GLOBAL X
by Mirae Asset

CHARTING DISRUPTION

OUTLOOK FOR 2023 AND BEYOND

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Charting Disruption

At Global X ETFs, we believe a chart is worth a thousand words, and then some, when it comes to our changing world. Charting Disruption is our annual thematic outlook on the trends, technologies and bold ideas shaping the future.

This year, we've organized our outlook into four sections – each unique, but connected by innovation. The pandemic demonstrated vividly that disruptions to the status quo can be fast-tracked in a crisis, and nowhere is that more evident than in healthcare with the trend toward Personalized Medicine. In parallel, as one global crisis is hopefully contained, another rages on in the form of climate change. Fortunately, public and private sector interests are converging, backed by unprecedented human innovation, to build a more resilient Greener Economy. At the same time, a new generation of Experiential Technologies are making the digital realm more immersive, changing the way we live, work and play. And, last but not least, the untapped potential of FinTech, Blockchain & Web3 remains too powerful to ignore, as their general-purpose technology characteristics transcend any one sector of our economy.

To explore the depth of these changes, we partnered with handpicked experts from academia, consulting and investing. In what follows, we present unique forecasts, datasets and analyses that reveal what we expect to shape our world in 2023 and beyond.

For more than a decade, our mission has been empowering investors with unexplored and intelligent solutions.

Headquartered in New York, with Global X ETFs listed throughout Europe, Asia, Latin America, and Australia.

$42bn in AUM across more than 150 ETF strategies[1]

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100 ETF Listings

Europe
33 UCITS ETF & Crypto ETP Listings

Australia
25 ETF Listings

Latin America
28 ETF Listings in Brazil & Colombia

Hong Kong
39 ETF Listings

Japan
26 ETF Listings

MIRAE ASSET
Building on principles

Global X ETFs is a fully-owned subsidiary of Mirae Asset Financial Group, a global industry leader with 50 offices and over 12,000 employees worldwide. Founded in 1997 as one of Asia's pioneering fund management companies, the Group now oversees $482bn in client assets across a portfolio that includes real estate, insurance, private equity, and venture capital.[2]

[1]As of November 30, 2022 [2]As of September 30, 2022

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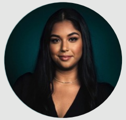

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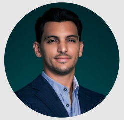

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Cathy is a globally recognized Metaverse/Web3 strategist, tech futurist, sought-after business executive, speaker, and media personality with deep expertise working in Metaverse-related fields with companies like HTC VIVE, Magic Leap, and Amazon Web Services. She's the Chief Metaverse Officer & Co-founder of Journey, where she leads Journey's Metaverse Studio, working with top brands on Metaverse/Web3 strategies, NFTs, gaming, virtual fashion, and how they can extend into virtual worlds. Her consultancy, Futures Intelligence Group, was acquired in just 10 months and is now a part of Journey.

Cathy, dubbed the Godmother of the Metaverse, hosts Adweek's Metaverse Marketing podcast. BigThink named Cathy one of the top 10 most influential women in tech in 2020. In 2021, she was included in the Thinkers50 Radar list of the 30 management thinkers most likely to shape the future of how organizations are managed and led.

Founder, “Exponential View”

Azeem Azhar

Azeem is an award-winning entrepreneur, analyst, strategist, and investor. He produces “Exponential View,” a leading newsletter and podcast on the impact of technology on our future economy and society. He is also Senior Advisor in Artificial Intelligence to the CTO of Accenture, a member of the World Economic Forum’s Global Futures Council on Digital Economy & Society, Advisory Member of HFS Research, and Advisor at CognitionX.

Azeem advises breakthrough entrepreneurial firms, including Kindred Capital, Onfido, Ocean Protocol, ReInfer and quantum-computing startup, Beit. He is an investor in early-stage startups in AI, renewable energy, female healthtech, self-driving cars, and marketplace. He is a trustee of the Ada Lovelace Foundation, an independent research entity focused on AI ethics. He sits on the Global Futures Council on the Digital Economy and Society for the World Economic Forum.

Co-Founder & CEO, Messari

Ryan Selkis

Ryan is Co-Founder & CEO of Messari, a leading provider of market intelligence products that help professionals navigate the crypto industry. Prior to founding Messari, Ryan was an entrepreneur-in-residence at ConsenSys. Also, he was on the founding teams of the Digital Currency Group, where he managed the firm's seed investing activity, and CoinDesk, where he led the company's restructuring and annual Consensus conferences. He has been an investor and prolific writer in the crypto industry since 2013.

CEO, Kojin Therapeutics & Managing Partner, Dana-Farber Cancer Institute Venture Fund

Luba Greenwood

Luba is a veteran biotech, pharmaceutical, tech, and life sciences investor and company builder. Luba serves as the Managing Partner of the Dana-Farber Cancer Institute Venture Fund, Binney Street Capital (BSC), which she built and launched. She is also the CEO of one of BSC's portfolio companies, Kojin Therapeutics, which is discovering and developing novel therapeutics in oncology, fibrosis, and immune modulation. She is a professor at Harvard University in the School of Engineering and Applied Sciences.

Luba previously served in leadership roles at Google Life Sciences (Verily) and as Vice President of Global Business Development and Mergers & Acquisitions at Roche, where she also established and led the East Coast Innovation Hub. Luba has led deals and investments totaling more than $5 billion across multiple therapeutic areas, life sciences, and tech sectors globally. She also co-founded biotech and digital health companies in the immunotherapy, artificial intelligence / machine learning, women's health, and microbiome spaces, including Luca Biologics.

Founder & Managing Director, Rho Motion

Adam Panayi

Adam is the Managing Director and Founder of Rho Motion, a specialist electric vehicle and battery research, as well as consultancy, business established in 2018. He has significant experience in automotive and lithium-ion battery research as the Head of Benchmark Mineral Intelligence's consultancy business, as well as leading the Environment and Emissions research team for Integer Research (now part of Argus Media).

He has worked with governments, financial institutions, raw material suppliers, battery and component manufacturers, as well as original equipment manufacturers on emissions and EV technology issues since 2012.

Chapter 01

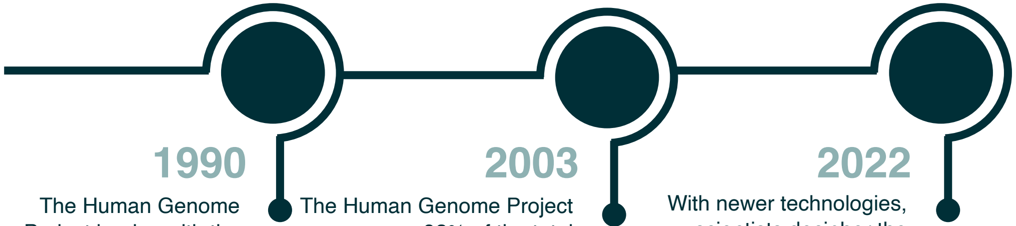
Genomic Sequencing & Diagnostics

The adoption of technologies like real-time PCR (RT) increased exponentially as laboratories around the world deployed capital at unprecedented rates to fight COVID-19. Diagnostic capabilities are more powerful than ever, but an estimated 350 million individuals worldwide have an undiagnosed disease.[1] A greater understanding of biology as well as rapid innovation and adoption of cutting-edge technologies are likely to increase the likelihood of this patient cohort receiving a diagnosis and treatment.

Sources: 1. Illumina, 2022

Genomics: Picking Up Speed

Next-generation sequencing is now integral to understanding disease links and biomarkers. Though lower sequencing costs facilitated widespread adoption, newer technologies offer a more comprehensive view to help answer biological questions.



1990

The Human Genome Project begins with the goal of mapping all the genes in the human genome.

2003

The Human Genome Project sequences 92% of the total human genome. The project concludes because it lacks the technology to decipher the remaining 8%.

2022

With newer technologies, scientists decipher the remaining 8% of the human genome.

The human genome is too long to be sequenced as one continuous string. Using short-read sequencing, DNA is broken into fragments, sequenced, and pieced together into a continuous genomic sequence. Given the breadth and complexity of the human genome, reassembling the genome can be difficult, leading to gaps in sequencing data.

Short-Read Sequencing

Though susceptible to gaps, short-read sequencing (SRS) opened the door for widely adopted sequencing capabilities, helping to address a wide variety of diseases.

Long-Read Sequencing

Long-read sequencing (LRS) allowed for the discovery of the remaining portion of the human genome and offered a comprehensive approach for variant detection.

Sources: Visual (LHS): National Institutes of Health, 2022; Visual (RHS): PacBio, 2020

Putting Genomic Data Into Action

Great strides in next-generation genomic sequencing create widespread value potential across healthcare.

Applications of Genomic Sequencing

Research: Next-generation sequencing is fueling the next cycle in drug discovery and disease understanding by answering long-held questions about the human body.

- Use: Drug discovery, microbiology, pathogen monitoring
- Customers: Biotech and pharmaceutical firms, academic institutions, government
- Main Criteria: Accuracy

Clinical Applications: Next-generation sequencing offers unique insights into the individual patients' genome, informing patient care.

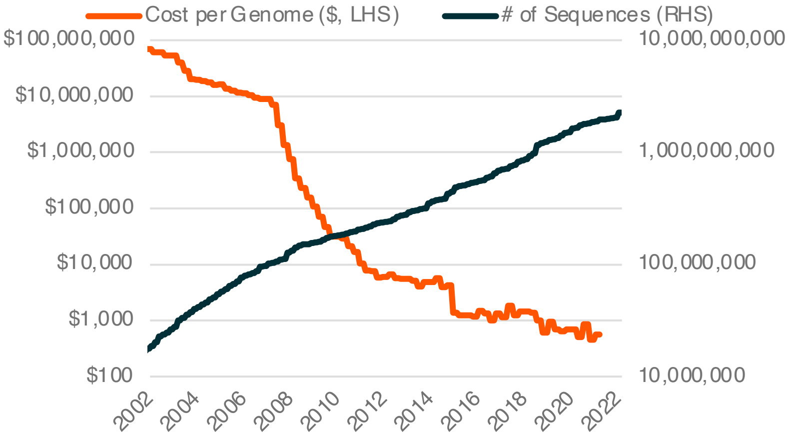
- Use: Diagnosis, precision medicine, reproductive health
- Customers: Laboratories, hospitals, physician offices
- Main Criteria: Price

$100 Cost per Genome Unlocks the Door

Adoption of novel technology like genomic sequencing begins in the research setting. After it's validated and prices decrease, the technology becomes available at a patient level. The cost per genome is much lower today than in 2002, and the industry now targets a price of $100 per genome.

This price will likely drive widespread adoption and unlock genomic sequencing's promise. For genomic sequencing to reach its full potential, it requires tens of millions of individuals' sequencing to enable a comprehensive and unbiased study of the human genome.

Cost per Genome Sequence ($, LHS)
Ordered Genome Sequences (#, RHS)



Adoption of sequencing technology is expected to increase significantly once cost per genome sequence reaches $100.

Sources: Visuals: National Library of Medicine, National Center for Biotechnology Information, n.d.; National Human Genome Research Institute, n.d.

Short-Read & Long-Read Sequencing: A Tag Team Effort

We expect short-read and long-read sequencing to work in tandem to answer biology's toughest questions while ensuring widespread access to genomic profiling.

		Read Length (Base Pairs)	Accuracy	Sequence Price	Market Share [15,16,17]	Products
Short-Read	**Illumina** [1,2,3]	300	99.9%	$600	70%	iSeq, MiniSeq, MiSeq, NextSeq, NovaSeq
	Thermo Fisher [4,5]	600	99.5%	-	15%	Ion Torrent, Ion Genestudio
	BGI [6,7,8]	150	99.9%	$200	9%	DNBSEQ-T7, DNBSEQ-G400, DNBSEQ-G50
Long-Read	**Oxford Nanopore** [9,10,11]	2,300,000	99.0%	$1,000	3.5%	MinION, GridION, PromethION
	Pacific Biosciences [12,13,14]	70,000	99.9%	$3,000	2.5%	Sequel, Sequel II, Sequel IIe

Firms That Offer a Range of Read Lengths and Price Points Will Disproportionately Succeed

Short-read sequencing opened the door for accurate, high-throughput sequencing. Reduced prices could allow widespread adoption of sequencing technology. In the research market, long-read sequencing will likely play a key role in answering longstanding questions about the human body. In many instances, the two technologies will be used jointly.

To that end, Pacific Biosciences acquired Omniome, a developer of short-read sequencing technology, in 2021.[18] Illumina, looking to protect its lead, announced a new line of analyzers with expected sequencing costs of $200 and the Illumina Complete Long-Read technology, which is expected to generate read lengths of 6,000 to 7,000 base pairs.[19,20]

Sources: 1. Illumina, n.d.-a; 2. Han, 2022; 3. Snyder, 2022; 4. Thermo Fisher Scientific, n.d.-a; 5. Thermo Fisher Scientific, n.d.-b; 6. BGI, n.d.; 7. MGI, n.d.; 8. Alpert, 2022; 9. Oxford Nanopore Technologies, n.d.-a; 10. Center for Genetic Medicine, n.d.; 11. Oxford Nanopore Technologies, n.d.-b; 12. DNA Tech, n.d.; 13. PacBio, 2020; 14. PacBio, 2021b; 15. Illumina, 2022; 16. Oxford Nanopore Technologies, 2022; 17. PacBio, 2022; 18. PacBio, 2021a; 19. Hale, 2022; 20. Illumina, n.d.-b

A Lineup of Technologies Offers a Comprehensive Understanding of Biology

New approaches along with data integration allow for increasingly precise understanding of how diseases impact the human body.

Each -omic technology is a piece of the puzzle, contributing key information about biological and disease mechanisms.

DNA: Contains a person's unique genetic code and supplies the genetic instructions for making all proteins in the human body.

Genomics identifies genetic mutations, or permanent changes to a gene's DNA sequence, and their links to diseases.

Transcription

RNA: Messager that carries DNA's information to create proteins.

Transcriptomics provides information about the crucial link between genetic and environmental factors and how gene expression can vary under different illnesses.

Translation

Proteins: Do most of the work in cells. Are required for the structure, function, and regulation of the body's tissues and organs.

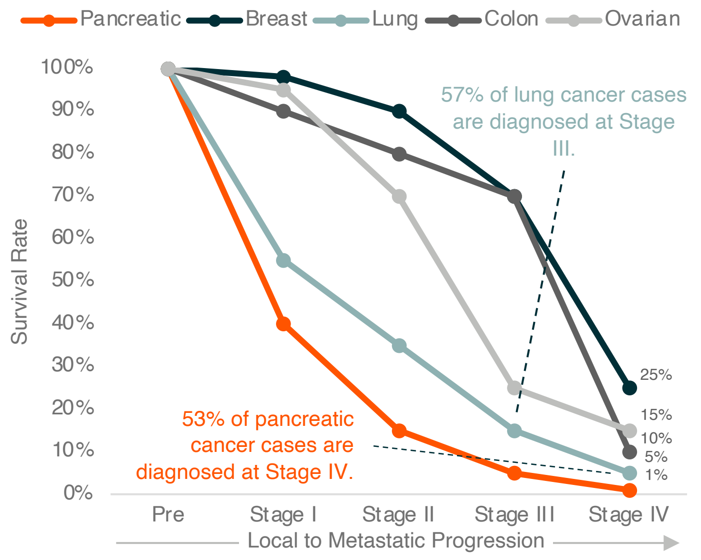
Proteomics aims to identify proteins involved in human disease and to understand how their expression, structure, and function can cause illnesses.

Epigenomics explains behavioral and environmental impacts on how genes work.

Understanding Disease: Allows for Earlier Detection, Better Prognosis

Historically, limited screening options hindered early cancer detection. Recent discoveries using sequencing technology opened the door to more effective diagnostic options.

Shortfalls in Cancer Diagnoses



New Diagnostic Capabilities Allow for Non-Invasive Early Detection

Using current standard of care, **only about 25% of cancers are detected via screening.**[1] The remaining 75% of cancers are detected when the patient is symptomatic, and most likely in a later stage of cancer.

Liquid biopsies offer fast and accurate early-stage detection of cancer via a simple, non-invasive blood test. The test looks for biomarkers in the patient's blood — biological molecules that serve as medical signs to specific illnesses.

Measuring biomarkers in the blood can help determine if a patient has cancer and localize the cancer signal, helping guide next steps.

The most studied biomarkers so far for liquid biopsy include:

- **Circulating Tumor Cells (CTC):** Cancer cells that split away from a tumor and circulate in the bloodstream. This tumor shedding in the blood can be measured to determine if a patient has cancer.
- **Circulating Tumor DNA (ctDNA):** DNA that circulates in the bloodstream and derives from cancerous cells and tumors. As tumors grow, cancerous cells die and are replaced by new ones. The dead cells get broken down, and their contents, including DNA, are released into the bloodstream.
- **Exosomes:** Cell-derived structures responsible for cell-to-cell communication and the transmission of diseases. They are secreted by living cells rather than secreted during cell death, giving a real-time window into the patient's health.

Sources: Text: 1. Exact Sciences, 2022; Visual: See Appendix: Genomic Sequencing & Diagnostics

Liquid Biopsy: Addressing the Cancer Care Continuum

The ability to detect and measure cancerous cells in the blood could have far-reaching impacts across the cancer care continuum. Partnered with tangential diagnostic capabilities, liquid biopsy players have the potential to disrupt the cancer industry.

	Proposed Benefit		Market Size
Early Detection	Health Check	Routine screen for presence of cancer-derived biomarkers in asymptomatic individuals.	$30B
	Diagnostic Aid	Informs diagnosis in suspected cases, such as for patients with an unidentified mass or nodule.	
Companion Diagnostic (CDx)	Therapy Guidance	Helps identify if a patient's tumor has a specific gene or biomarker that is targeted by a commercially available drug. Helps predict response to the drug, and thus determines if the patient should receive the drug.	$6B
Minimal Residual Disease (MRD)	Intervention Outcome	Measures cancer cells during treatment. Helps determine patient response to treatment.	$15B
	Recurrence Monitoring	Measures cancer cells during remission, to monitor any recurrence of cancer cells. Currently, 85% of relapses are caught too late.	

We anticipate other verticals will converge with the segments of traditional oncology diagnostics that liquid biopsy addresses.

Hereditary Cancer	Genetic Predisposition	Searches for specific genetic mutations that can help identify patients at a higher risk of developing cancer in their lifetime.	$6B
Real World Data (RWD)	Pharmaceutical Decision Making	Robust databases of genetic and patient information that help pharmaceutical firms prioritize drug development and predict patient response.	$40B

Sources: Global X analysis based on data derived from: Exact Sciences, 2022; Grand View Research, n.d.(a); Grand View Research, n.d.(b); Natera, 2022

Liquid Biopsy: An Evolving Diagnostic Modality

In our view, the firms best positioned to drive test adoption will be those that have comprehensive portfolios with diagnostic options at each step along the cancer care continuum, from diagnosis through remission.

