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INTO THE NOT-SO-DISTANT FUTURE – INNOVATIONS SHAPING TOMORROW'S ECONOMY

Executive Summary

- In the biotech space, we explore the use of Machine Learning (ML) to analyze large data sets to assist in new drug discovery and the potential applications for gene editing technology.
- Despite years of setbacks, companies like Tesla, Alphabet's Waymo, Amazon's Zoox, and GM's Cruise are forging ahead with autonomous driving with the help of Artificial Intelligence (AI).
- New oilfield innovations, which started being implemented more widely in 2023, have made it possible for fracking to be faster, less expensive and higher yielding.
- As a result of both the fusion breakthrough and the rise in power demand, big tech companies are turning to nuclear energy in hopes of powering AI data centers, which need 24/7 access to reliable electricity.
- Quantum computing is a rapidly emerging technology that harnesses the laws of quantum mechanics to solve problems that even today's most powerful supercomputers lack the capacity to crack.
- Exploring the potential for 3-D printing technology to become an alternative building solution.

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From the moment early man discovered uses for fire 1.5 million years ago, human evolution and innovation became intertwined. Every advancement laid the groundwork for what came next.

The agricultural revolution (circa 10,000 BCE) transformed nomadic cultures to agrarian societies. The first Industrial Revolution, fueled by coal, revolutionized production and laid the groundwork for modern industry. Gas-powered lighting and factories debuted in the 1800s. Automobiles began being mass produced in the early 1900s. The invention of transistors and semiconductors birthed the electronics industry in the 1950s. Nuclear power transformed the energy industry in the 1960s. In the 1980s, computers went from specialized capital equipment for industry to an appliance everyone wanted in their homes. The 1990s saw the rise of the internet, the 2000s the smartphone.

Today, with the rise of Artificial Intelligence (AI), the pace of innovation keeps on accelerating (Figure 1). In the latest CIO Perspectives, we present emergent technologies and innovations that have the potential to transform the industries and sectors in which we invest. These innovations include: quantum computing, DNA modification using "genetic scissors," autonomous automobiles, and 3-D printing systems now being used to construct entire buildings.

