triggered debates on ethics, privacy, and the future of work as it enables machines to have problem-solving capabilities and redesigns automation in the workforce.

The agricultural industry, for example, is being changed by the wide adoption of AI. With increasingly unpredictable weather patterns as climate change worsens, utilizing AI in agriculture has significantly grown in the past year. IBM's Watson Decision Platform for Agriculture uses satellite imaging and sensors in crop fields, and the AI analyzes the data and assists farmers in making informed decisions by providing insights on water and pesticide usage, crop and soil health, and weather patterns. The global AI agriculture market is projected to grow from 1.7 billion in 2023 to 4.7 billion in 2028, with a compound annual growth rate of 23.1% and the fastest-growing market in Asia.

AI is also playing an increasingly important role in the clean energy transition, especially in managing and optimizing the electric grid, from companies like Exelon and Duke Energy adopting AI in their operations to AI software suppliers like c3.AI and IBM. Integrating AI software into energy systems can improve demand and generation forecasting, allowing utility companies to predict energy spikes better and adjust without stressing the grid. Traditionally, grid monitoring and maintenance depend on manual inspections, regular, schedule-based maintenance, and data collection through basic meter systems, leading to slow response times and service interruptions. With AI, operators can monitor the grid in real-time with the help of data analysis from sensors and smart meters, equip technicians with data-driven insights to detect cybersecurity attacks and equipment failures and identify historical patterns to recommend optimized maintenance schedules and power distribution.

Earlier this year, Microsoft and Pacific Northwest National Lab also collaborated to identify optimal battery materials using Microsoft's Azure Quantum Elements (AQE). This cloud computing system has combined AI and high-performance computing to scan 32 million inorganic materials down to 18 potential candidates for battery production. One potential candidate is now being prototyped and tested; it uses 70% less lithium content than a standard lithium battery. Typically, the prototype would take years to build, but was completed in 80 hours. With the world's increasing dependence on lithium, from electric vehicles to medical devices to our phones, alternatives to lithium could have a significant impact. Despite the nascent research and the possibility that a prototype might not be feasible on a larger scale, the surprising and most significant part is the speed at which the material was discovered with AI.

These collaborations and technologies demonstrate not only the growth of but also the potentially innovative uses of AI to solve the world's climate and energy challenges. Though the proliferation of AI-powered devices and data centers requires a significant amount of energy, compounding the complexity of the energy transition, the number of solutions is also significant.

The proliferation of biotechnology

Finally, everything we interact with is either grown or mined, and while mining metals, minerals, fossil fuels, and other materials are finite, the growth of living organisms is not, and as such biotechnology should not be overlooked in its transformative role in shaping the next century.

Biotechnology is a broad term to describe a range of applications that use living organisms and their derivatives to form products and processes. Its origins date back to the production of beer and bread, unknowingly harnessing microbial power and practicing selective breeding to improve desirable crops and livestock. Fast forward, and the invention of pasteurization revolutionized food safety and eliminated harmful bacteria in consumer products. The 20th century prompted the discovery of penicillin, an antibiotic originating from microorganisms and marking a milestone in pharmaceutical research. By the 1950s, scientists laid the foundation for molecular genetics by discovering the double-helix structure of DNA. Not long after, in the 1970s, scientists introduced recombinant DNA technology, enabling the manipulation of genetic material to create genetically modified organisms (GMOs). Decades of progress led to the groundbreaking discovery of CRISPR Cas9, a gene-editing technology allowing precise DNA modification.

The industry continues to evolve, driven by advances in synthetic biology, genetic engineering, and bioinformatics, impacting the future of biotech applications in agriculture, medicine, and the environment. New technologies like synthetic biology, a subset of biotechnology, are focused on designing and constructing new biological parts and systems from scratch or redesigning existing biological systems at a fundamental level that doesn't exist in nature. These synthetic biological organisms can be placed to specific-designed uses or instructed to grow to create a specific 'product.'

Biotechnology has dramatically reshaped our approaches to agriculture, health, and climate resilience. Investments continue to grow, with advances in AI, food, and more driving the future bioeconomy to as much as $3.44 trillion globally by 2030. However, only a fraction of these investments focus on climate solutions. With increasingly unpredictable floods, droughts, and extreme heat waves, building up the resilience of the global food system will be critical, presenting an opportunity for unique climate biotechnology solutions**.** Researchers at Stanford University are utilizing synthetic genetic circuits to modify the root structures of plants and enable the control of decisions made in plant cells. This tool could help redesign crops to better absorb water and nutrients from the soil and withstand different environmental pressures.