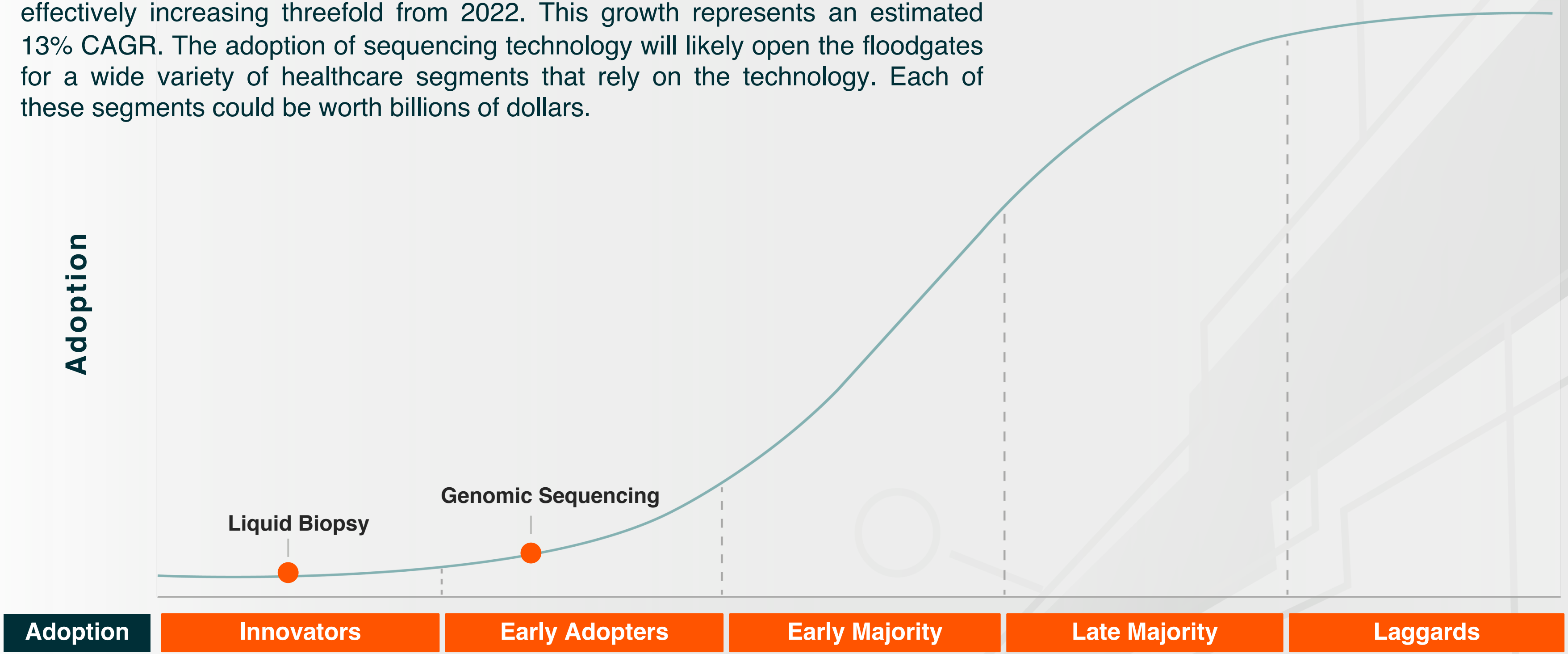
	Hereditary Cancer	Early Detection	CDx Tissue	CDx Blood	MRD	Real World Data
Agilent Technologies			SureSelect, ClearSeq	ctDx		
Caris Life Sciences		Announced	Molecular Intelligence	Caris Assure		CODEai
Exact Sciences	RiskGuard	CancerSeek	OncoMap		OncoType	
Guardant Health		Shield	Guardant360		Guardant Reveal	GuardantINFORM
Illumina		Galleri*	TruSight Oncology 500		Announced*	
Invitae Corp	Cancer Panels		FusioPlex Dx, LiquidPlex Dx, VariantPlex		PMC	
Myriad Genetics	MyRisk, Colaris, BRACAnalysis		MyChoice CDx	BRACAnalysis CDx	EndoPredict	
Natera	Empower	Announced	Altera		Signatera	
NeoGenomics			NeoTYPE	NeoLAB, InVisionFirst	RaDaR	NeoAccelerate, NeoPixel, NeoEngage
Roche			AVENIO, FoundationOne			CGDB, Insights
Qiagen			Therascreen, QiaSeq	QiaSeq		Real World Insight

Legend: Commercially Available, In Development
*Part of the GRAIL Umbrella

Sources: Aijian, 2022; Exact Sciences, n.d.; Invitae, n.d.; Myriad Genetics, n.d.

S-Shaped Curve of Adoption – Genomic Sequencing & Diagnostics

We expect the global sequencing industry to reach $15 billion in revenue by 2030, effectively increasing threefold from 2022. This growth represents an estimated 13% CAGR. The adoption of sequencing technology will likely open the floodgates for a wide variety of healthcare segments that rely on the technology. Each of these segments could be worth billions of dollars.



Sources: Global X analysis based on data derived from: Grand View Research, 2022

Displayed for illustrative purposes. Curve shape not indicative of mathematical transformation

Chapter 02

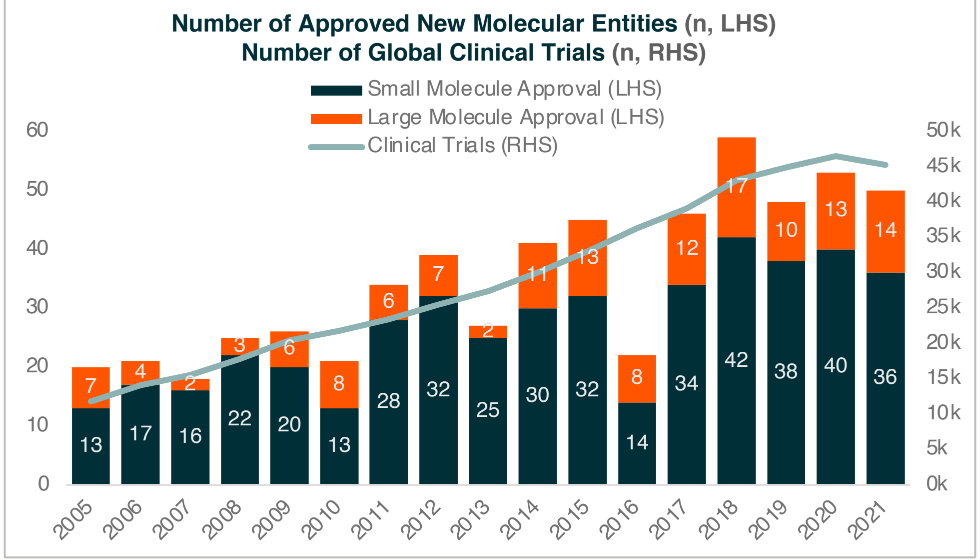
Therapeutics

Exciting developments in genomic technology have propelled a new era of drug discovery and therapeutic innovation that promises to change the way the healthcare industry operates. Increased focus on appropriate disease management and illness prevention will become a reality via new therapeutic technologies like gene therapies and gene editing.

Pharmaceutical Development Speeds Up

Validation and adoption of new genomics technologies have fueled clinical development, allowing highly targeted treatments to seek regulatory approval.

Increasing Clinical Trials, a Leading Indicator for Upcoming New Drug Launches



Increasing Complexity of Approvals[1]

Small Molecule Drugs have an explicit chemical structure and can be administered orally, injected, or infused.

Large Molecule Drugs (aka Biologics) are made from living cells, tissues, and viruses. They cannot be taken orally, they must be injected or infused.

Soaring Number of Clinical Trials

- **Demographic Changes:** The rapid aging of the global population is shifting the medical field to accommodate the treatment of patients over 65. Through 2100, the global population is expected to grow 30%, while the global population of those 65+ is expected to grow 218%.[2]
- **Increasing Prevalence of Disease:** Cancer, cardiometabolic diseases, and neurodegeneration increasingly affect younger people, where in the past such diseases would traditionally strike those over 60.
- **Better Understanding of Biology:** With more knowledge, the therapeutics industry is reevaluating how it treats diseases. The goal is to offer next-generation therapeutics with improved efficacy.

Sources: Text: 1. U.S. Food & Drugs Administrations, 2022; 2. Department of Economic and Social Affairs Population Division, 2022; Visual: World Health Organization, 2022

Prevention Comes Into Focus, Allowing Inefficient Treatment to Become a Thing of the Past

Genomic developments introduce new ways of thinking about disease management.

Understanding Links to Diseases

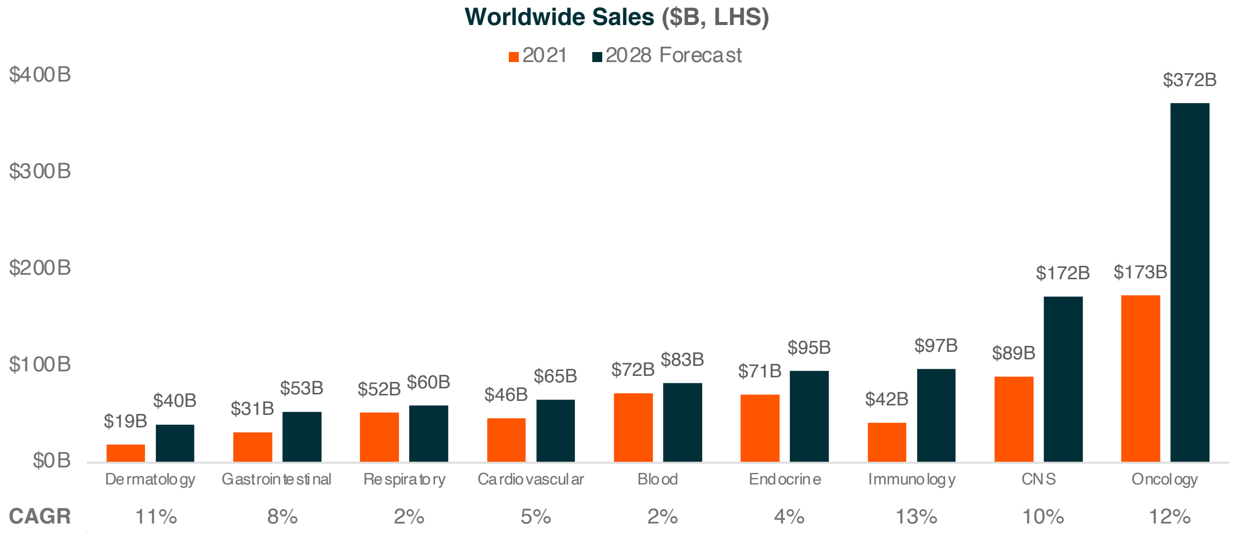
Symptom Management
Ineffective disease management, limited to symptomatic treatment.

Halting Disease Progression
Addressing the root cause of the disease and halting its progression.

Reverting Disease Progression
Curing the disease and reverting any previous symptoms.

Disease Prevention
Identifying predisposition to disease and addressing prior to symptom onset.

Much to Be Done Across Indication Categories, Though Unmet Need Will Drive Adoption in the Short Term

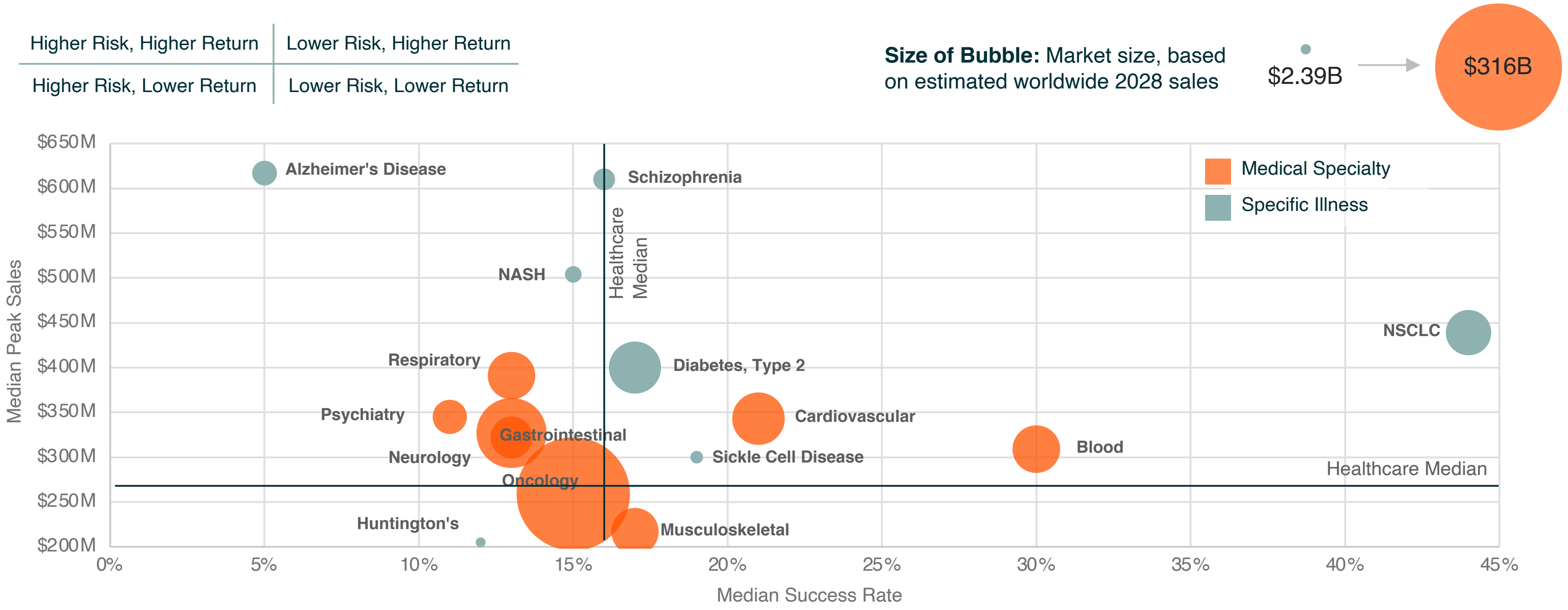


CNS: Central Nervous System

Sources: Global X analysis based on data derived from Evaluate, n.d.

Therapeutics Industry Innovating Across the Disease Spectrum

The level of unmet medical need, the number of patients affected, historical success in treating the disease, and the competitive environment all play a role in how pharmaceutical companies prioritize their development of novel therapeutics.



Sources: Global X analysis of data derived from Evaluate, n.d.

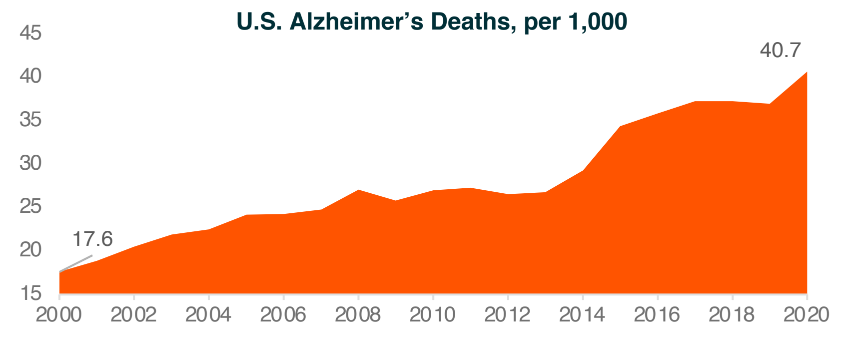
NSCLC: Non-Small Cell Lung Cancer; NASH: Non-Alcoholic Steatohepatitis

Alzheimer's Case Study: Growing Concern Raises the Stakes

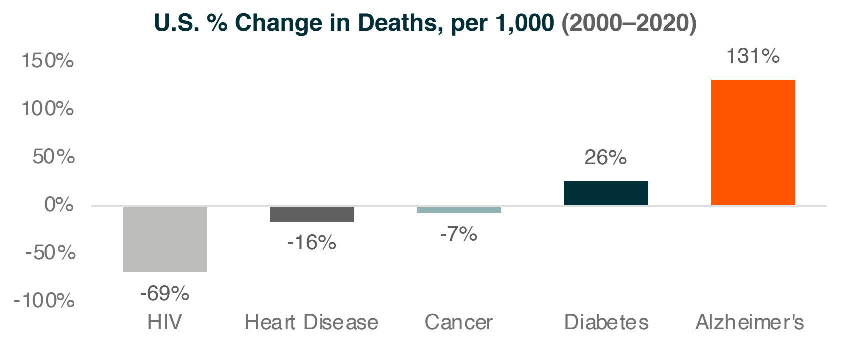
Alzheimer's sticks out as the highest risk, highest return category for therapeutic development, given changing demographics for the disease and historical difficulty in managing the illness.

Growing Patient Population[1]	▪ An estimated 18 million people worldwide have Alzheimer's. This number is expected to reach over 30 million by 2025. ▪ In the United States, 1 in 8 individuals aged 65 or older has Alzheimer's. The rapid aging of the global population is expected to drive the increase in Alzheimer's cases through 2100.
Heterogenous Patient Pool[2]	▪ Alzheimer's is often a disease of exclusion, meaning diagnosis is reached by a process of elimination. ▪ An estimated 60–70% of dementia patients are believed to have Alzheimer's. The imprecise definition of the disease creates a heterogeneous patient pool, making effective treatment tougher.

Alzheimer's Is a Rapidly Escalating Problem



Other Indications Show Dramatic Improvement

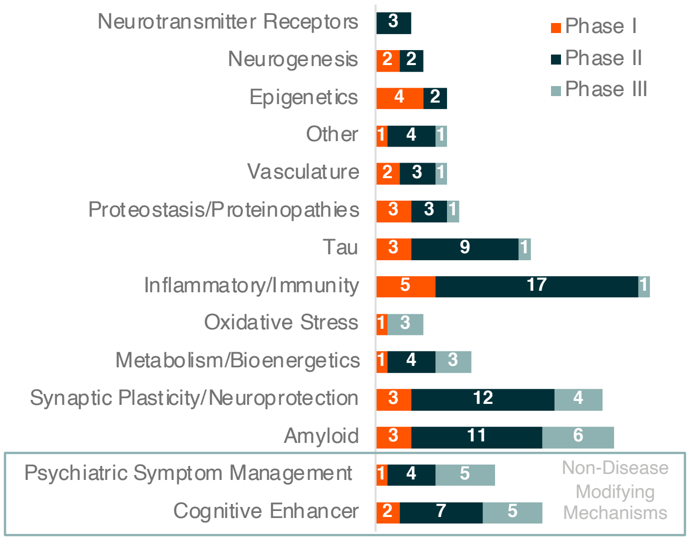


Sources: Text: 1. Evaluate, n.d.; 2. Evaluate, n.d.; Visuals: Centers for Disease Control and Prevention, n.d.

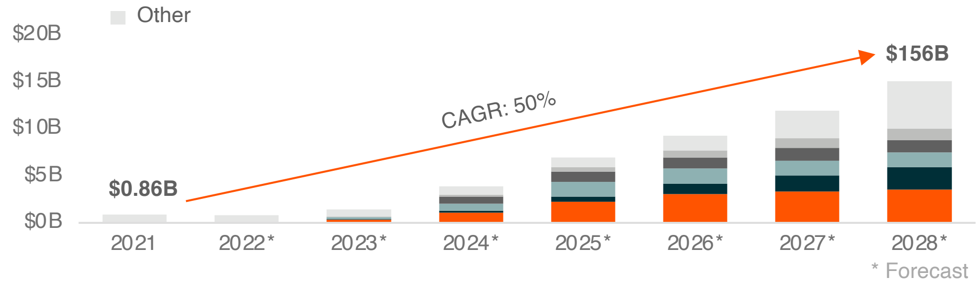
Alzheimer's Case Study: Disease-Modifying Therapies Will Lead the Way

Approved therapies for Alzheimer's are ineffective at stopping the disease's progression, much less reverting dementia. However, 143 investigational therapies provide optimism for improved treatment efficacy.

Investigational Therapies: An Array of Mechanisms



Top Assets in Alzheimer's: A Step in the Right Direction



	Mechanism Class	Expected Market Entry	2028 Projected Market Share
Roche's Gantenerumab	Amyloid	2023	23%
ACADIA's Nuplazid	Cognitive Enhancer	2022	16%
Eli Lilly's Donanemab	Amyloid	2022	11%
Anavex's ANAVEX 2-73	Synaptic Plasticity / Neuroprotection	2023	8%
Eisai's Lecanemab	Amyloid	2022	8%

Sources: Cummings, Lee, Nahed, Zadeh, Nojoo Kambar, Fonseca, Zhong, Fonseca, & Taghva, 2022; Evaluate, n.d.

Precision Medicine: A Targeted Approach That Actually Works

The future of medicine offers a more nuanced, personalized approach to treating illnesses, opening the door for more effective disease management.

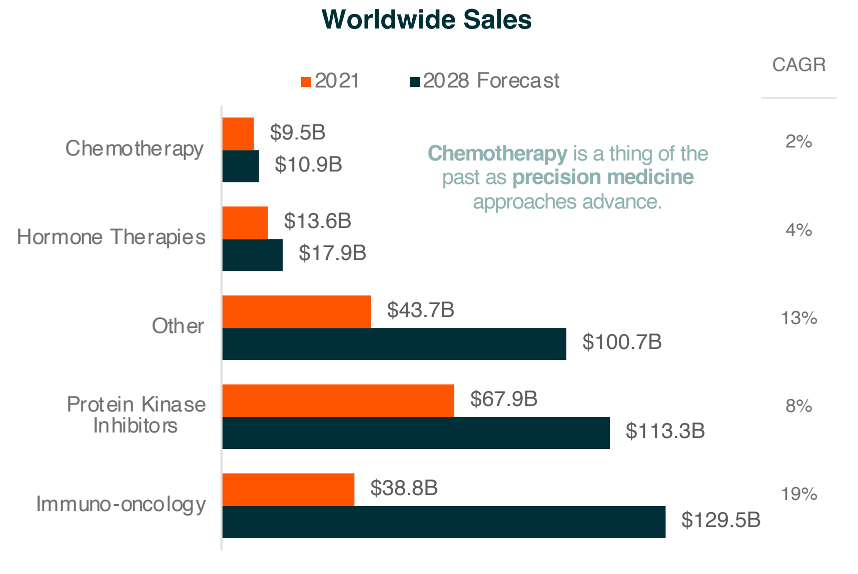
Traditionally, cancers were treated with a one-size-fits-all approach. Given a lack of understanding of the disease, the medical community utilized chemotherapy, a scattergun approach that kills any cells that multiply quickly. This approach only offers about a 30% success rate.