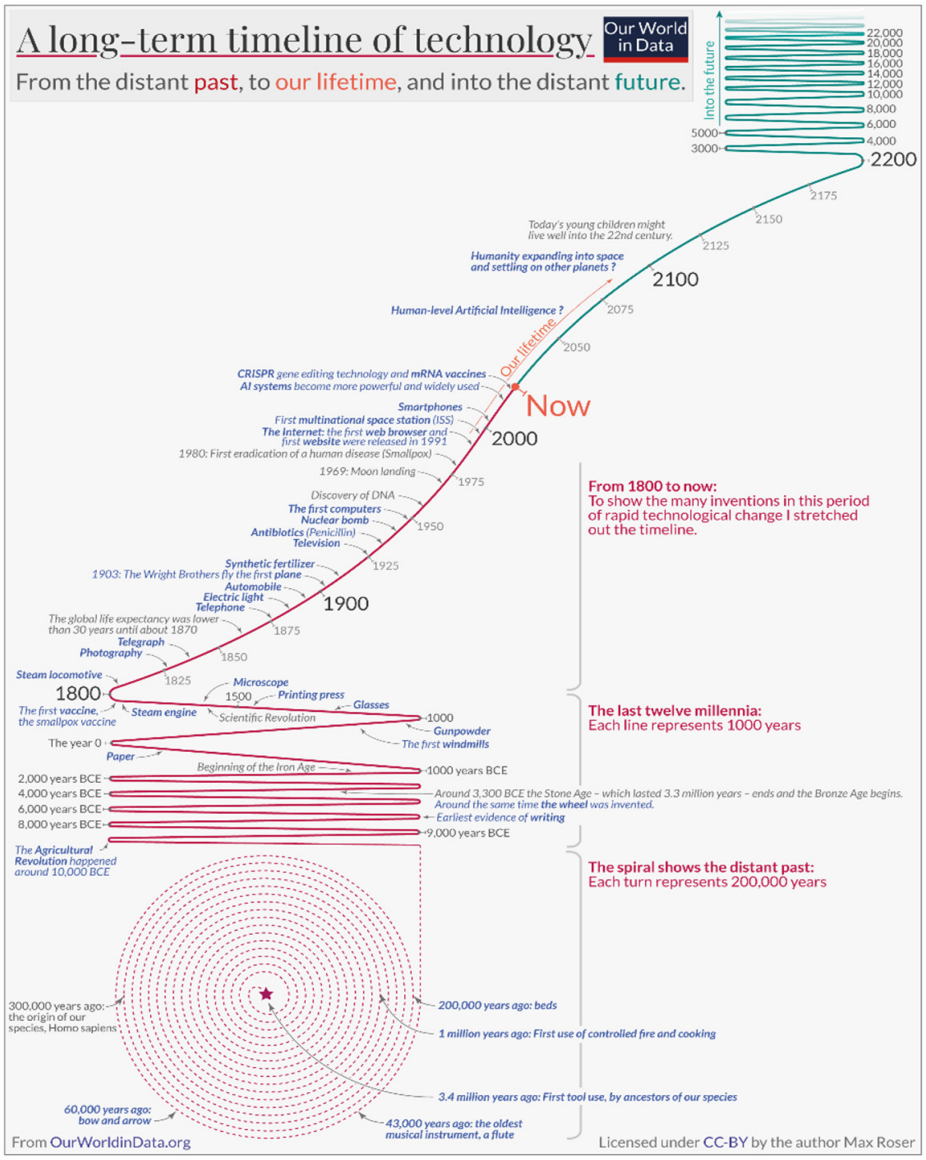
We provide an overview of how such innovations may impact the economy, financial markets and our lives. Some of these discoveries have the potential to revolutionize existing industries, while others may give rise to entirely new one's, changing the labor market. While new technologies often pave the way for progress, they can also lead to significant challenges such as job displacement in traditional industries. Yet, history shows that disruption is often accompanied by the creation of new opportunities, leading to the emergence of new jobs and industries we cannot imagine today.

We provide insights into how some of these innovations might make the transition from an idea in a lab to a product or service. **While we do mention several individual companies in this report—many of them still in start-up mode—these references are not intended as investment recommendations for the underlying equities or bonds issued by these firms. Our objective is solely to showcase here some of the**

technologies and innovations for informational purposes only, many analysts and investors are keeping an eye for their promise to make a significant impact. Readers should not interpret these mentions as endorsements, nor should they be relied upon for investment decisions. We discuss these companies to highlight the innovations they're working on. Something else to keep in mind: The companies that profit most from new technologies are not always the ones that first developed them.

FIGURE 1

A long-time timeline of technology.



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Biotech

On average, it takes more than 10 years and a billion dollars to develop a new drug and receive government approval,[1] with only about 10% of the drugs that enter clinical studies making it all the way through the approval process.[2] With the introduction of AI, the time it takes to develop these drugs could be reduced significantly, slashing the cost of bringing new drugs to market. As a result, there has been a wave of startup companies spearheading the AI-drug discovery revolution by applying machine learning models to pair patients with the most effective cancer treatments.[3] Machine learning (ML) is a field of AI that teaches computers to analyze large data sets to improve performance of a given system over time.

According to researchers, using a small tissue sample from patients, along with robotic automation and ML models to detect subtle cellular changes, it is possible to simultaneously analyze both normal and cancerous cells and expose those cells to various treatments at the same time.