A combination of AI and biotechnology can take this research a step further to improve climate-smart agriculture outcomes even further. Digital twins (DT) are virtual simulations of objects or systems created using machine learning algorithms to process sensor data and identify patterns. AI can use the real-time data the digital twin receives to model different simulations and predict specific outcomes, making developing and optimizing a product much more comprehensive and accurate. In precision farming systems, digital twins can provide real-time insights, analytics, and simulations of corrective or preventive actions, evaluate the impact of the action on the digital twin, and finally, execute the chosen action remotely, followed by another analysis and so on. Eventually, this process can help develop genetically modified crops that are more resilient to extreme weather, or it can even help develop better green infrastructure and support urban planning for climate-resilient cities.

Finally, recent innovations in synthetic biology have shown that DNA can be a stable digital data storage medium. Although the idea of storing data in DNA was first suggested by Richard Feynman in 1959, breakthroughs in research over the past year have made something thought science fiction, into reality. By mapping binary information of a digital object onto the nucleotide sequences, researchers have stored large amounts of the original data into synthesized DNA, like 36 million copies of the *Avengers: Endgame* movie in a single gram of DNA. DNA is a far denser storage medium and requires less energy than solid-state drives and hard disks commonly found in data centers, and DNA doesn't require energy use until its data is retrieved. With warehouse-sized data centers with thousands of rows of servers continuing to manage massive amounts of data every time we send an email, mine bitcoin, or power AI applications, it accounts for roughly 2% of global electricity consumption. Although this niche sector can be limited by the energy-intensive cooling needed to maintain nucleic acid integrity, particularly in health-related applications, the potential for DNA is ever-growing.

Looking forward

The examples presented represent just a handful of interactions between these major forces, but a concerted cross-sectoral dialogue is necessary to maximize their potential climate and societal benefits.

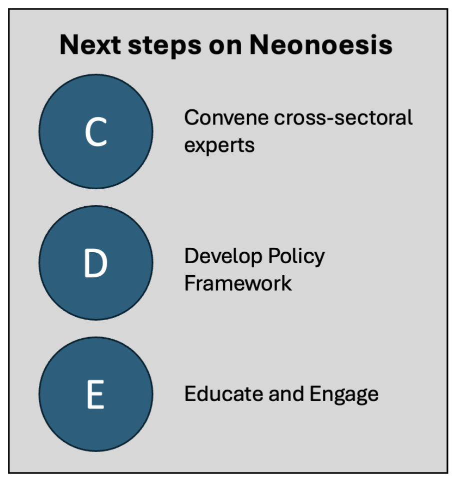
The Aspen Institute Energy & Environment Program has long convened energy, environment, and climate stakeholders around many of the thorniest issues and biggest questions of the times, and is thus uniquely positioned to advance these critical conversations. While the experts working in clean energy deployment, adaptation and resilience, environmental biotechnology, and AI, are all working to reshape the future, they are working in silos.

The Energy and Environment Program envisions a series of conversations that will convene a selection of key stakeholders from across these four emerging areas to share visions of the future and the tools that they anticipate using to get there. Leaders can discuss opportunities for collaboration, generate ideas together, and conceptualize a multi-sector vision leveraging each of their individual strengths to amplify their impact. Instead of each pushing forward an individual, and perhaps at times, at odds, vision of the future, how much more effective would a collective push be?

Each of these technologies offers innovative and scalable solutions to the climate crisis, but each of them has also faced questions and challenges around ethics and privacy, increased demand for energy, community engagement, and their own potential negative climate impacts. To navigate the landscape of these technologies effectively, these dialogues can inform a set of policies that protect people and the planet, without stymying the progress of these technologies. Cross-sector players will need to identify existing policies in each space and determine where positive lessons learned might be shared and what gaps still exist. Undoubtedly, these policies will need to include workforce issues, acknowledging the implications that these new technologies, a warming world, and ideally a global clean economy will have on employment, job displacement, and skills development.

Finally, educating the public and policymakers will be a key step in this process. The clean energy transition has been met with a series of roadblocks that could have been avoided if, for example, proper community engagement and education efforts had preceded the introduction of the new technologies. Developing accessible and digestible descriptions of what these technologies are, how they interact with each other, how they *should* be used as a force for a healthier planet and increased equity and prosperity, and also how they should *not* be used to minimize negative impacts, will be key to ensuring that these cultural shifts are used as forces for good.

The climate crisis will undoubtedly reshape life on this planet over the next century and there are technologies at our disposal that already are, and will continue to, play a huge role in determining just how affected human life is. The Aspen Institute is uniquely suited to take experts out of their everyday work environment and the silos and to look forward – *far forward* – and to set a vision for the planet, that if we collectively chart towards, we will have a much better chance of reaching.



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This paper was co-authored by Greg Gershuny, Catherine Pollack, and Nadia Phyu, with contributions from María Ortiz Pérez, Bea Kuijpers, Alexis Anderson, and Jade Rouse.