By **tailoring treatment** to a specific driver of the disease and considering patient-specific factors such as genes and lifestyle, researchers can better recommend the right therapy for each patient at the right time. **Targeted therapy is successful in up to 80% of cases**.[1]

Though exciting developments changed the landscape for cancer treatment, **only 8% of cancer patients have FDA-approved treatments that match their unique needs**.[2] This area of clinical research is growing rapidly, with the pharmaceutical industry rushing to expand its precision medicine repertoire for cancer.

The industry is also working to expand the promise of precision medicine to other areas, such as immunology, cardiovascular diseases, and neuroscience.

Oncology Market by Treatment Category[3]



Sources: 1. Pitakkitnukun, 2018; 2. Cutler, 2020; 3. Evaluate, n.d.

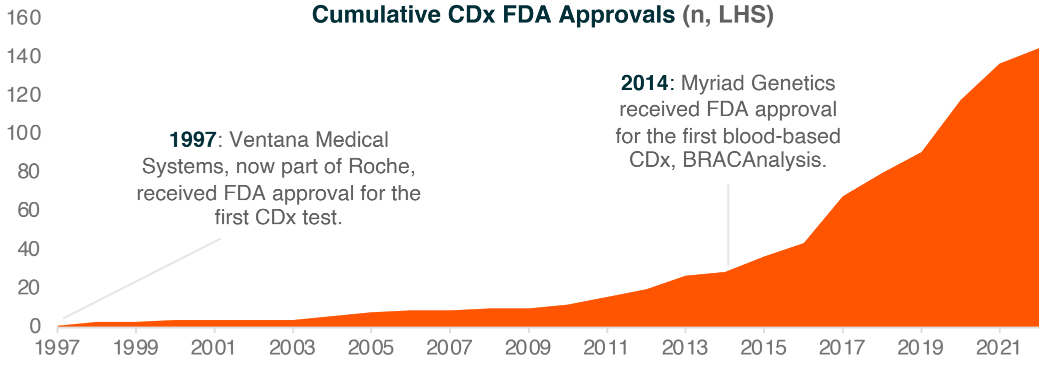
Precision Oncology: A Roadmap to Effective Therapeutic Treatment

As cancer can affect every patient differently, the oncology community developed an evolving set of tools to guide treatment. Matching patients to the correct medication lowers cost of care, improves patient outcomes, and reduces the risk of side effects.

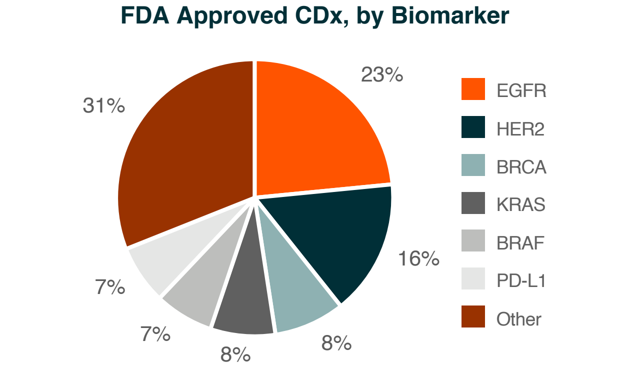
Physicians rely on different approaches **to recommend the right therapy for patients at the right time**. The approaches include companion diagnostic (CDx) tests, wearable sensors, artificial intelligence (AI), and machine learning (ML) to find correlations and recommend highly targeted therapies.

A CDx assay is used **to help match a patient to a specific therapy or drug** by identifying possible factors for the cancer. The test looks for gene changes or biomarkers in the patient's sample that commercial drugs target. The test can shed light on potential side effects and measure how well the treatment is working.

Increasing Validation of Companion Diagnostic (CDx) Tests



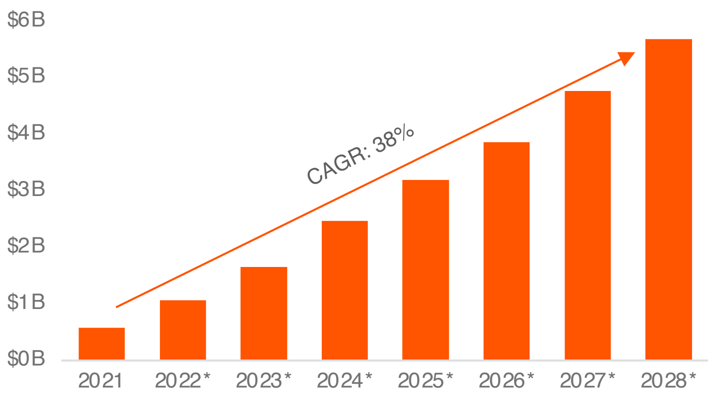
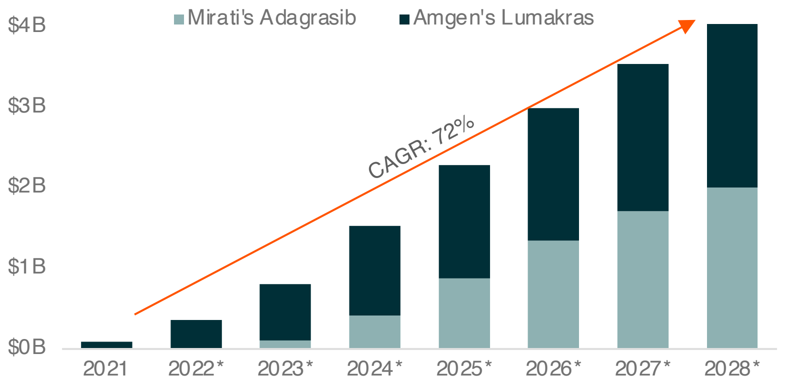
Growing Adoption, Though Concentrated Mutations



Sources: U.S. Food & Drugs Administration, 2022

Precision Oncology: Understanding Target Inhibition and Its Impact on Cancer Progression

Common precision oncology drugs target known oncogenes, which are genes that can mutate and cause normal cells to become cancerous or prompt cancerous cells to grow.

	HER2	KRAS
Mutation	HER2 genes are involved in normal cell growth, but they can mutate to become overexpressed, potentially causing cancerous cells to grow and spread quickly.	KRAS genes play an important role in signaling cells to grow and divide or to slow their division. If mutated, cells can't regulate the growth, causing cancerous cells to grow and spread quickly.
Prevalence	15–20% of breast cancers[1], 10–30% of gastric cancers[2]	20–25% of lung cancers[3], 30–40% of colon cancers[4], 95% of pancreatic cancers[5]
Top Drug(s)	**Daiichi Sankyo & AstraZeneca's Enhertu** 	**Mirati's Adagrasib and Amgen's Lumakras** 

* Forecast

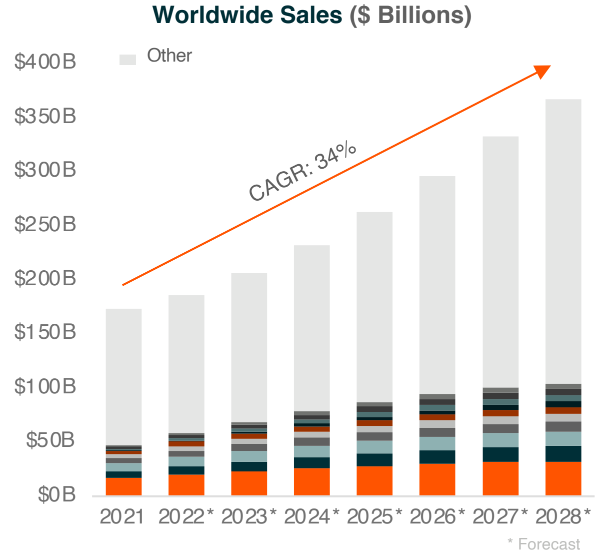
Sources: Text: 1. American Cancer Society, 2022; 2. Iqbal & Iqbal, 2014; 3. American Lung Association, n.d.; 4. Dinu, Dobre, et.al., 2014; 5. Rosenzweig, 2021; Visuals: Evaluate, n.d.

Precision Oncology: Checkpoint Inhibitors and Immuno-Oncology Leading the Charge

The top 10 oncology drugs in 2028 are expected to account for 28.3% of sales of the $367 billion oncology sector, fueled by highly targeted inhibition of common mutations. The industry now looks to expand the reach of its precision oncology to more patients.

	Target	2028 Projected Market Share	Key Indications, 2028
Merck's Keytruda	PD-1	8.7%	Breast, NSCLC, Melanoma
Johnson & Johnson's Darzalex	CD38	4.0%	Multiple Myeloma
Bristol Myers Squibb's Opdivo	PD1	3.6%	Renal Cell Carcinoma, Melanoma
AstraZeneca's Tagrisso	EGFR	2.5%	NSCLC, Glioblastoma
Roche's Tecentriq	PD-L1	2.0%	NSCLC, Renal Cell Carcinoma
Johnson & Johnson's Imbruvica	BTK	1.6%	Leukemia, Non-Hodgkin Lymphoma
Daiichi Sankyo's Enhertu	HER2	1.5%	Breast, NSCLC, Stomach
Eli Lilly's Verzenio	CDK6/4	1.5%	Breast, NSCLC
AstraZeneca's Lynparza	PARP	1.5%	Ovarian, Prostate, Pancreatic
AstraZeneca's Calquence	BTK	1.3%	Leukemia, Non-Hodgkin Lymphoma

Top Oncology Assets Through 2028



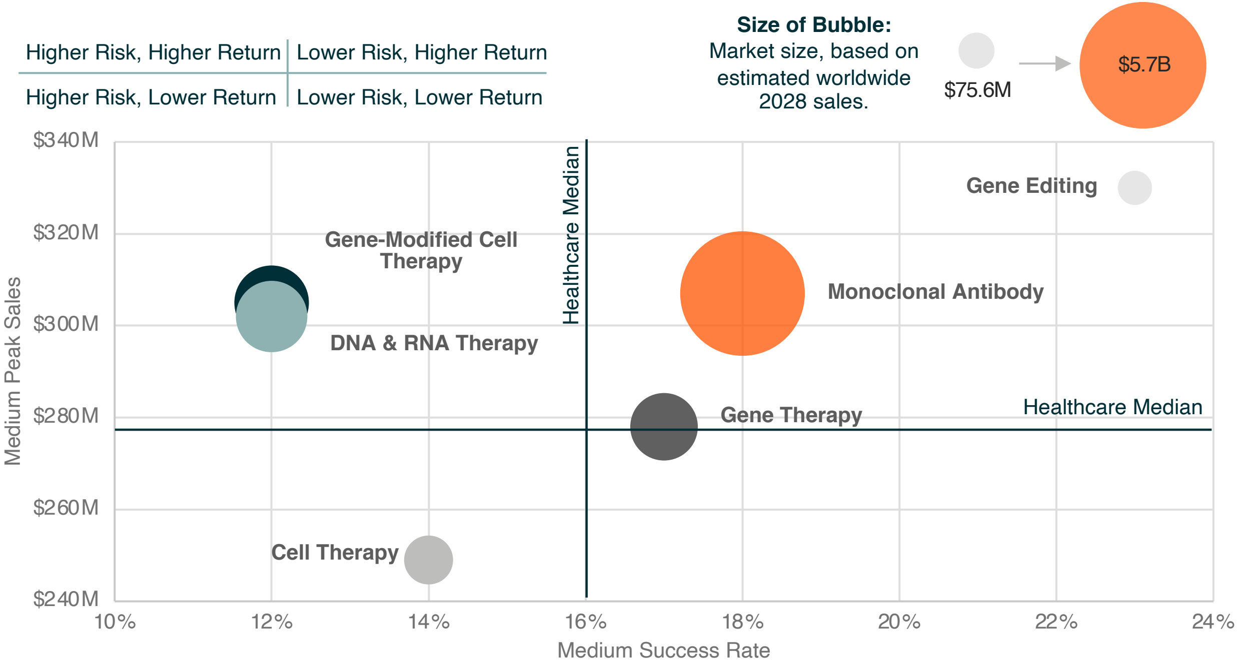
Sources: Global X analysis of data derived from Evaluate, n.d. NSCLC: Non-Small Cell Lung Cancer; SCLC: Small Cell Lung Cancer

An Arsenal of Investigational Technologies to Combat Diseases

The pharmaceutical industry now has numerous technologies to address, and ultimately cure, common diseases.

Novel Technologies Show Promise

- **Gene Editing:** Editing parts of the genome by removing, adding, or altering sections of DNA.
- **Cell Therapy:** Transplanting of healthy human cells to replace or repair damaged tissue and/or cells.
- **Gene Therapy:** Replacing a defective or missing gene in a patient's cells with a healthy version of that gene.
- **DNA & RNA Therapy:** Providing instructions to the body's RNA for making proteins or turning genes on and off.
- **Gene-Modified Cell Therapy:** Transplanting genetically modified cells to fight disease.
- **Monoclonal Antibodies:** Attaching an antibody to diseased cells or proteins to stimulate the immune system.



Sources: Global X analysis of data derived from Evaluate, n.d.

The Value of Genomic Medicines: An Evolving Discussion

New therapeutic categories offer a one-time treatment for cumbersome illnesses, changing the way we think about drug pricing.

Sickle Cell Disease: A Case Study

Sickle Cell Disease (SCD) is an inherited disorder that distorts the production and structure of hemoglobin, the protein in red blood cells that carries oxygen. Without enough normal hemoglobin, red blood cells change shape, allowing them to clump together and block blood flow. Patients often require frequent transfusions to restore blood volume levels and oxygen flow.

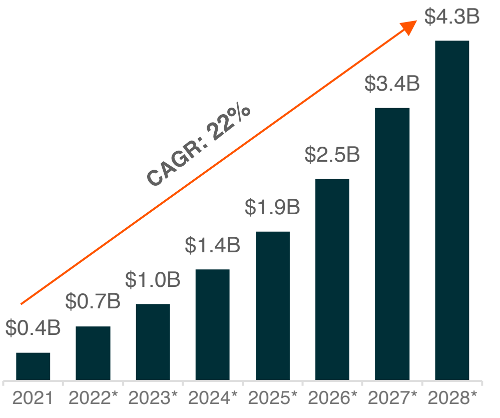
Quantifying Disease Burden[1]

- Americans with SCD pay an average of $44,000 in out-of-pocket costs for care in their lifetime.
- Insurers pay an average of $1.7 million per SCD patient in their lifetime.
- SCD patients lose about $700,000 over their lifetime due to their inability to work.

One-Time Treatment

- Regenerative medicines usually come with a higher price tag.
- Bluebird bio's SCD gene therapy costs $2.8 million per patient. The heavily anticipated gene editing therapy Exa-cel is expected to come to market above $2 million per patient.
- Development and manufacturing inflection points will help decrease therapy price.

Sickle Cell Disease, Worldwide Expected Sales



* Forecast

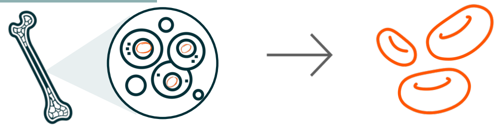
Before Therapy

Stem cells in SCD patients' bone marrow make unhealthy hemoglobin, changing the shape of red blood cells.

During Therapy

Stem cells are extracted, genetically modified, and then given back to the patient.

After Therapy



Modified stem cells produce healthy hemoglobin and normal red blood cells.

Sources: Text: 1. National Institutes of Health, 2022; Visual: Evaluate, n.d.

Driving Innovation: A Tag Team Effort

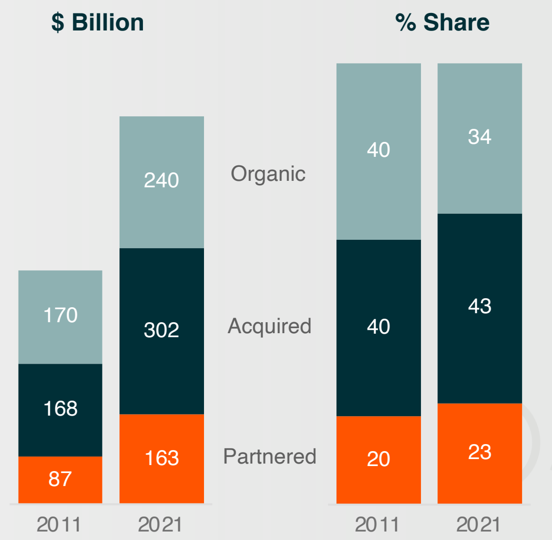
Luba Greenwood

To drive the next phase of innovation, large pharmaceutical firms now look to biotech companies to fill out their pipelines. Deals will likely be a key contributor to developing groundbreaking therapeutics, fueled by in-house innovation in the small biotech sector.

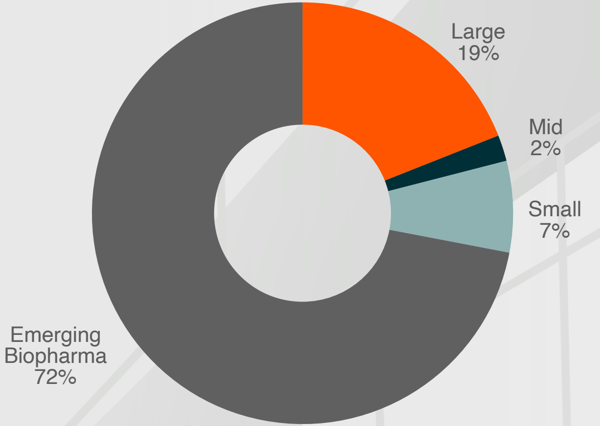
Collaboration Is Key

- **Biotech's Role in Industry Innovation:** Large pharma drives long-term growth from externally sourced therapies, as they have higher chances of success in clinical trials. These therapies come from a dedicated clinical, medical and scientific team built around one pathway or drug approach. The result is highly innovative drugs with strong clinical data.
- **Large Pharma Offers Focus and Scale:** Only 34% of drugs sold by large pharma are sourced via internal R&D, though they do rely on multiple business development strategies to collaborate with small biotech firms and academic centers.[1] Large pharma's clinical and manufacturing scale, along with regulatory knowhow, play an integral role in advancing industry innovation.

Industry Revenue From New Molecular Entities



Emerging Biopharma: Fueling Early-Stage Innovation



Emerging Biopharma: < $500 million in Sales or < $200 million in R&D Spend; Small Pharma: Sales $500 million to $5 billion; Mid-Size Pharma: Sales $5 billion to $10 billion; Large Pharma: Sales > $10 billion

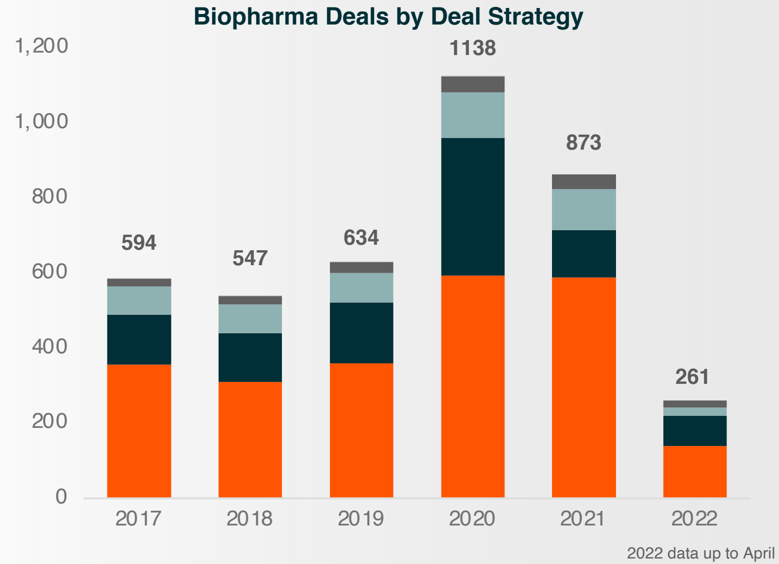
Sources: Text: 1. Pont, Fleming, Moss, Robke, Smietana, & Wurzer, 2022; Visual (LHS): Bloomberg, L.P.; Visual (RHS): IQVIA, 2022

Large Pharma: Deal Activity Down, Not Done

Luba Greenwood

Biopharma deals slowed in 2022 but should pick up in 2023. Large pharmaceutical firms rely on external innovation for internal R&D. We expect economic shocks to be short-term effects and firms need to fuel pipeline innovations to drive long-term growth.