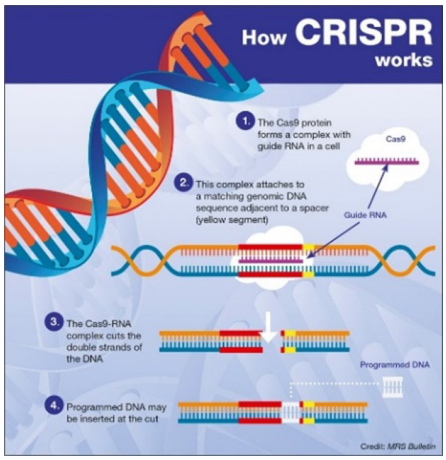
This approach allows for AI to carry out the intensive and exhaustive process of searching for the right cancer treatment—without subjecting cancer patients to one chemo drug after another for months until doctors find the one that works. Instead of putting a patient through multiple, months-long trials to see how the patient would react to each type of chemotherapy, researchers are testing dozens of treatments all at once in a lab, using ML to pair the patient with a drug that has the highest likelihood of success. We are increasingly seeing how AI-assisted processes will improve industries like biotech, as AI excels at analyzing complex data sets and determining the best next steps far beyond human capabilities.

ML technology is one of many innovations with the potential to transform biotech and drug discovery via AI. While still a nascent industry, more AI breakthroughs will create more opportunities and efficiencies. Morgan Stanley estimates that as little as a 1% improvement in preclinical development success could generate an incremental $15 billion in value for the biotech industry over 10 years.

Another innovative biotechnology is CRISPR (short for "clustered regularly interspaced short palindromic repeats"). CRISPR is a Nobel Prize-winning breakthrough with the potential to improve lives, so long as guardrails and regulations are in place. (The technology is controversial due to concerns around gene modification.) With CRISPR, scientists are able to use "genetic scissors" to change the DNA of animals, plants and micro organisms with high precision, potentially revolutionizing molecular science (Figure 2).

FIGURE 2

How CRISPR gene editing technology works.



Disclosure: This illustration is for informational purposes only. This is not considered an investment recommendation.

Source: MRS Bulletin

For example, gene editing can be used to create more disease-resistant farm animals. In one experiment researchers were able to eliminate respiratory diseases like swine flu from certain pig populations. CRISPR technology can also be used to help farmers tackle the effects of climate change by producing bacteria-resistant crops that better withstand extreme heat and cold. It could even help tackle climate change more directly by producing crops that capture more carbon from the atmosphere and store it inside their roots.[4]

We are only beginning to scratch the surface of what this technology can do for plants and organisms, as most of the focus for CRISPR thus far has been on the human genome. In recent years, CRISPR has been able to help with diagnosing and preventing diseases such as HIV and cancer. The first CRISPR therapy to gain FDA approval[5] came to market in late 2023 and has proven to be an effective treatment for sickle cell disease. Currently the cost of this treatment is around $2 million,[6] but, with time, the costs should come down. As reported by the NHGRI Genome Sequencing Program (GSP), the cost of DNA sequencing has fallen exponentially (more than 175,000-fold) since the completion of the first sequencing project in 1976.

Autonomous driving

The Jetsons envisioned a future with flying cars, but reality hasn't quite caught up to the cartoon dream. Instead, we are knocking on the door of a future of fully autonomous vehicles driving through city streets. Despite some setbacks, companies like Tesla, Alphabet's Waymo, Amazon's Zoox, and GM's Cruise are forging ahead and insisting that the tech will be ready in a few years, albeit with some human supervision still needed as a precaution.

Alphabet's Waymo, one of the leaders in the autonomous space with more than 25 million driverless miles of data as of the end of 2024, says there is already strong consumer demand and increased public trust, averaging 150,000 driverless trips every week in the cities of San Francisco, Los Angeles, Phoenix, and Austin.[7] Safety standards have also improved: Waymo says that based on data tracking airbag deployment crashes, injury-causing crashes, and police-reported crashes, its safety record exceeds the human-driver benchmark.[8] According to the consulting firm McKinsey, autonomous driving could account for a market opportunity of $300 to $400 billion as early as 2035.[9]

Tesla unveiled its version of the "Cybercab" at its "We, Robot" event in October 2024. Its fleet of futuristic taxi cabs have no steering wheels no pedals, and no drivers—just two seats and an autonomous system powered by AI to get passengers to their destinations. The timeline offered by Tesla targeted a production start date for the Cybercab as early as 2027 in its Austin, Texas factory. Critics think Tesla's timetable is overly ambitious, but Tesla does have one advantage over its rivals: existing data from the millions of human-operated Teslas on the road, each of which provides the company with a steady stream of driver alerts and other data that it can use to improve Cybercab's AI.