Biopharma Deal Slowdown: A Temporary Move



Source: Global X analysis of data derived from: Stoll, Sapletal, Pothier, Stephenson, Neil, & Iannozzi, 2022

Delaying In-Licensing or M&A Is Not an Option

Large pharma relies on multiple strategies to drive growth. With the biotech space outperforming the market in 2022, we expect deal activity to pick up, including in-licensing deals and M&A.

- **Licensing:** Large pharma relies on in- and out-licensing. Where they might utilize in-licensing to gain limited exposure to risky early-stage clinical assets, they might also out-license de-prioritized clinical assets that do not match their strategic direction.
- **R&D Collaborations:** This strategy requires large upfront payments to biotech partners to help fund clinical development of novel therapeutics. The current economic environment likely makes firms hesitant to pursue these deals, though they will continue to rely on milestone-based deals.
- **Corporate Acquisition:** Large pharma uses these deals to gain access to intellectual property and clinical and manufacturing operations. Typically, they can be integrated smoothly with scale and regulatory knowhow. Antitrust regulation might tamper activity for large acquisitions in the short term.
- **Product Acquisition:** Sometimes pharmaceuticals purchase single assets. Currently, the pool of publicly available biotech assets is significant. We expect this strategy to remain popular in this environment.
- **Megamerger:** Large pharma seeks megamergers when looking to advance in a particular area, such as cell therapy or oncology. This strategy can be a way to gain expertise and credibility in a sector.

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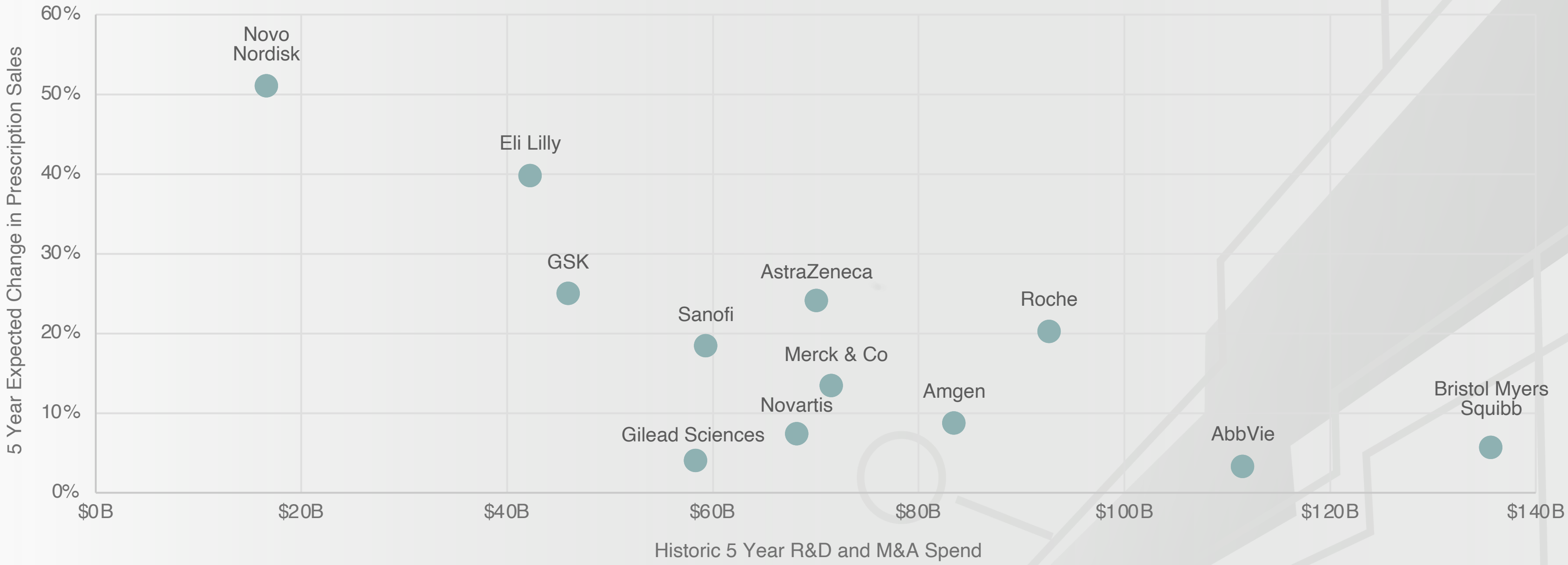
Large Pharma: Deal Activity Down, Not Done

Luba Greenwood

With varying levels of expected sales growth, large pharmaceutical firms will likely have varying needs for R&D funding to drive short-term revenue growth.

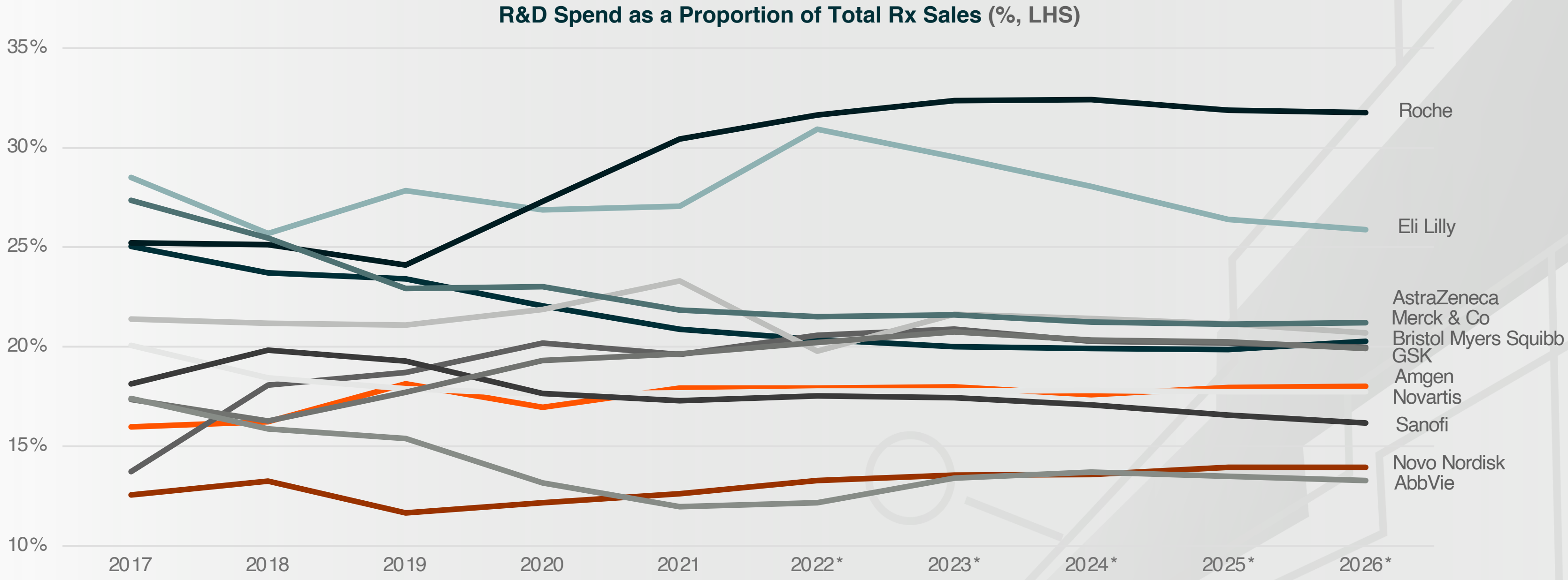


Source: Global X analysis of data derived from: Bloomberg, n.d.; Evaluate, n.d.

Large Pharma: Funding Innovation

Luba Greenwood

The average R&D spend as a proportion of total prescription sales for the top 11 pharmaceutical firms is expected to stay constant through 2028, which suggests a consistent appetite for business development deals.



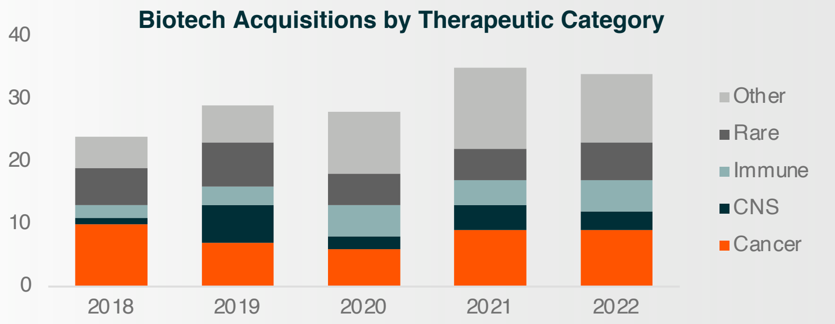
Source: Global X analysis of data derived from: Evaluate, n.d.

Biopharma Deal Activity: What's Next?

Luba Greenwood

We expect highly innovative targets will continue to receive outsized interest in this environment. Economics, company need, investigational drug history, and technological advancements, among others, are all expected to play key roles in decision making.

Growing Focus Outside Oncology

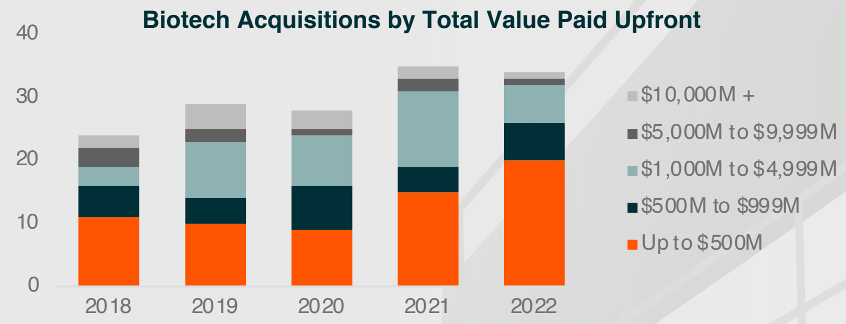


Oncology is a longtime area of interest for large pharma. As the sector's maturation continues, we expect acquirers to focus on highly innovative approaches.

Immunology and **autoimmune disorders** are likely to attract more interest in coming years given population aging.

Neurology's past disappointments in investigational treatments may cause interest to wane. But with greater understanding of the space and higher success rates with investigational drugs, we anticipate renewed interest in acquiring relevant biotechnology firms.

Smaller Deals Have Become More Popular



Acquisition size has decreased in the last couple years given greater risk aversion and valuation depreciation.

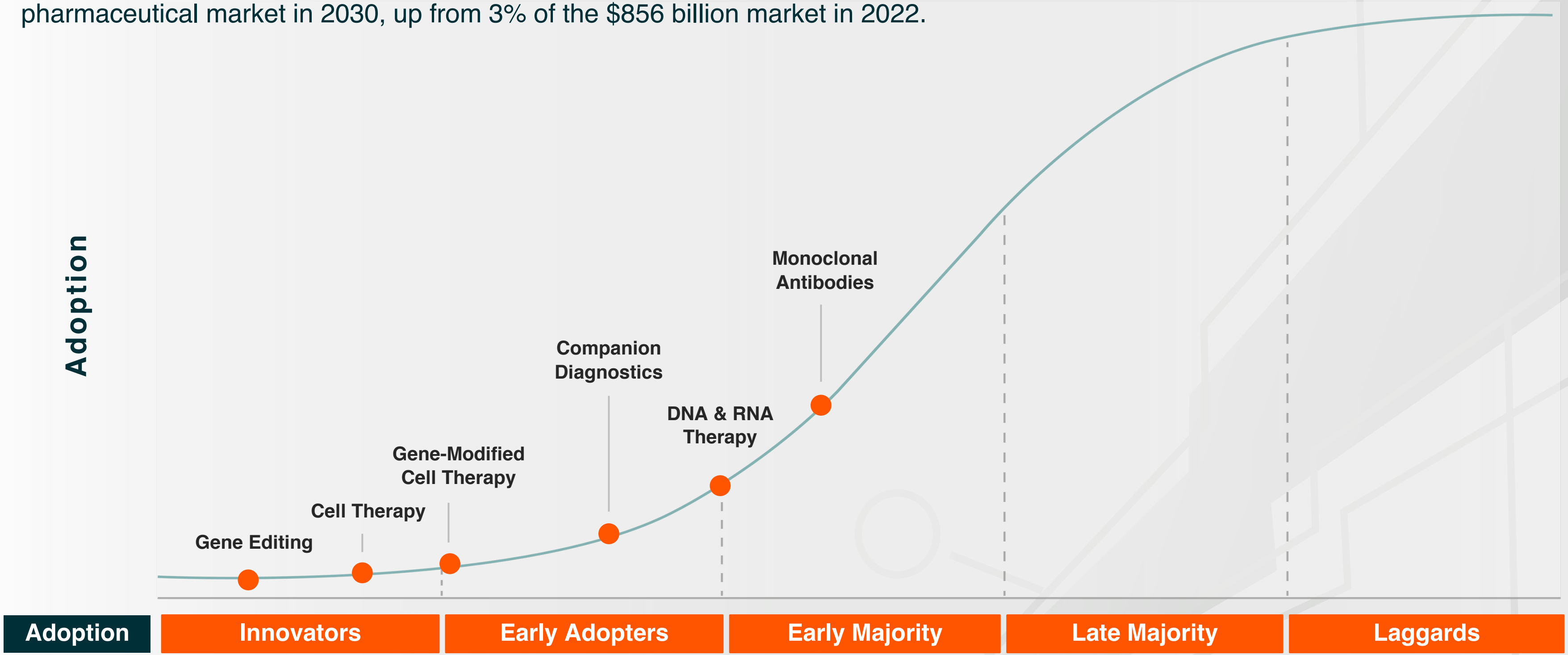
Highly innovative acquisitions remain a focus for large pharma, though increased risk aversion affects what firms view as attractive. **Lower upfront payments** and **earlier-stage firms** will be popular in the current environment.

Upfront value for biotech acquisitions is likely to increase in 2023 as valuations rebound across the industry.

Source: Global X analysis of data derived from: Bell, 2022

S-Shaped Curve of Adoption – Therapeutics

We expect sales of next-generation medicines to comprise 18% of the $1.35 trillion pharmaceutical market in 2030, up from 3% of the $856 billion market in 2022.



Sources: Global X ETFs analysis of information derived from Evaluate, 2022

Displayed for illustrative purposes. Curve shape not indicative of mathematical transformation

Chapter 03

Telemedicine & Digital Health

The logistical challenges brought on by the COVID-19 pandemic accelerated the adoption of digital health technologies and demonstrated the widespread impact that they can have on healthcare. Now, artificial intelligence, wearable sensors, and telemedicine are working to permanently disrupt patient care.

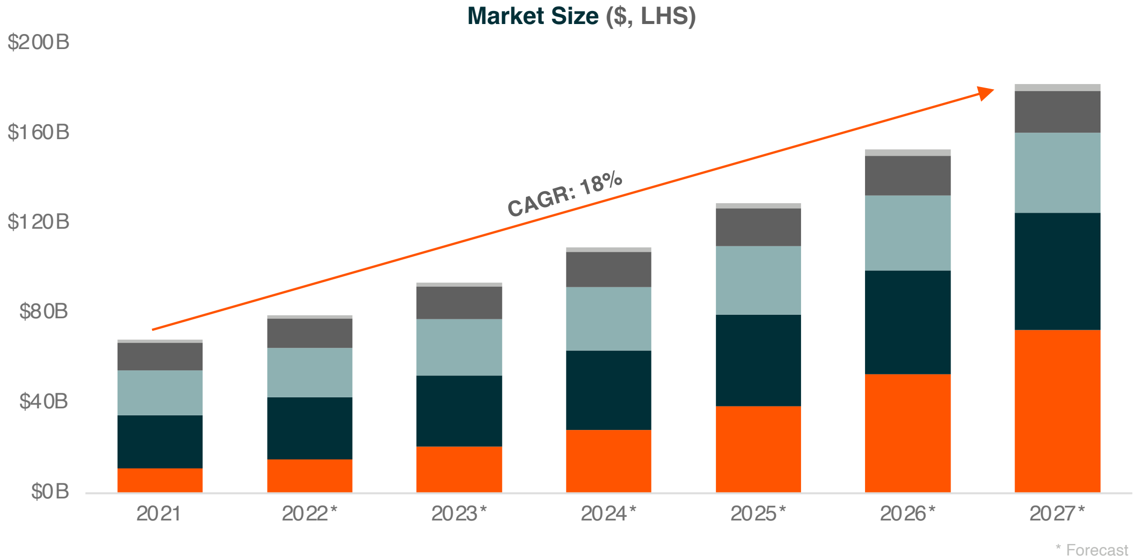
Digital Health: Just Scratching the Surface

The pandemic fueled innovation and investment in digital health, which we expect to accelerate the rate of adoption across all digital health segments.

A New Technological Toolkit

	Health Apps: Applications to monitor, detect, and analyze physical health conditions.[1]	**14% CAGR**
	Sensors: Devices that automatically transmit data and results to patients and their physicians.[2]	**7% CAGR**
	Telemedicine: Connects physicians and patients digitally, facilitating a range of medical activities.[3]	**10% CAGR**
	Online Pharmacies: Sale of over-the-counter and prescribed medications via online channels.[4]	**14% CAGR**
	AI in Healthcare: Use of artificial intelligence to optimize healthcare processes and systems.[5]	**37% CAGR**

Growing Market Opportunity: Digital Health Gaining Momentum

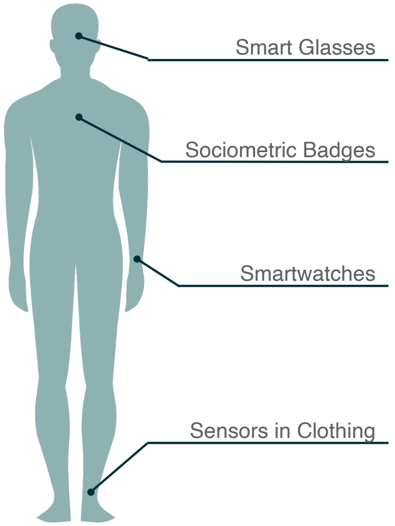


Sources: 1. Statista, 2022a; 2. Statista, 2022b; 3. Statista, 2022c; 4. Statista, 2022d; 5. Stewart, 2022

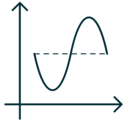
Wearable Sensors: A Growing Field With Widespread Potential

Wearable technology has the potential to disrupt patient care via a host of monitored digital biomarkers. The popularity of consumer products like smartwatches can help normalize sensors as part of standard care.

Digital Biomarkers Collected via Continuous Monitoring



- Blood Pressure
- Cardio Fitness
- Cough Frequency
- Electrocardiogram
- Electromyograph
- Fall Detection
- Fertility Levels
- Glucose Levels
- Hydration Levels
- Medication Delivery
- Mobility
- Neonatal Monitoring
- Pollution Levels
- Pulse Oximeter
- Respiratory Rate
- Seizure Detection
- Sleep Quality
- Sleep Apnea Diagnosis
- Stress Management
- Thermometer
- UV Exposure



Preventative Monitoring

Connected devices provide comprehensive insight into health risks and give providers a real-time glimpse into patient health.

Automatic Drug Discovery

Devices detect when a patient needs a dose of medication and optimize delivery, which can reduce side effects and improve outcomes.

Automatic Alerts

In emergencies, devices can alert others of patient distress and contact 911.

Diabetes Case Study: Proof of Concept on Wearable Technology and Automatic Drug Delivery

Continuous glucose monitors (CGMs) decrease diabetes patient hospitalization by 67%.[1] Closed-loop systems that integrate CGMs and insulin pumps help remove guesswork in administering insulin, further improving quality of life.

Past

Blood Glucose Monitoring: Patient pricks their finger and a device measures glucose in blood. Recommendation of 4–10 readings a day.[2] Requires manual data collection and data sharing.

Insulin Injections: Patient intervenes via insulin based on glucose level.

Present

Continuous Glucose Monitoring: A sensor inserted under the skin measures glucose and transfers data to smart device. Allows for up to 288 readings a day and automatic data collection and sharing.[3] Alerts approved individuals when blood sugar is outside target range.

Insulin Injections: Patient intervenes via insulin based on glucose level.

Future

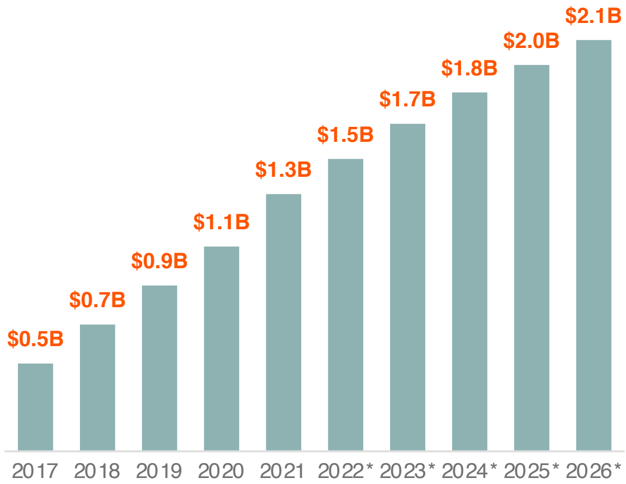
Continuous Glucose Monitoring: Sensors measure glucose levels under the skin and transfer data to smartphone. Allows for up to 288 readings a day and automatic data collection and sharing. Alerts approved individuals when patient's blood sugar is outside target range.

Insulin Pumps: System automatically adjusts insulin delivery based on glucose.

Diabetes is expected to affect 552 million individuals worldwide by 2030, a 33% increase from 2022.[4] The diabetes management space has been proactive in integrating monitoring and insulin delivery systems. Their success may encourage the use of similar systems in other therapeutic categories.

Continuous Glucose Monitors Near Widespread Adoption

Continuous Glucose Monitor Market Size



* Forecast

Sources: Text: 1. Taylor, 2022; 2. Mayo Clinic Staff, 2022; 3. Dexcom, n.d.; 4. Evaluate, n.d.; Visual: Statista, 2022; World Health Organization, 2022

Artificial Intelligence: Harnessing Data to Save Lives

Enhanced data collection software and increased use of wearable technology give AI the opportunity to fill in the gaps in traditional patient care and scale it to improve outcomes.

Data Sources

- Clinical Trials
- Prescriptions
- Insurance Claims
- Apps & Wearables
- Medical Targets
- Electronic Medical Records
- Pharmacies
- Genomic Sequencing

→ Artificial Intelligence →

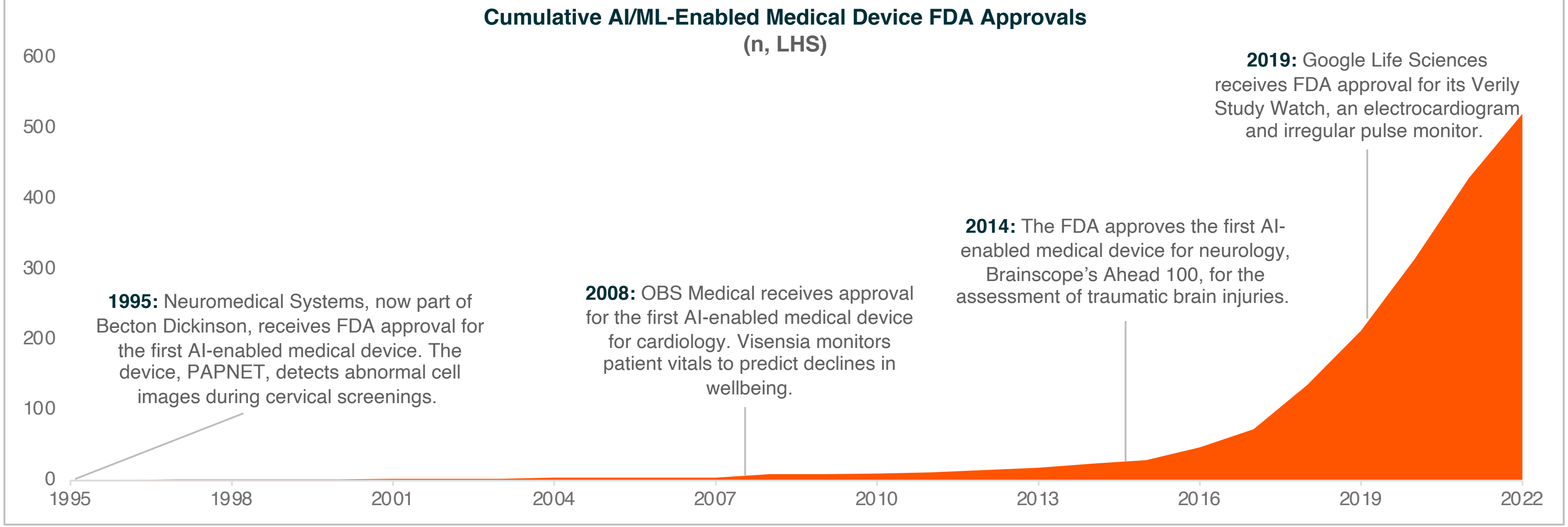
Output

- **Medical Imaging Interpretation:** Helps prioritize patient care and review scans to find rare abnormalities.
- **Data-Driven Drug Discovery:** Supplements ongoing clinical trial information to speed up drug development and decrease burden on clinical trial participants.
- **Anticipating Medication Efficacy:** Creates access for clinically underrepresented ethnic groups with unique medical characteristics to receive better care.
- **Feeding Information to Surgical Robots:** Improves patient outcomes by giving robots more accurate data.
- **Customized Care:** Supplements existing healthcare data to customize care to different demographic groups.
- **Patient Triage:** Predicts which patient is likely to miss appointments, and changes schedules in real-time, reducing costs for hospitals and wait times for patients.

Wearable Sensors & Artificial Intelligence: Data Conversion Driving Adoption

Greater integration of AI-enabled medical devices in patient care create development opportunities for progressively innovative devices. Notably, tech players such as Apple and Alphabet's Google Life Sciences are entering the device development fold.

Growing Use of AI-Enabled Medical Devices Improving Patient Outcomes

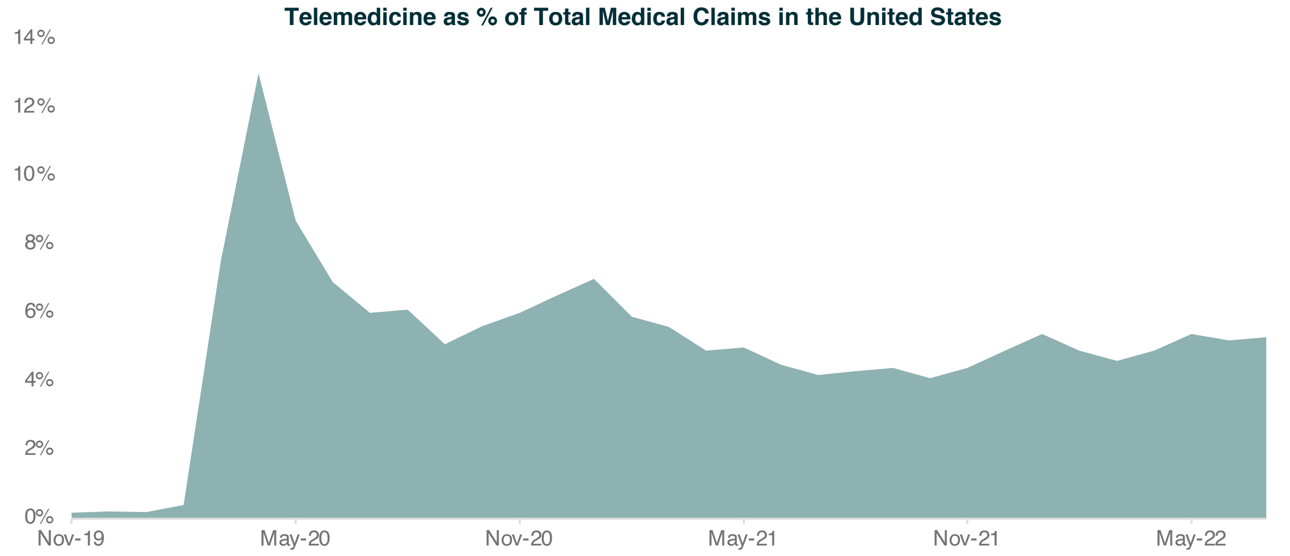


Source: U.S. Food & Drug Administration, 2022

Telemedicine: A Growing Field With Clear Advantages

Telemedicine use increased significantly during the COVID-19 pandemic in the United States. Moving forward, we expect increased use of digital offerings to drive telemedicine adoption. At maturity, 1 in every 3 patient visits is expected to be virtual.

Stabilizing Demand Points to Steady Long-Term Use



Telemedicine Offers Quantifiable Benefits[1]

- Patients who use telemedicine have 19% fewer visits to the ER or urgent care.
- Average cost of a virtual specialist visit is $120 less than average.
- Average cost of a non-urgent virtual visit is $93 less than in-person visits.
- Average virtual urgent care appointments are $141 less than average in-person urgent care visits.
- Patients who use telemedicine avoid unnecessary tests, saving an average of $118 per episode of care.

Sources: Text: 1. Dodds, n.d.; Visual: Fair Health, n.d.

Toolkit in Action: A Better Way to Develop and Vet New Treatments

Developing new medicines is time-consuming and expensive. Digital health can help decrease development costs, speed up advancement of new therapies, and drive improved patient outcomes.

AI Drug Discovery

This $50 billion market promises faster and cheaper development of novel treatments.[1]

Powered by vast reams of health data, AI can help scientists refine the trial-and-error nature of drug discovery, guiding them towards more effective drug formulation.

Currently, only about 10% of phase I drug targets make it to the market.[2] With improved accuracy, a 20–40% reduction in costs for preclinical development of biotechnology drugs is expected.[3]

New Clinical Endpoints

Each new medication uses a rubric to evaluate its efficacy. For some illnesses, quantifying improvement is straightforward. For others, the industry relies on surrogate endpoints, which measure the effect of the treatment that may correlate to clinical improvement but do not necessarily have a guaranteed relationship.

Wearable technology opens the door for new ways to measure efficacy for hard-to-appraise drugs and for continuous monitoring of patients during clinical trials. Wearables can help ensure that new drugs offer the highest correlation to patient outcomes.

Sources: 1. Morgan Stanley, 2022; 2. Merck KGaA, n.d.; 3. Morgan Stanley, 2022

Toolkit in Action: Patient Care From Three Distinct Segments

Patient care's three main verticals—Primary Care, Chronic Care Management, and Mental Health—require different combinations and degrees of digital health tools to ensure the best patient experience. No vertical will drive large-scale adoption on its own.

	Primary Care	Chronic Care Management	Mental Health
Description	Day-to-day healthcare provided by physician. Services include family medicine, general internal medicine, general pediatrics, and obstetrics and gynecology. When appropriate, the provider coordinates with specialists and offers a hybrid approach of telemedicine and in-person care.	Continuous care to patients living with chronic conditions like diabetes, congestive heart failure, and chronic obstructive pulmonary disease (COPD). CMS reports that 93% of overall Medicare spending comes from two-thirds of Medicare beneficiaries with multiple chronic conditions.	Teletherapy and telepsychiatry services to patients struggling with mental health disorders. Currently, 65% of current virtual visits are mental health-related. About 11% of the global population, an estimated 800 million people, live with a mental health condition.
Telemedicine Potential	Medium	High	High
Wearable Tech Potential	Medium	High	Low
AI Potential	Medium	High	Medium

Sources: 1, Comfort, 2021; 2. Auxier, Bucaille, & Westcott, 2021

Digital Health: Consolidation Is Key

Luba Greenwood

The technological infrastructure is set up to ensure interoperability between digital health verticals and providers. Now, the industry looks to innovate its business models to ease data sharing, which can unlock the real value of digital health.

Large Tech Increasing Its Presence in Digital Health

Tech companies have the tools and the funds to improve healthcare, such as by integrating healthcare data across providers. The increasing conversion of technology and healthcare is expected to speed up digital health innovation and decrease the barrier to entry for wearable technology.

Amazon: A Focus on Services

- Amazon's entry into healthcare leaned on its comparative advantage: logistics. The company focused on areas of the healthcare supply chain where automation and logistics improvements would have a big impact. The move provided all 200 million Amazon Prime members access to offerings like online pharmacy services. Amazon wants to expand its reach via adoption of healthcare services targeted to young individuals, such as in-person primary care.

Alphabet: Connecting Health Information

- Alphabet wants to connect the world's health information to make healthcare more accessible. Alphabet expanded its services to decrease healthcare costs and improve clinical outcomes by building software to accelerate R&D, enabling better telemedicine, and building medical devices with healthcare partners. The firm's technology-agnostic reach is expected to help drive healthcare innovation.

Apple: A Device-Centric Approach

- Apple continues to look for ways to utilize its wearable consumer devices in healthcare. Over 102 million individuals have an Apple Watch, which gives them immediate access to new healthcare monitoring features as they launch. Given Apple's structure and talent, expanding the healthcare capabilities of its consumer device suite will likely remain a focus.

Sources: Coppola, 2022; Laricchia, 2022

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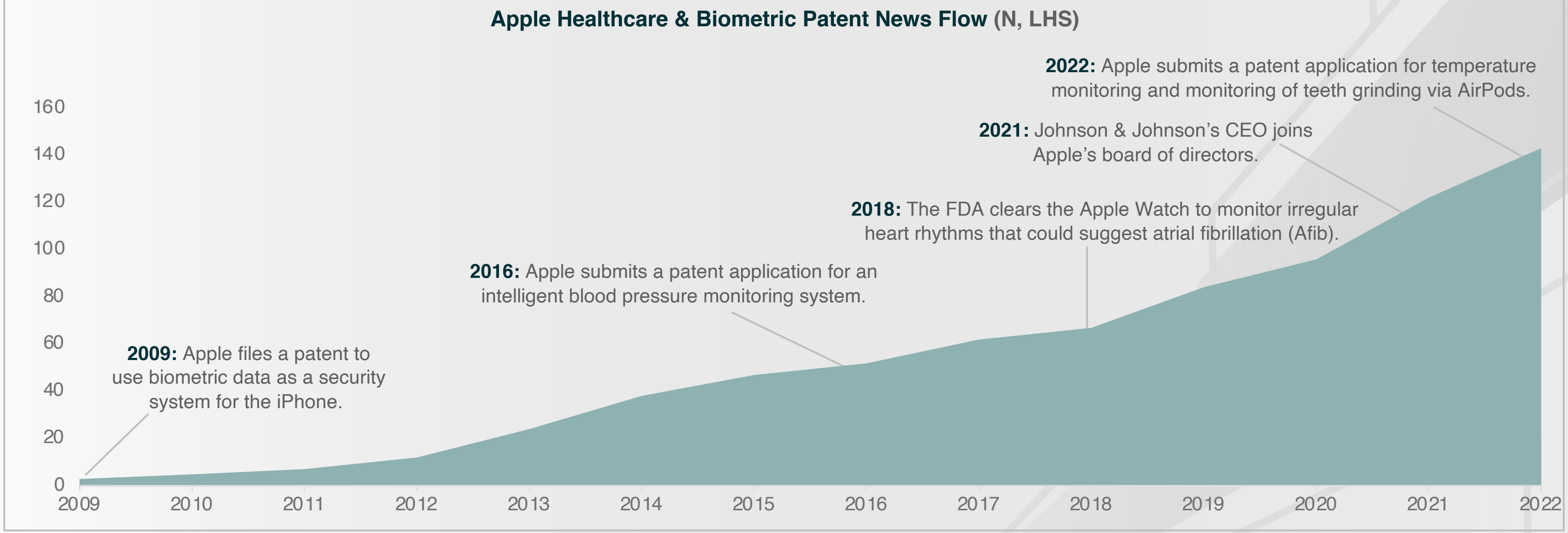
Large Tech Players: Doubling Down

Luba Greenwood

Apple, like other large tech players, accelerated its efforts in the healthcare space with increasingly complex offerings.

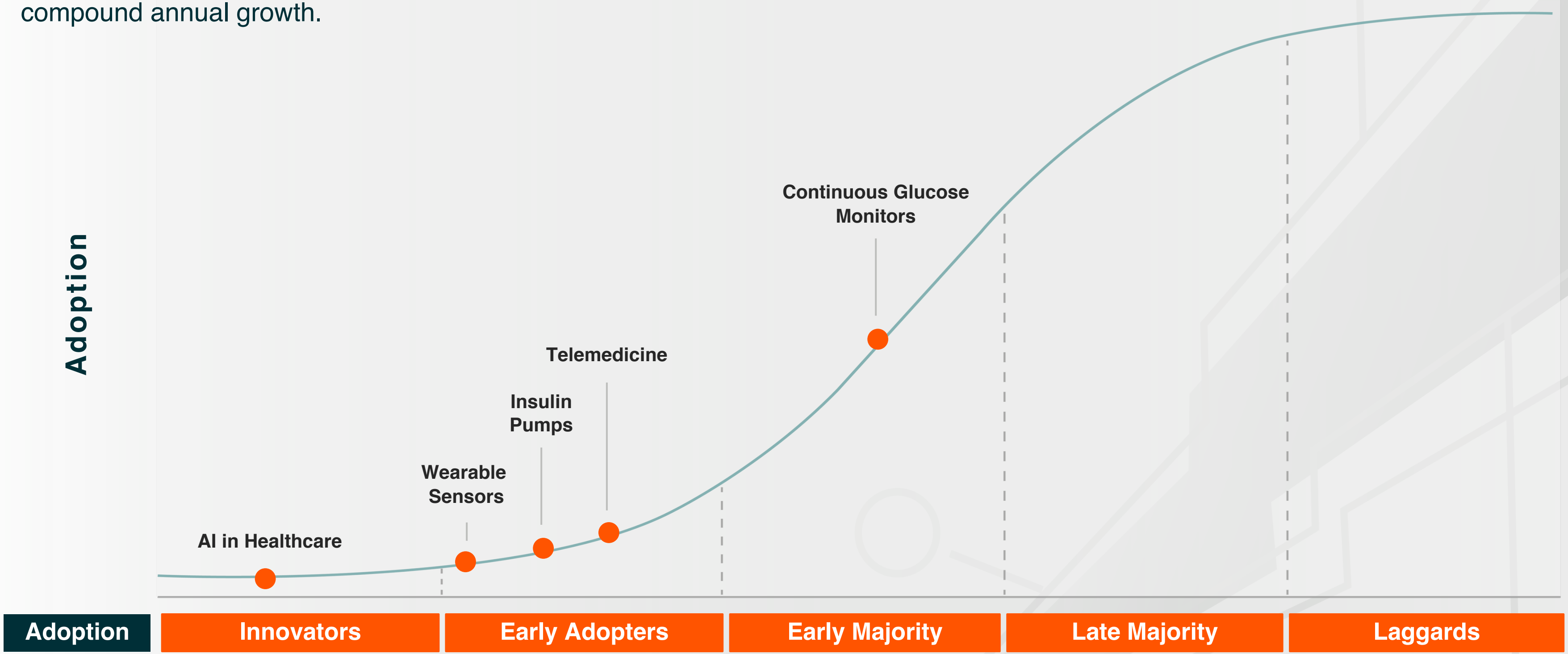
Apple Makes Its Intent Clear: An Integrated Technology and Healthcare Offering



Source: Patently Apple, 2022

S-Shaped Adoption Curve – Telemedicine & Digital Health

We expect the digital health industry to reach $182 billion by 2027, representing 18% compound annual growth.



Sources: Statista, 2022a; Statista, 2022b; Statista, 2022c; Statista, 2022d; Stewart, 2022

Displayed for illustrative purposes. Curve shape not indicative of mathematical transformation

Chapter 04

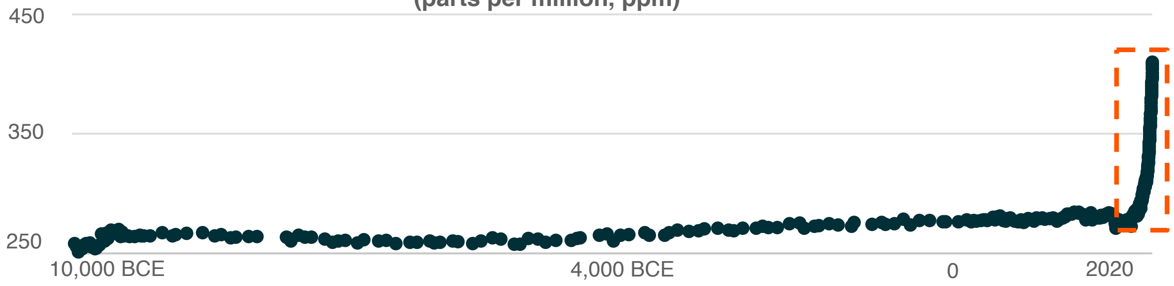
Climate Change

Heightened concentrations of greenhouse gases (GHG) are rapidly increasing the Earth's temperature, resulting in a range of negative environmental and societal impacts. While human activity created the climate crisis, human innovation can also solve it. Technology-driven solutions for climate change mitigation and adaptation include renewable energy, energy storage, hydrogen, AgTech, and green buildings.