Other products Tesla highlighted at "We, Rebot" included the more conceptual "Robovan," an autonomous minibus that can help solve high density travel issues, and the humanoid robot "Optimus" that would be marketed as your "Personal R2D2." Currently, there are no production timelines for either.

In addition to delivering future fleets of robotaxis and cybervans, autonomous driving technology could also promote more efficient farming. A company based out of Livermore, California that looks to incorporate electrification, autonomy and smart tech into farming equipment, has invented the world's first tractor that's both fully electric and self-driving.[10] The MK-V tractor, a TIME Magazine Best Invention of 2023, estimates that a single California farm that mows and tills its fields can save up to $79,000 annually per tractor on fuel alone and another $120,000 in labor costs due to automation. Although twice the upfront price of a standard diesel John Deere tractor, the MK-V looks to improve profitability of small farms over time by lowering fuel and labor costs, with the added benefit of zero carbon emissions.

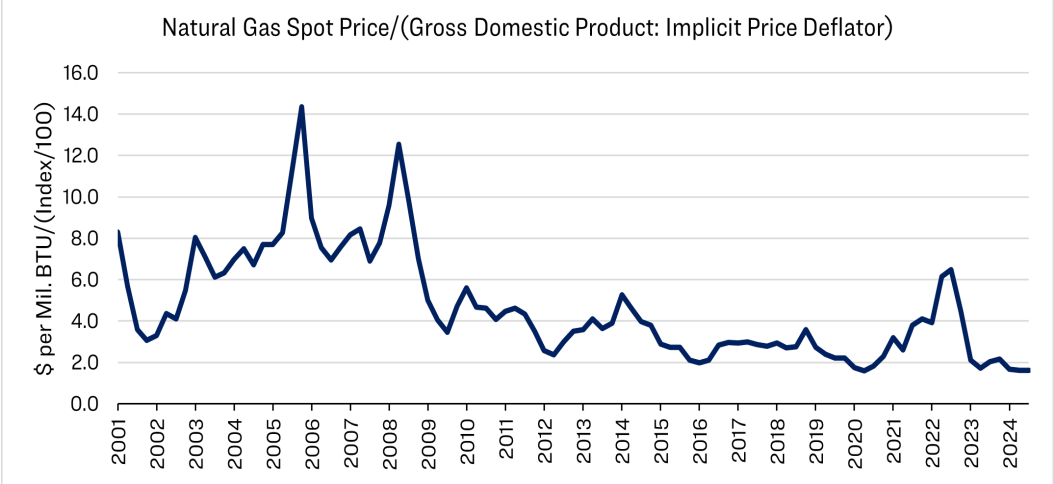
Energy

In the future, energy will likely come from a wide range of resources—solar, wind, geothermal, nuclear and perhaps even a technology not yet invented. In the here and now, however, our economy is still heavily reliant on fossil energy sources for electricity generation—and could become even more so with President Trump pushing to expand domestic oil-and-gas drilling. Simul-fracking is a new technology that is helping the U.S. shale-oil industry reverse years of well productivity declines; it can double the yield of natural gas in lateral footage, in less time, versus previous fracking operations.[11] These new oilfield innovations, which started being implemented more widely in 2023, have made it possible for fracking to be faster, less expensive and higher yielding. In essence, rather than just drilling one well, a system of wells is drilled as pumps inject fluids and extract oil out of the ground through use of multiple wells, rather than just one in standard fracking.

Exxon (XOM) says this technology will allow it to extract an extra 700,000 barrels of oil equivalent per day (boepd). Chevron (CVX) is increasing use of simul-fracs and says the technique will boost its Permian Basin production in Texas and New Mexico by 10% this year to 900,000 boepd.[12] While fracking in particular and fossil fuels in general have plenty of critics, the U.S. economy needs dependable and low-cost power generation. As we wrote in September, the proliferation of AI-related data centers is having a material impact on U.S. power consumption. The good news: Natural gas prices, already down since the start of the fracking boom, have fallen sharply on an inflation-adjusted basis due to innovations in the field (Figure 3).