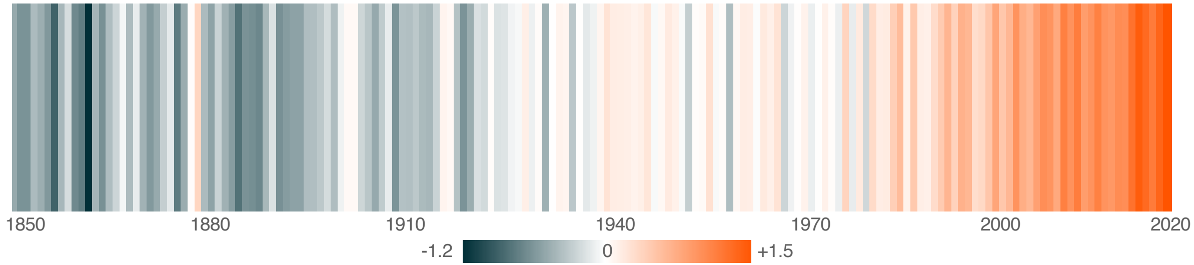
A Warming Planet Unequivocally Linked to Human Activities

Over the past 60 years, atmospheric carbon dioxide (CO_2) concentrations have increased 100x faster than ever recorded, including the end of the last ice age.[1]

Atmospheric CO_2 Concentration
(parts per million, ppm)



Annual Temperature Change Relative to 1950–1980 Average (°C)



+49%

increase in the atmospheric CO_2 concentration from 1750–1800 to 2021. Concentrations increased from an average of 279ppm to nearly 415ppm.[1,2]

~100%

of warming emissions are human-produced.[3] The most carbon-intensive sectors are electricity, heating, transport, manufacturing and construction, and agriculture.[4]

+1.2°C

increase in average temperature from the pre-industrial period to 2021. Only +/-0.1% could be from natural drivers like solar activity.[5]

Sources: Text: 1. Masson-Delmotte, et.al., 2021; 2.Betts, 2021; 3. Lindsey & Dlugokencky, 2022; 4. Ge, Friedrich, & Vigna, 2022; 5. Lindsey & Dlugokencky, 2022; Visuals: Dlugokencky & Tans, n.d.; IPCC AR6 Working Group I, 2021; IPCC AR6 Working Group I, 2022; Berkley Earth, n.d.; Hawkins, n.d.

Negative Impacts of Climate Change Continue to Mount

Near-term mitigation actions can substantially reduce negative impacts for humans and ecosystems, but climate hazards, losses, and damages are unavoidable.

Today's warming is changing the planet. Tomorrow's warming could bring catastrophe.[1]

The past decade was 1.1°C warmer than the pre-Industrial Era and impacts are evident.

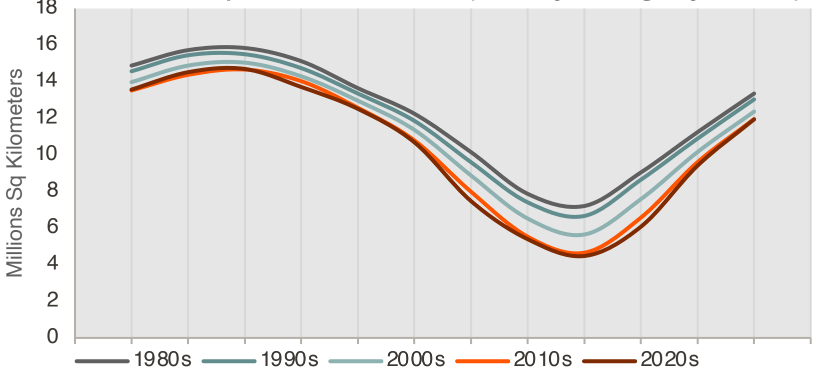
- 10-year extreme heat events are likely to occur 2.8x more often than between 1850 and 1900, while 50-year extreme heat events are now likely to occur 4.8x more frequently.
- Heavy precipitation events and droughts are more frequent and intense since the 1950s.
- Retreating and melting glaciers are causing sea levels to rise faster than any previous century over the last 3,000 years.

On the current path, warming could rise 3°C by 2100. 2°C would have drastic impacts.

- 10-year extreme heat events would occur 5.6x more often. 50-year extreme heat events would occur 13.9x more often, with these events 2.6–2.7°C hotter.
- Extreme precipitation events would occur 1.7x more often and be 14% wetter.
- Extreme droughts would occur 2.4x more often and be 0.6 standard deviations drier, further stressing food and water security.

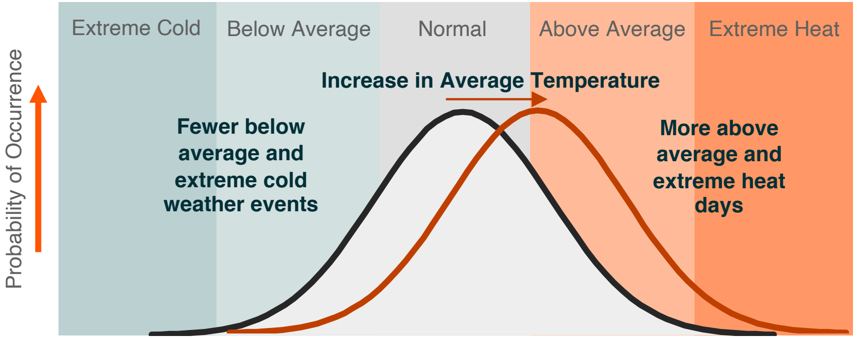
Falling sea ice levels point to a rapidly warming world.

Northern Hemisphere Sea Ice Extent (Monthly Average by Decade)



A warming world means higher probabilities for extreme heat events.

Temperature Probabilities in a Warming World



Sources: Text: 1. Masson-Delmotte, et.al., 2021; Visuals: National Snow & Ice data Center, n.d.; Masson-Delmotte, et.al., 2021

Rapid and Deep Decarbonization Across Industries Can Limit Warming

Limiting warming to 1.5°C above pre-Industrial Era levels can mitigate the worst impacts of climate change. Achieving this goal requires decarbonizing every sector by transitioning to clean energy sources, sustainable fuels, sustainable land use, energy efficiency measures, and new agricultural practices.

The success of decarbonization depends on policy, investment, and adoption. The IEA presents four scenarios for decarbonization.[1]

Net Zero Emissions Scenario (NZE)

Achieves net-zero energy sector emissions by 2050, limiting warming to 1.5°C by 2050 (1.4 °C by 2100) without a temporary overshoot.

Sustainable Development Scenario (SDS)

Meets the United Nations' sustainable development goals, reaching net zero by 2070. Would limit warming to 1.7°C by 2050 (1.6°C by 2100).

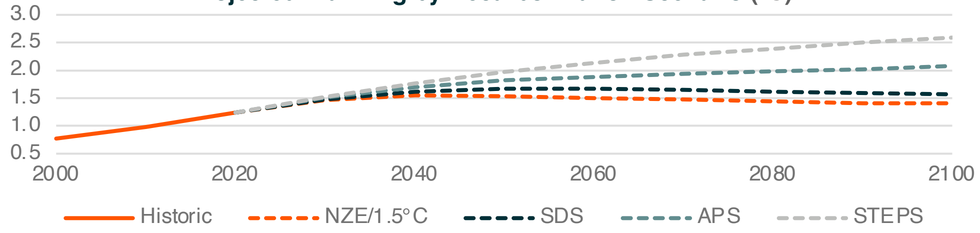
Announced Pledges Scenario (APS)

Countries meet most recent announced climate commitments on schedule, which would limit warming to 1.8°C by 2050 (2.1°C by 2100).

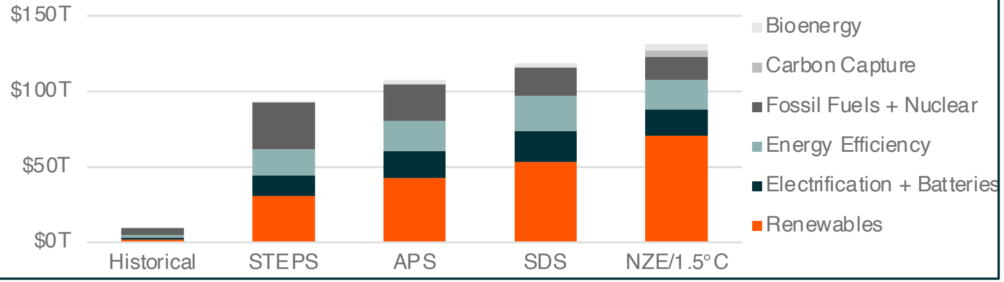
Stated Policies Scenario (STEPS)

Based only on enacted policies and recognizing that announced pledges might not be met. Would limit warming to 2.0°C by 2050 (2.6°C by 2100).

Projected Warming by Decarbonization Scenario (°C)



Cumulative Investment Across Clean Technologies by Decarbonization Scenario (°C)



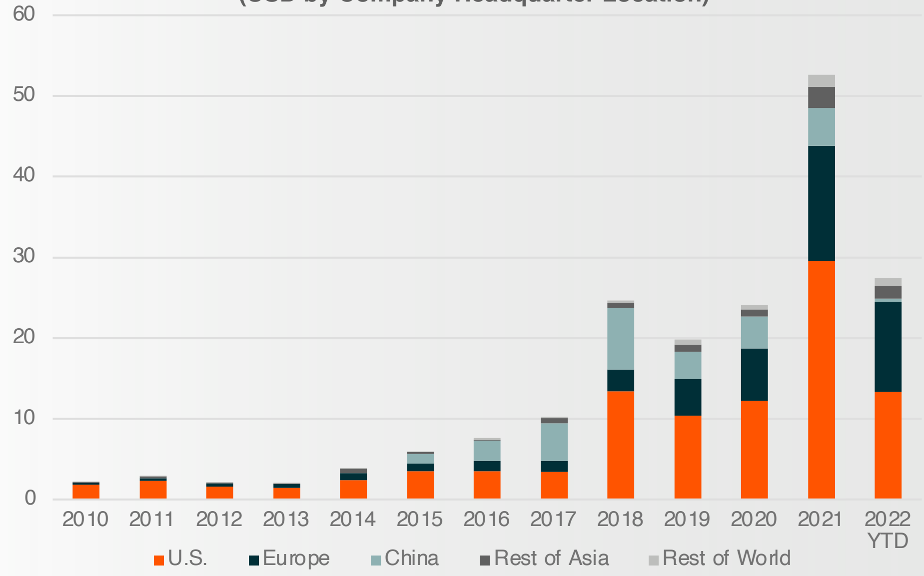
Sources: Text: International Energy Agency, 2021; Visuals: International Energy Agency, 2021

Race to Net Zero Underway With Uptick in Climate Tech Investments

Azeem Azhar

The rapid increase in climate tech investment comes as the impacts of climate change become clearer and governments and companies ramp up climate change mitigation and adaptation efforts.

Investments in Climate Tech Companies Across All Funding Rounds
(USD by Company Headquarter Location)



Sources: Text: Johnson & Cox, 2022; Visuals: Dealroom.co

Key Trends of Climate Tech Investments[1]

- **The U.S. leads, but the climate tech market is increasingly global:** The U.S. captured 54% of all climate tech investments between 2010 and 2021, followed by Europe with 21%. China ranks third at 18%, despite being a relatively new player in venture capital. Other emerging markets continue to gain interest, particularly from foreign investors.
- **The mobility and transport sector generates the most investments:** Companies focused on transport and mobility receive the largest share of investments in every region, followed by the energy and food and agriculture sectors.
- **Most companies focus on mitigation, potentially creating opportunities in adaptation:** Climate change adaptation is the focus for only 1% of 3,000 climate tech companies analyzed by PwC. With climate change impacts expected to increase, the need for further innovation and funding in this space is significant.

GLOBAL X by Mirae Asset

Tipping Points in Climate Tech Can Yield Rapid Decarbonization

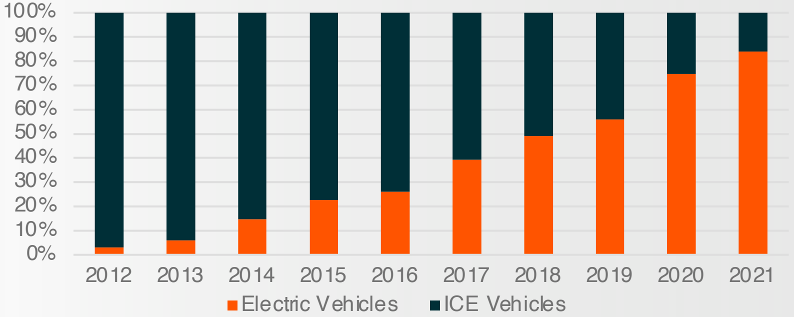
Azeem Azhar

In contrast to tipping points in the physical environment that could exacerbate climate change, tipping points in clean technology adoption can lead to systemic change yielding rapid and deep decarbonization. Electric vehicles (EVs) are a prime example.

Reaching a 5% penetration rate appears to be the tipping point that triggers the rapid uptake of EVs in a country.[1]

- In 2021, EVs accounted for 84% of new vehicle sales in Norway. Rapid growth in sales occurred after surpassing a 5% share in new vehicle sales in 2013.[2]
- Over a dozen other countries followed the same trend, including Sweden, China, and Germany. The United States is likely to reach a 5% EV sales share in 2022, with rapid growth forecast to follow.[3]

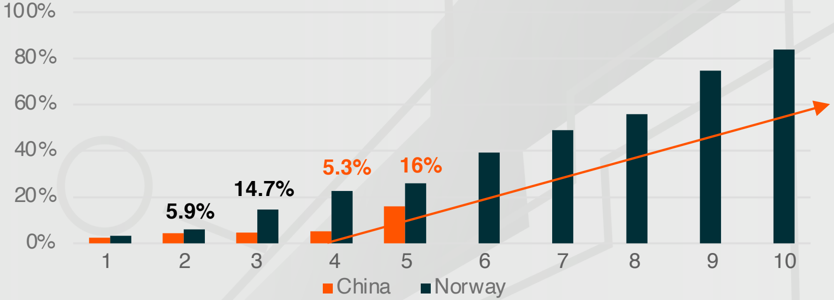
Share of New Vehicle Sales in Norway, by Technology



The 5% threshold often yields systemic levels of societal change, supporting the rapid growth that follows.

- Systemic changes that can occur once EV adoption takes off include a buildout of public chargers, diminished returns for gas stations, larger EV supplies, shifting industry expertise, and elevated consumer interest.
- After Norway surpassed 5%, sales jumped to nearly 15% the next year. China is following Norway's lead, only a couple years behind. After a 5% share in 2020, EV sales in China jumped to a 16% share in 2021.

EV Share of New Vehicle Sales in China and Norway
(Sales from first year with at least 2% penetration rate)



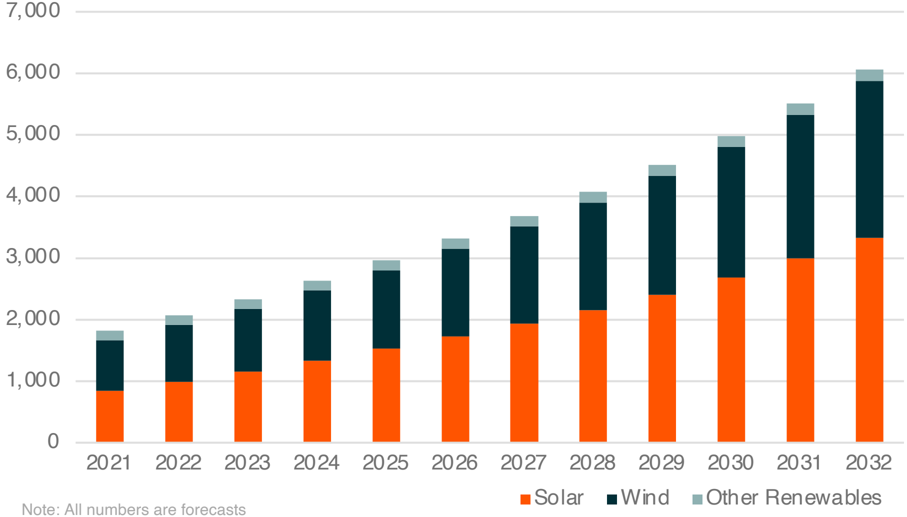
Sources: Text: 1. Randall, 2022; 2. International Energy Agency, 2022; 3., Randall, 2022; Visuals: Global X analysis of Global EV data from International Energy Agency, 2022

Clean Energy Transition Well Underway and Poised to Accelerate

Global non-hydropower renewable electricity generation is forecast to increase more than threefold from 3,567TWh in 2021 to 11,324TWh in 2032. Non-hydro renewables are forecast to account for 31% of total electricity generation in 2032. In 2021, non-hydro renewables accounted for a 13% share.[1]

Non-hydropower renewable capacity is forecasted to grow from 1,817GW in 2021 to 6,060GW in 2032.[2]

Global Non-Hydro Renewables Capacity, by Technology (GW)



Note: All numbers are forecasts

Key Drivers of Renewable Energy Adoption

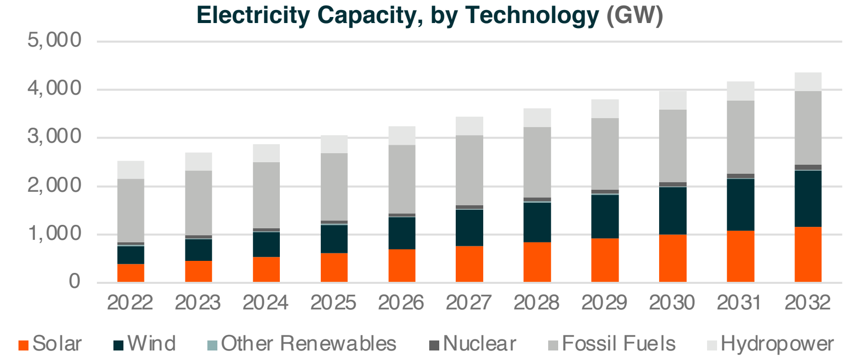
- **Favorable Policy Environments:** Over 135 countries have economy-wide net zero emissions targets, with nearly all aiming for 2050 or earlier.[3] To incentivize renewable energy adoption, many countries use subsidies, feed-in-tariffs, and renewables auctions and project tenders.
- **Corporate Sustainability Efforts:** Corporations are seeking their own renewable energy supply to meet sustainability targets. The top three corporate clean energy buyers in 2021 were Amazon, Microsoft, and Meta.[4]
- **Technology Improvements:** Advancements in wind and solar power components, such as solar modules and wind turbines, are expanding the suitability range and performance of systems and further cutting costs.
- **Increased Cost Competitiveness:** Onshore wind and solar photovoltaic (PV) power costs declined 68% and 88%, respectively, between 2010 and 2021.[5] Supply chain challenges increased wind and solar power prices over the past year, but both remain highly cost competitive, given steeper cost increases to natural gas and coal prices.[6]

Sources: Text: 1. Global X forecast based on information derived from several sources – see Appendix: Sources – Climate Change; 2. Ibid.; 3. Net Zero Tracker, n.d.; 4. Clean Energy Buyers Association, n.d.; 5. International Renewable Energy Agency, 2022; 6. International Energy Agency, 2022; Visual: Global X forecast based on information derived from several sources – see Appendix: Sources – Climate Change

China and the United States to Remain Top Renewables Markets

With the two largest power grids in the world, ample wind and solar resources, and increasingly supportive government policies, China and the United States are poised for significant wind and solar power growth over the coming decade.

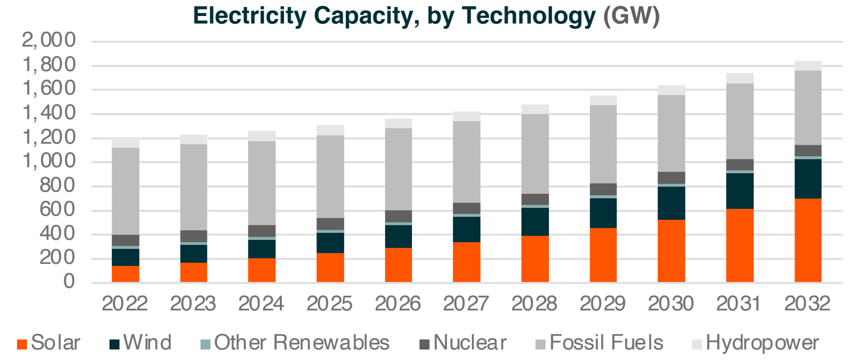
China



Note: All numbers are forecasts

- China is set to remain the global leader in renewable energy growth, accounting for 41% of global wind and solar power capacity additions through 2032.
- The non-hydro renewables sector is forecast to account for nearly 85% of China's net electricity capacity growth over the next 10 years, reaching 2,345.5GW in 2032.
- Clean energy, including hydropower, nuclear, and renewables, is forecast to account for 46% of China's electricity generation by 2032, up from 33.6% in 2021.

United States



Note: All numbers are forecasts

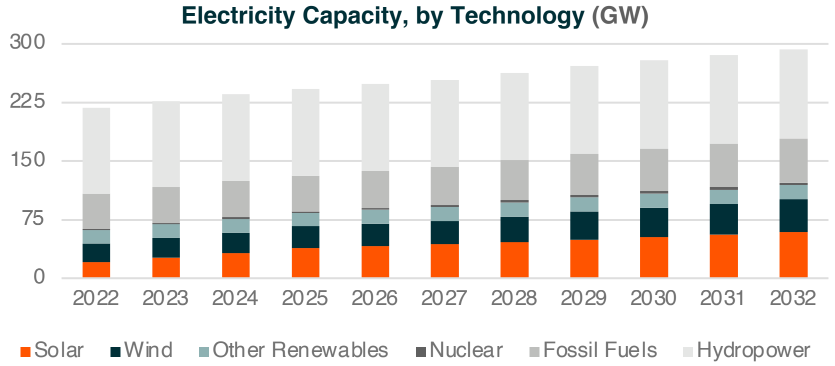
- The United States is forecast to have the second highest growth in renewables capacity and generation.
- U.S. solar power capacity is forecast to grow from 121.5GW in 2021 to 700.1GW in 2032. Wind power capacity is forecast to increase from 132.4GW to 328.7GW.
- The wind and solar power sectors are forecast to account for 45% of U.S. electricity generation by 2032, up from 13% in 2021. All clean energy sources combined could account for nearly a 70% share by 2032, compared to 40% in 2021.

Sources: U.S. Energy Information Administration, n.d.; Fitch Solutions, n.d.; China Energy Portal, 2022; Myllyvirta & Zhang, 2022; U.S. Energy Information Administration, 2022; Musial, Spitsen, Duffy, Beiter, Marquis, Hammond & Shields, 2022

Renewables Growth in Brazil and Germany Shows the Importance of Government Policy

Favorable policies and abundant wind and solar resources are key to establishing competitive renewables industries. Brazil and Germany are renewables leaders in their regions, and their energy transitions are forecast to accelerate due to supportive polices.

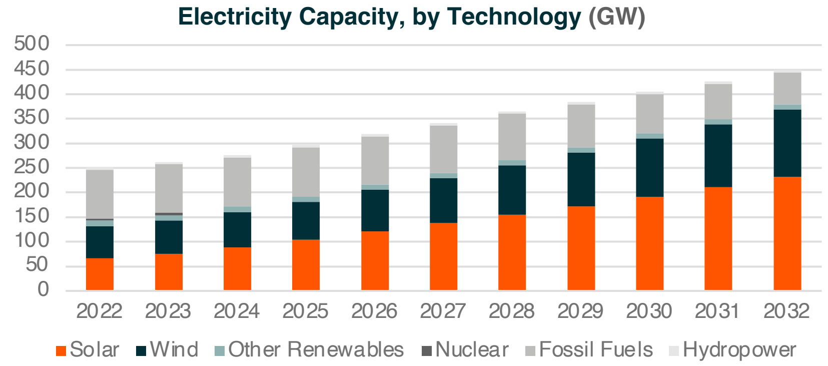
Brazil



Note: All numbers are forecasts

- In Brazil, the solar sector is forecast to account for 53% of capacity additions through 2022 due to favorable policies for utility-scale and distributed solar power systems. Solar power capacity is forecast to reach 59.4GW in 2032.
- Wind power is forecast to comprise 24% of net capacity growth, growing from 21.0GW at year-end 2021 to 41.4GW in 2032.
- Non-hydro renewables' power generation share is forecast to grow from 23% in 2021 to 32.8% in 2032. Hydropower will maintain the largest share in Brazil's power mix.

Germany



Note: All numbers are forecasts

- In Germany, the solar sector is forecast to increase by 172.3GW and the wind power sector by 73.6GW between 2021 and 2032.
- In contrast, we expect the nuclear power and thermal power sectors to contract. While extensions are possible, Germany is currently set to phase out its remaining nuclear power fleet by the middle of the decade.
- Non-hydro renewables' share of power generation is forecast to double from 38.1% in 2021 to 76.4% in 2032.

Sources: U.S. Energy Information Administration, n.d.; Fitch Solutions, n.d.; Empresa de Pesquisa Energetica, n.d.; Absoluar, 2022; Energy-Charts, 2022; Whitlock, 2022

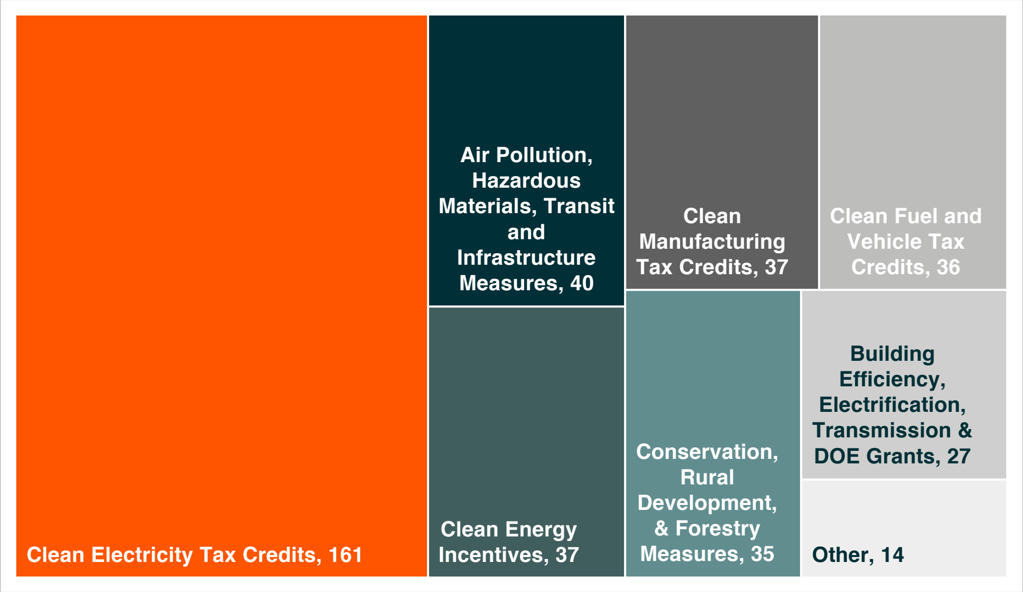
U.S. in Focus: Inflation Reduction Act Could Provide Major Boost for Renewables and CleanTech

On August 16th, 2022, President Biden signed the Inflation Reduction Act (IRA) into law, a reconciliation package that represents the country's largest-ever investment in climate change.[1] The bill directs $386 billion to climate resilience and energy security.[2]

Potential Benefits of the Inflation Reduction Act

- **Enhanced Wind and Solar Power Growth:** A significant expansion and extension of tax credits, including for solar power, wind power, biomass power, geothermal power, and energy storage systems, is expected to boost growth.[3] The wind and solar power sectors could benefit from 10s of gigawatts of additional annual capacity growth over the coming decade.[4]
- **Development of Robust Green Hydrogen Industry[5]:** The new clean hydrogen tax credit may help accelerate the development of the nascent low-carbon hydrogen industry in the United States by making green hydrogen cost-competitive with grey hydrogen. Renewables also play a vital role in the establishment of a green hydrogen industry.
- **Accelerated Decline in GHG Emissions[6]:** With the Inflation Reduction Act, U.S. economy-wide emissions are forecast to decline 37% to 41% below 2005 levels by 2030. Without it, U.S. emissions were forecast to fall well short of emissions targets, declining just 24% by 2030.

Inflation Reduction Act Climate Spending by Area ($, Billions)



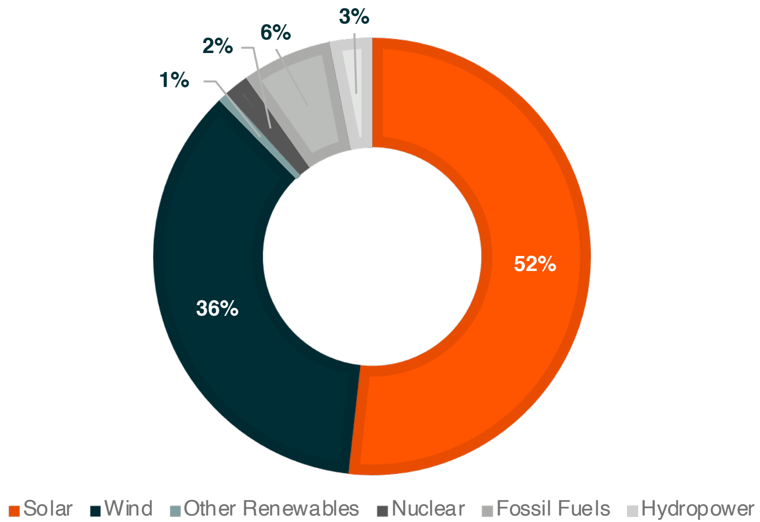
Sources: Text: 1. Smith, 2022; 2. Committee for a Responsible Federal Budget, 2022; 3. Senate Democrats, 2022; 4. Jenkins, Mayfield, Farbes, Jones, Patankar, Xu, & Schivley, 2022; 5. Senate Democrats, 2022; 6. Mahajan, Ashmoore, Rissman, Orvis, & Gopal, 2022; Visuals: Global X ETFs with information derived from Committee for a Responsible Federal Budget, 2022

Solar and Wind Power Are Forecast to Drive Growth in Global Power Sector

Wind and solar power are becoming technologies of choice due to strong policy support and their cost competitiveness.

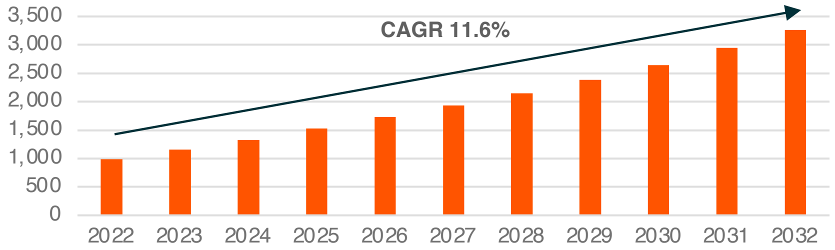
The solar and wind power sectors may account for a combined 87.5% of net electricity capacity additions from 2022 to 2032.

Share of Net Capacity Additions From 2022–2032 (%)

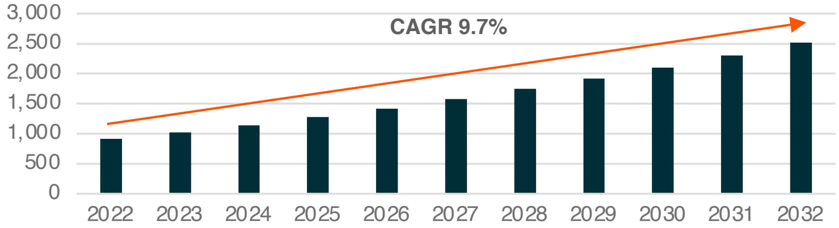


Note: All numbers are forecasts

Global Solar Power Capacity (GW)



Global Wind Power Capacity (GW)



Sources: Global X forecast based on information derived from several sources – see Appendix: Sources – Climate Change

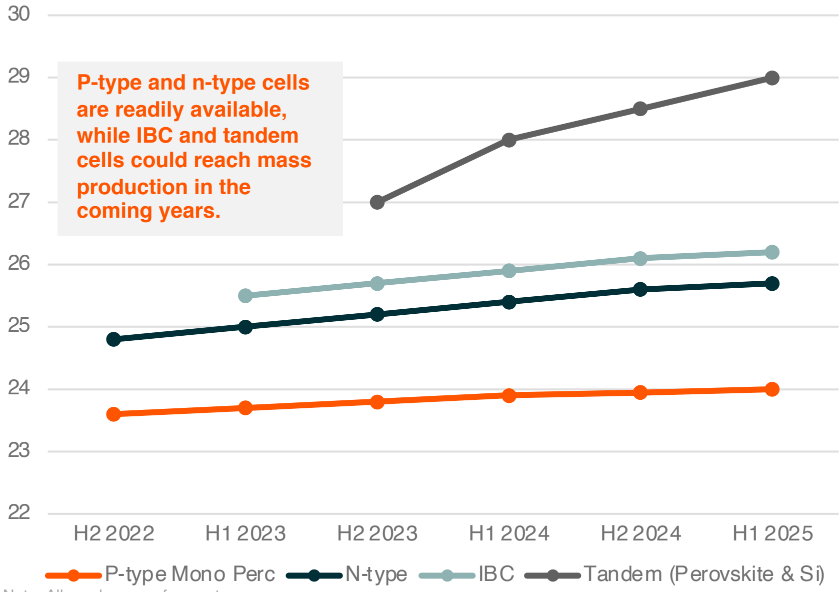
Expected Advancements in Solar Power Technologies to Expand Growth Opportunities

Technology advancements could yield better performance, lower costs, and a wider suitability range for solar PV systems.

Developing more powerful modules and easier installation and maintenance processes are key to further cost declines and growth in the solar sector.

- **Next-Gen Modules:** More powerful and ultra-high efficiency solar modules can lead to better project performance and lower costs by reducing the number of modules needed in a project. Additionally, solar modules built from new materials, such as perovskite, could be bigger, cheaper, and more efficient than those made from silicon.[1]
- **Improved Solar Cells:** Advancements in solar cell technologies are key to developing the next generation of modules. Increased use of multi-junction cells, tandem cells, thin film cells, and interdigitated back content (IBC) solar cells can yield higher efficiencies, boosting performance and lowering costs.[2,3]
- **Advanced Installation and Maintenance Processes:** Innovations ranging from easier-to-install racking to robotic cleaning and data-driven failure prevention could cut down on installation, maintenance, and operating costs.
- **Increased Adoption of Agrivoltaic and Floating Solar Systems:** The scaling up of more niche solar PV system equipment for use on agricultural land (agrivoltaics) and bodies of water will allow developers to build solar projects on a wider range of landscapes.

Average Efficiency of Mass-Produced Solar Cell, by Technology (%)



Note: All numbers are forecasts

Sources: Text: 1. Okinawa Institute of Science and Technology, 2021; 2. Yamaguchi, Dimroth, Geisz, & Ekins-Daukes, 2021; 3. Svarc, 2022; Visual: Svarc, 2022

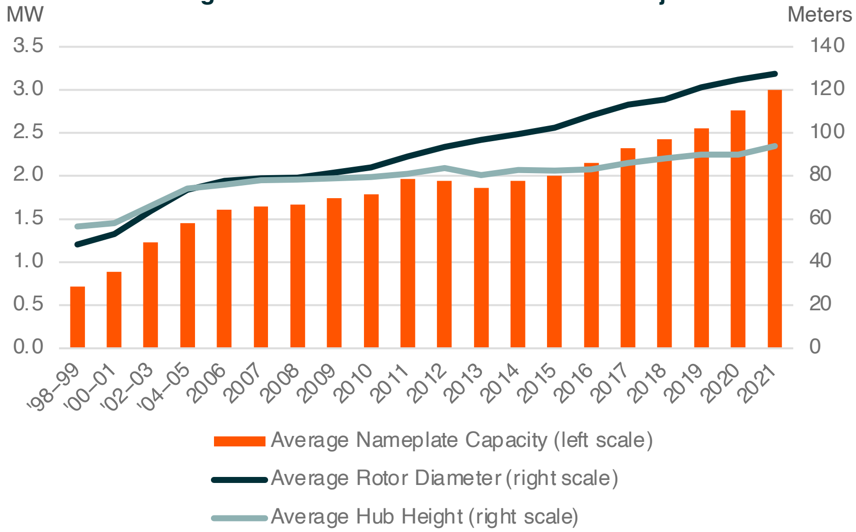
Expected Advancements in Wind Power Technologies Key to Robust Growth Outlook

Additional wind power technology advancements, combined with improvements to transport, installation, and operation and maintenance (O&M) processes, can result in further cost reductions and improved wind power project performance.[1,2]

Taller turbine towers, bigger blades, and improved onsite assembly practices are some of the advancements that could benefit the wind power sector.[1,2]

- **Higher Hub Height:** Taller towers, resulting in higher hub heights, can help developers capture more energy because wind speeds generally increase at higher latitudes. Offshore wind turbines are projected to increase from an average height of 100 meters in 2016 to 150 meters in 2035.
- **Bigger Blades:** Longer blades result in a larger rotor diameter, or the width of the circle swept by the rotating blades. Projects with larger rotor blades can produce more wind energy, with increased efficiency even at lower wind speeds. Blade size is expected to continue improving over the coming years.
- **Increased Nameplate Capacity:** Improvements in wind turbine components are leading to higher maximum power capacity ratings. As a result, developers can install fewer turbines to reach the target capacity for a project, which can lower costs. Nameplate capacity is likely to continue improving due to advancements in turbine technology and O&M procedures.
- **Improved Transport and Assembly Processes:** Using segmented wind turbine pieces and assembling on-site could reduce shipping and transportation challenges. Lighter materials such as carbon fiber could also make on-site assembly easier.

Average Measurements for Onshore Wind Projects



Sources: Text: 1. Office of Energy Efficiency & Renewable Energy, 2022; 2. Thilmany, 2021; Visual: Office of Energy Efficiency & Renewable Energy, 2022

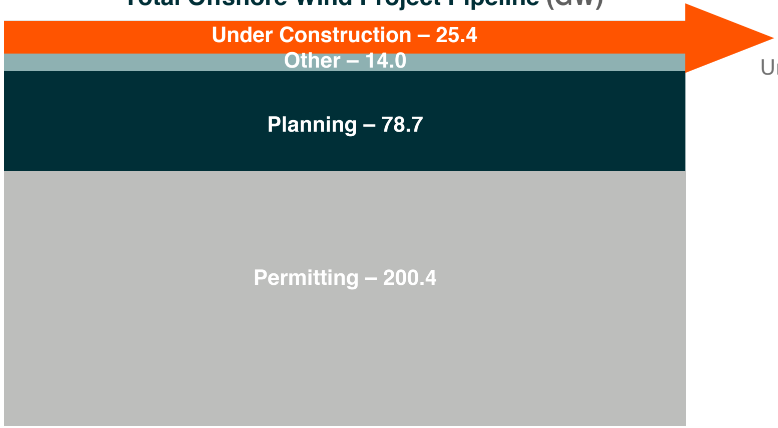
Offshore Wind Power Gaining Momentum Globally, Unlocking Sizeable Growth Potential

Global offshore wind capacity could increase 3.5x from 50.6GW in 2021 to 177.5GW by 2027.

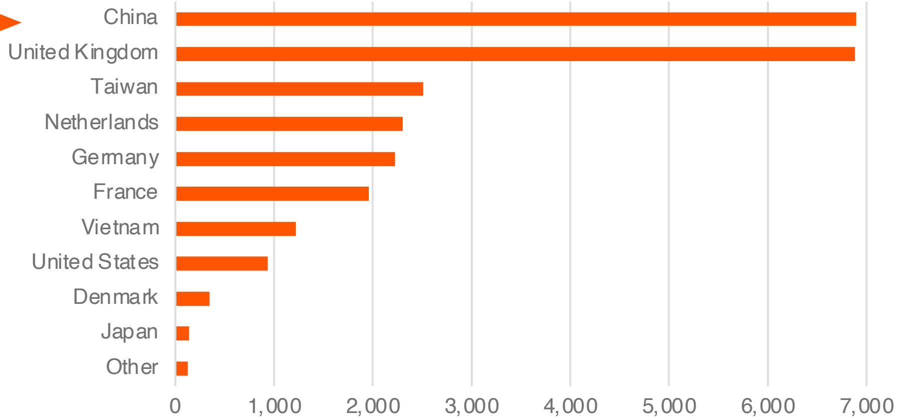
Robust global offshore wind project pipeline of 318.5GW points to rapid growth potential.