FIGURE 3

Natural gas prices have fallen significantly over time on an inflation-adjusted basis.



Source: TIAA Wealth CIO, FRED

In order for the U.S. and the world to address climate change and to reduce reliance on fossil fuels, there first must be a viable, large-scale energy alternative. In recent years, there has been a renaissance in nuclear energy research aimed at positioning nuclear as a clean, reliable source of power. During the January 2024 COP28 UN Climate Change Conference, there was a multi-country pledge to de-carbonize economies and triple nuclear capacity by 2050; this opens the door for what analysts estimate might attract as much as $1.5 trillion in capital investment in nuclear energy through 2050.[13]

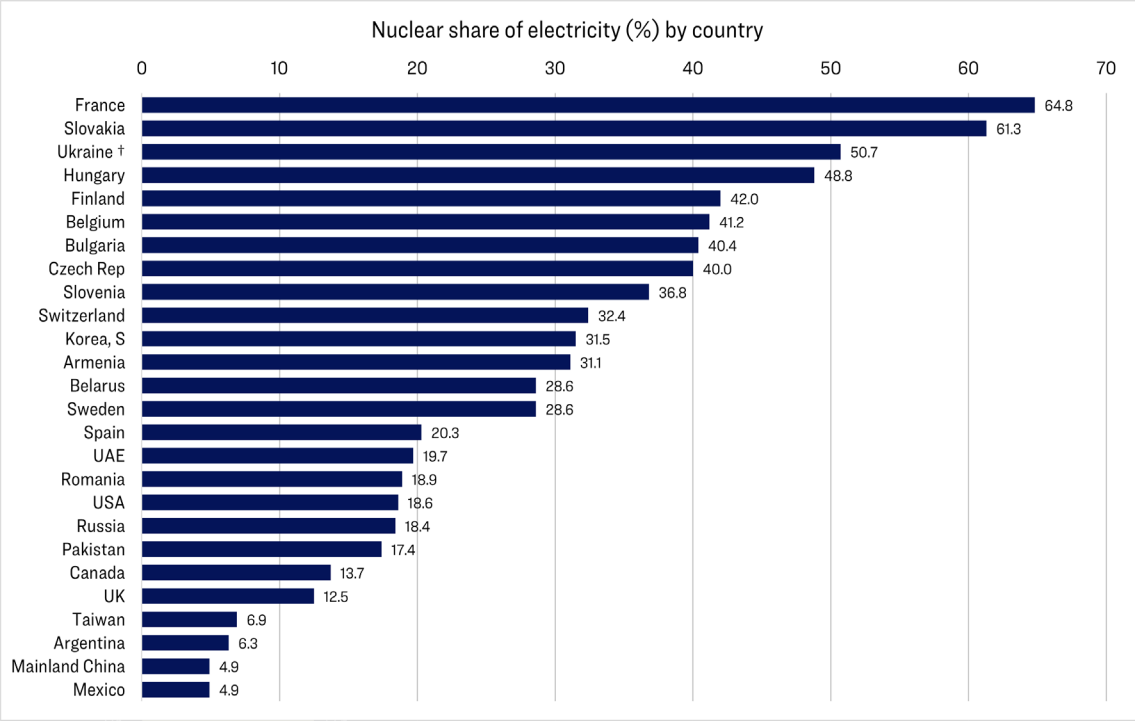
In late 2022, the U.S. Department of Energy (DOE) and the National Nuclear Security Administration (NNSA) paved the way for nuclear advancement when they achieved the world's first fusion ignition in a lab setting that was net energy positive.[14] In other words, when the fusion reaction reached ignition, the nuclear energy output was greater than the energy required to start the reaction. Unlike nuclear fission, which is generated by the division of atoms—the type of nuclear reaction used in today's nuclear plants—nuclear fusion occurs when two light atoms combine to form a heavier atom. Also, unlike nuclear fission, nuclear fusion leaves no legacy of long-lived radioactive waste.

As a result of both the fusion breakthrough and the rise in power demand, big tech companies are turning to nuclear energy in hopes of powering AI data centers, which need 24/7 access to reliable electricity. Companies like Microsoft (MSFT), Amazon (AMZN), and Alphabet (GOOGL) have recently made investments and announced partnerships in nuclear power providers.[15] Constellation Energy (CEG) is restarting Three Mile Island in Pennsylvania to power Microsoft data centers.[16] On October 16, 2024, Amazon Web Services (AWS) announced it was investing $500 million in nuclear power as its need for clean energy keeps increasing as it expands its generative AI offerings.[17] Partnering with utility Dominion Energy (D), Amazon will look to develop Small Modular Reactors (SMRs) in Virginia to keep up with its future power demand. Nuclear power (by way of fission) currently accounts for nearly 20% of all the electricity generated in America today, and that percentage is expected to grow with more capital investment, government support and technological advancement.[18]

Around the world, countries have increased their reliance on nuclear sources for energy (Figure 4). France now generates around 65% of its electricity from nuclear energy, while Ukraine, Slovakia and Hungary get about half. Japan used to rely on nuclear power for more than one-quarter of its electricity but has cut back since the Fukushima nuclear accident in 2011. Still, Japan is expected to return to near prior levels with updated technologies and improved safety standards.[19]

FIGURE 4

Nuclear electricity generation by country (As of August 6, 2024)



† Ukraine 2022 and 2023 electricity generation estimated.

Source: TIAA Wealth CIO, World Nuclear Association

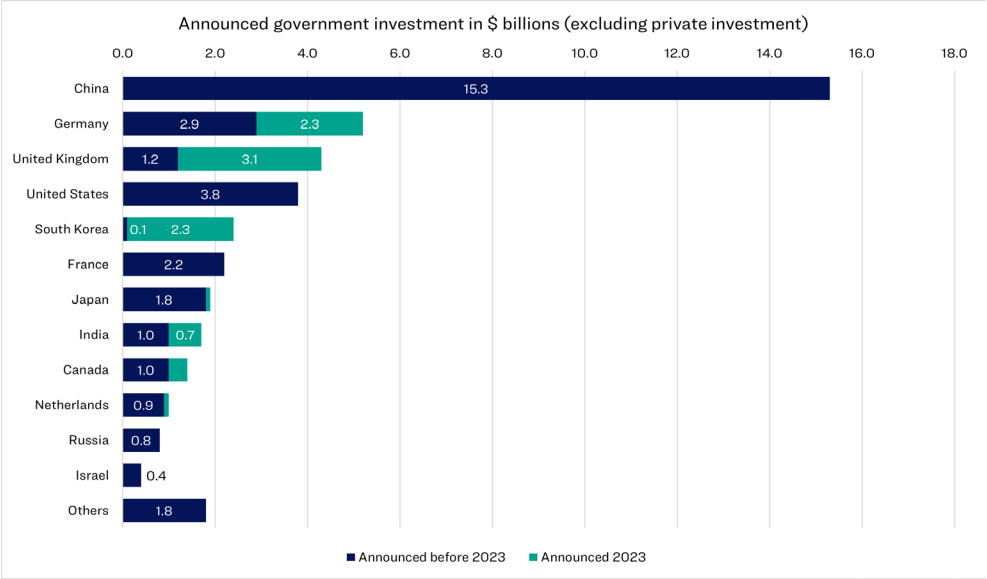
Quantum technology (QT)

Quantum computing is a rapidly emerging technology that harnesses the laws of quantum mechanics to solve problems that even today's most powerful supercomputers lack the capacity to crack. We're not going to try to explain quantum mechanics or illuminate how it can be used to improve modern computing (you're welcome!). Suffice it to say that experts believe recent advances in quantum technology (QT) will allow faster information processing versus today's "classical" computers. Practical applications of QT could lead to advancements in drug and chemical research, improvements in route and traffic optimization, enhancements in cybersecurity and encryption, and improved manufacturing processes for products such as batteries and semiconductors. According to McKinsey, quantum technologies could create trillions of dollars in value within the next decade.[20]

While the United States and China have taken the early lead in terms of private investments, governments all over the world have increased public investment in QT with a growing realization of its importance for national security and defense, with China taking the early lead. (Figure 5).

FIGURE 5

Global public investments in quantum technology reached $42 billion in 2023



Source: McKinsey, TIAA Wealth Chief Investment Office

The ability to tap QT's computational potential could help researchers identify new medicines and treatments faster. IBM, in partnership with the Cleveland Clinic, has installed the first quantum computer in the world specifically dedicated to healthcare research and assisting in accelerating biomedical discoveries[21]. By combining quantum computing with AI, the Cleveland Clinic-IBM Discovery Accelerator has been able to tackle a multitude of projects including developing quantum computing pipelines to screen and optimize drugs targeted to specific proteins, making improvements in prediction models for cardiovascular risk following non-cardiac surgery, and breaking down patient genome sequencing to find effective, existing treatments for patients with Alzheimer's and other diseases.

3-D Printed Real Estate and Construction

Walmart operates over 10,500 stores and clubs in over 19 countries, but for the first time, it's been able to 3-D print a warehouse dedicated to online pickup and delivery. In partnership with 3-D printing construction companies, Walmart built an 8,000 square-foot, 20-foot-high structure to assist online pickup and delivery in Athens, Tennessee in the summer of 2024. It is the largest 3D concrete-printed (3DCP) commercial building of its kind in the U.S.[22] With another 200 such warehouses in the pipeline, Walmart is on the forefront of taking this technology mainstream. Presently, the cost and time it takes to 3-D print a warehouse is roughly the same as traditional construction, but with more experience and the help of AI, the cost should come down over time.

According to Zillow, the U.S. is grappling with a housing deficit and needs to build 4.5 million new homes.[23] 3-D building material technology has been touted as one of the ways to alleviate the shortage. Coming out of the COVID-19 pandemic, supply chain backlogs and labor shortages put pressure on homebuilders to meet demand for new homes. To find alternative building solutions, residential homebuilder Lennar Corp. and construction-technology firms are teaming up and collaborating on the U.S.'s largest 3-D printed housing community, just outside of Austin, Texas.[24] Most newly built homes in the U.S. today are constructed onsite and framed with wood using traditional building methods. With this 3-D printing technology, a concrete exterior and interior of a 2,000 square-foot one story home can be constructed in a week, with robotic printers that squeeze concrete stacked in layers "like toothpaste out of a tube."

Other innovations now being adopted by the real estate industry include the use of robotics to create safer conditions for construction workers and to automate tasks normally performed by workers or engineers. For example, the need for a robotic solution lead to the invention of a commercially available small, autonomous robot that draws blueprint layouts directly onto a construction site floor, rather than having a construction crew do the job manually[25]. Robotic welding is being implemented across construction sites as robots can work consistently and tirelessly, completing a job quicker with the same level of quality as a human welder. The rise of automated welding is creating new human jobs such as welding inspection, robot maintenance, and quality assurance. As of 2020, the global robotic welding market size was $5.42 billion and is expected to grow to over $9 billion by 2028, with the Asia Pacific region taking the lead with a robotic welding market share of 35% in 2020.[26]

Conclusions

Technological innovations have been a defining force throughout human history, propelling progress and change. As we enter the next chapter, innovation will drive change at an exponential pace, reshaping our world faster than ever. When the last bull market began in 2009, ride-hailing apps and smartwatches did not exist. By the time it ended eleven years later, Uber had become a verb, and Apple was selling more luxury watches than all Swiss watchmakers combined[27].

Do some of these innovations mentioned in this CIO Perspectives hold the potential to take a similar leap? Time will tell but if one thing is for certain, the future of the economy will be defined by how effectively we embrace new technologies and leverage them in our world.

Endnotes

1 https://phrma.org/policy-issues/Research-and-Development-Policy- Framework#:~:text=On%20average%2C%20it%20takes%2010,to%20the%20COVID%2D19%20pandemic.
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CIO PERSPECTIVES

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