- In 2021, global offshore wind power capacity increased by just under 17,500MW to 50,600MW.
- This capacity accounts for only a 6% share of total global installed wind power capacity, but momentum for offshore wind projects has picked up. Governments are looking for ways to use offshore wind power to decarbonize electricity production, particularly near demand centers. Cost declines in wind power technology also play a role.
- Floating offshore wind projects, as opposed to traditional anchored offshore wind projects, are expected to create potential growth opportunities as the technology advances and costs decline.

Total Offshore Wind Project Pipeline (GW)



Offshore Wind Projects Under Construction (MW)

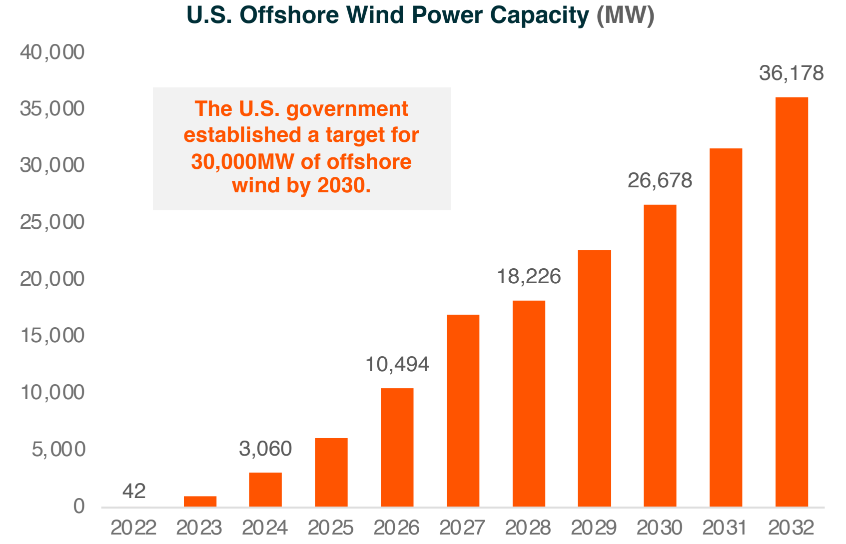


Source: Office of Energy Efficiency & Renewable Energy, 2022

U.S. in Focus: State and Federal Support Bolster Offshore Wind Power Growth Outlook

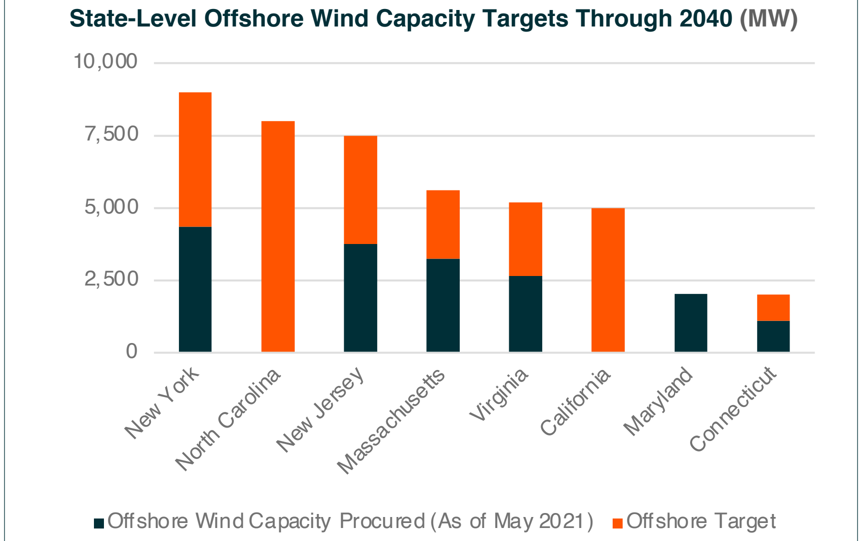
Historically, the United States was a laggard in offshore wind power. Today, falling offshore wind prices, robust state-level commitments, and federal efforts such as offshore wind lease area auctions are creating a sizeable offshore wind power industry.[1]

U.S. offshore wind power sector set to take off.



Note: All numbers are forecasts

Additional growth likely due to strong federal and state-level policies.



Source: Office of Energy Efficiency & Renewable Energy, 2022

Short- and Long-Duration Energy Storage Essential to the Clean Energy Transition

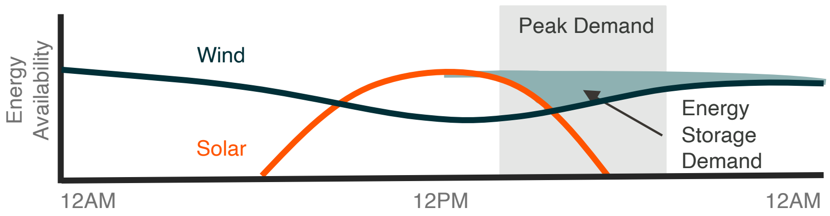
Renewables power generation goes only as far as transmission infrastructure and nature allow. Energy storage can help.

Short- and long-term energy storage can help fill daily and seasonal differences between intermittent renewables generation and peak demand.[1]

<10 hours **Short-Duration Energy Storage** is any storage system that can discharge energy for up to 10 hours at its rated power output.[2]

- Lithium-ion battery energy storage systems (BESS), which typically have a storage duration of 4–6 hours, are the technology of choice globally due to their cost competitiveness and established supply chain.[3]
- Global energy storage is forecast to explode from 17GW/34GWh in 2020 to 358GW/1028GWh in 2030.[4] Lithium-ion BESS will continue to dominate the market and account for most of the growth through at least 2030.
- The rapid uptake of lithium-ion BESS can help balance daily differences between renewable power generation and peak electricity demand.

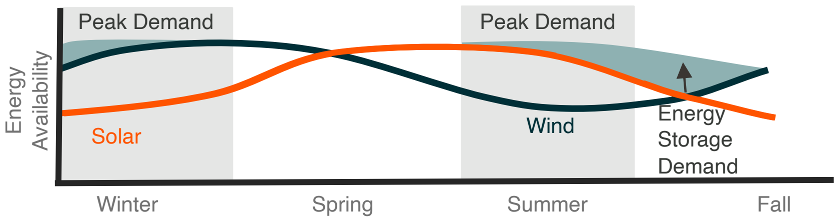
BESS Systems Can Address Daily Generation Patterns



10+ hours **Long-Duration Energy Storage (LDES)** offers stable energy output ranging from 10 hours to days, weeks, and even seasons.[5]

- While LDES systems have traditionally been limited due to cost, permitting, technological, and policy barriers, significant growth opportunities are emerging.
- To reach global net-zero power sector targets, LDES must be scaled up by an estimated 400x from present-day levels to 85–140TWh by 2040. This increase equates to a $1.5–3.0 trillion investment opportunity.[6]
- Pumped hydropower storage systems are the main LDES technology. But compressed air energy storage, liquid air energy storage, non-lithium-ion batteries, and hydrogen-based storage systems may be poised to gain traction.

LDES Systems Can Address Seasonal Generation Patterns



Note: Graphics are illustrations & do not reflect exact or approximate numbers.

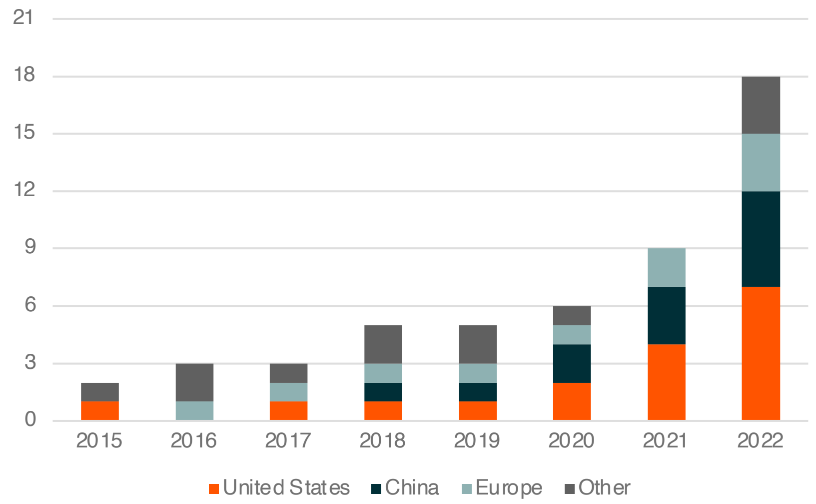
Sources: 1. Congressional Research Service, 2019; 2. Guerra, 2021; 3. Argonne National Laboratory Staff, 2021; 4. Bloomberg NEF, 2021; 5. Guerra, 2021; 6. LDES, 2021; Visual: Global X ETFs with information derived from Congressional Research Service, 2019

Energy Storage Investments Accelerating Globally, With Widespread Potential Benefits to Grids

Countries that implement energy storage systems can address growing grid challenges, including high transmission congestion and increasing risks of extreme weather events that disrupt supply.[1]

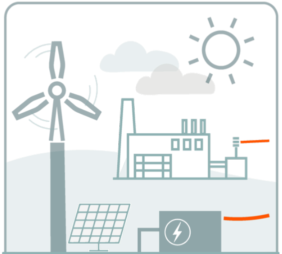
Energy storage investments are set to double in 2022, driven by energy storage's key role in the proliferation of renewables.

Energy Storage Investments ($ Billions)



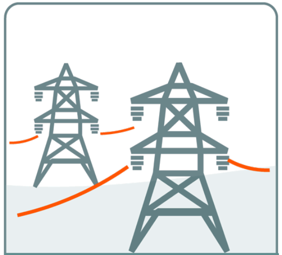
Energy storage systems can provide several benefits to electricity grids across the generation, transmission, and distribution segments.

GENERATION



- Address supply disruptions
- Address variability of renewable resources
- Provide peaking capacity

TRANSMISSION



- Defer transmission upgrades
- Relieve transmission congestion
- Provide ancillary grid services

DISTRIBUTION

- Defer distribution upgrades
- Provide backup power during outages
- Support microgrids
- Reduce demand changes

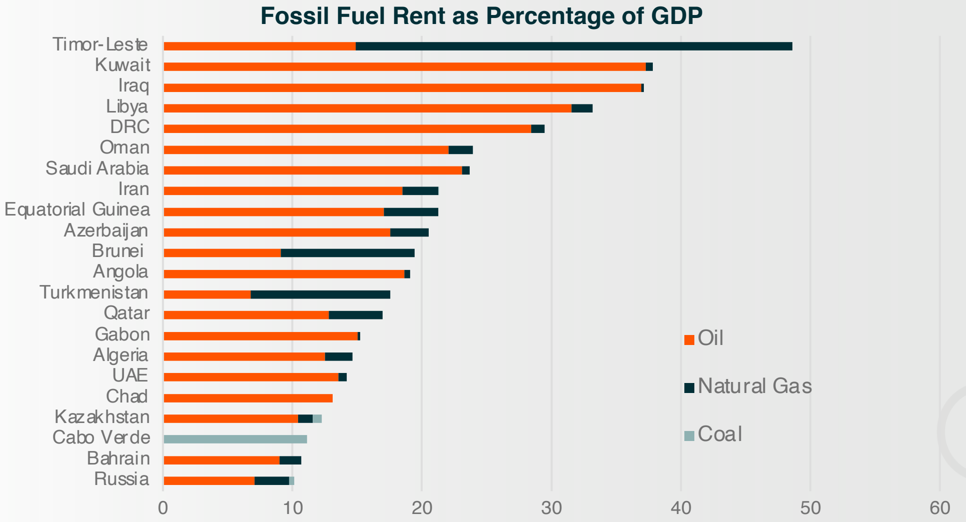
Sources: Text: 1. Smith, 2018; Visual (LHS): International Energy Agency, 2022; Visual (RHS): Smith, 2018

Shifting Geopolitics in an Increasingly Electrified World

Azeem Azhar

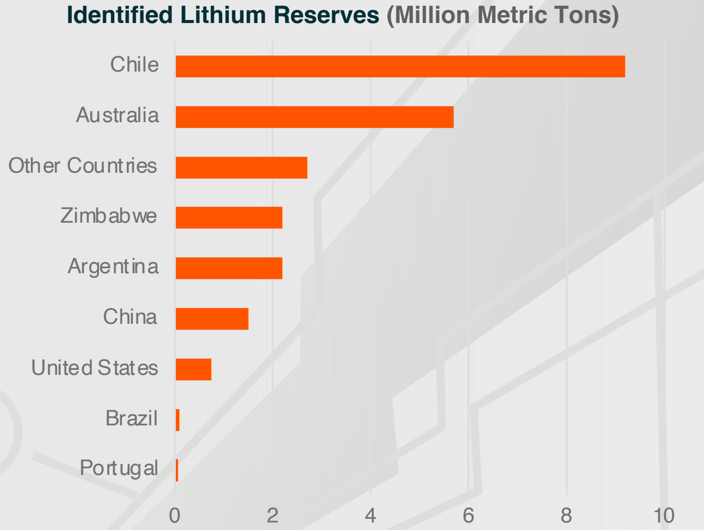
The geopolitical landscape is changing as the world shifts away from fossil fuels towards a world with higher levels of electrification, renewable energy, and low-carbon fuels.[1]

Countries that currently derive high shares of their GDP from fossil fuel rents could experience higher socio-economic and security risks if they do not adapt.[2]



Note: DRC – Democratic Republic of Congo, UAE – United Arab Emirates.

In contrast, countries with high lithium reserves potentially benefit, given lithium's importance to EVs.[3]



Sources: Text: 1. Global Commission on the Geopolitics of Energy Transformation, 2019; 2. Jaskula, 2022; 3. Ibid.; Visuals: World Bank Staff, 2022a; World Bank Staff, 2022b; World Bank Staff, 2022c

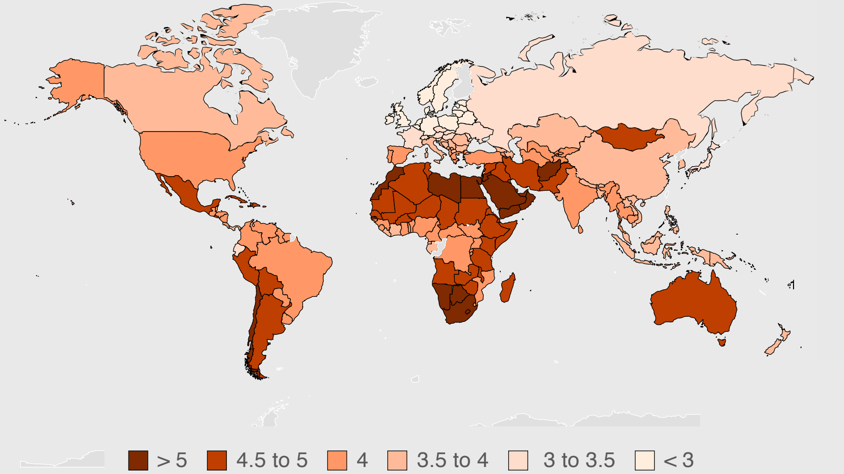
Renewable Energy Provides Opportunities for Energy Independence

Azeem Azhar

Renewables offer countries a pathway to boost energy security and improve energy independence by reducing reliance on fossil fuel imports.[1] Countries with high renewable energy generation may also benefit from exporting electricity and producing green hydrogen.

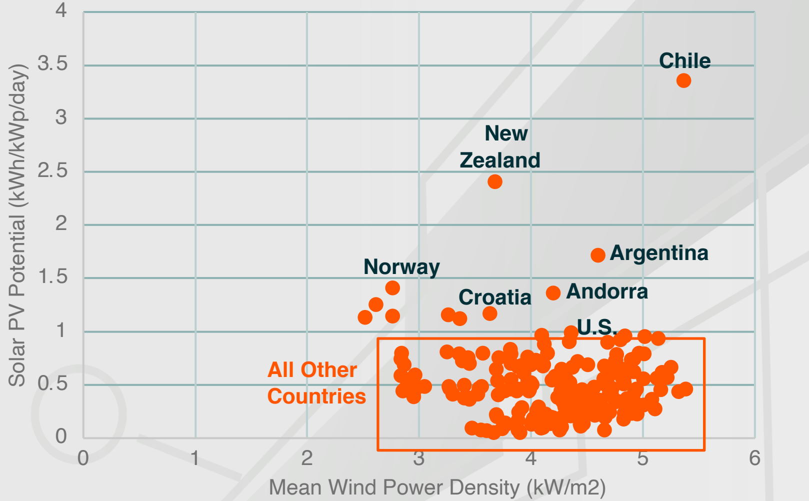
Many countries have sizeable solar power potential.[2] Solar is highly scalable from small residential to utility-scale systems.

Average Practical Solar PV Potential (kWh/kWp/day)



Countries that have abundant solar and wind resources have even higher potential benefits from the clean energy transition.

Average Practical Solar & Wind Power Resources



Note: Larger numbers mean higher wind and/or solar power potential.
Mean wind power density for 10% windiest areas, at 100m height.

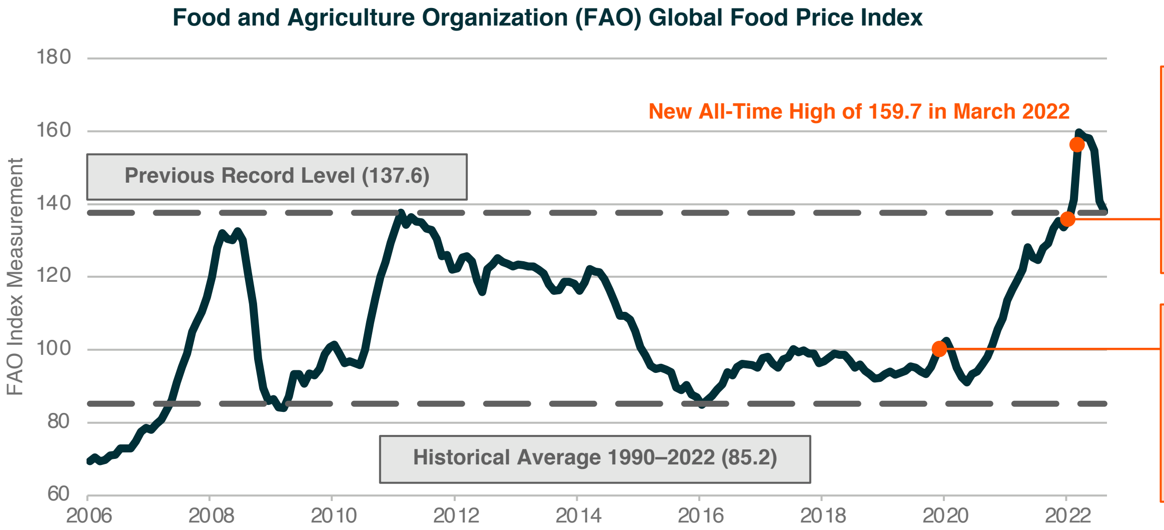
Sources: Text: 1. Global Commission on the Geopolitics of Energy Transformation, 2019; 2. Suri, Betask, Rosina, Chrkavy, Suriova, Cebecauer, Caltik, & Erdelyi, 2020; Visual (LHS): Suri, Betask, Rosina, Chrkavy, Suriova, Cebecauer, Caltik, & Erdelyi, 2020; Visual (RHS): Suri, Betask, Rosina, Chrkavy, Suriova, Cebecauer, Caltik, & Erdelyi, 2020; World Bank Group & Vortex, 2022

GLOBAL X by Mirae Asset

AgTech: Elevated Food Prices Are Leading to Food Insecurity

Food systems are struggling with worsening climate conditions, the pandemic, unfavorable commodity pricing, warfare, and labor shortages. These conditions highlight the need for further AgTech innovation to help secure the world's future food supplies.

Global food prices reached all-time highs in March 2022 following Russia's invasion of Ukraine. March benchmark prices were 16% higher than the previous record set in February 2011. As of August 2022, prices remained above the previous record.[1]



Russia-Ukraine War: About 50 countries rely on Russia and Ukraine for at least 30% of their wheat imports, and 26 of these countries depend on them for over half of their wheat supplies.[2] The war also disrupts global trade of sunflower oil, maize, and barley, as well as supplies for agricultural inputs.

First Cases of COVID-19 Reported in China: Supply chain disruptions, increasing input costs, and varied worker availability have tormented food producers since the onset of the pandemic. Higher prices and limited supplies have reportedly doubled global food insecurity since 2020.[3]

Note: Traditional farm yield based on U.S. 2020 average.

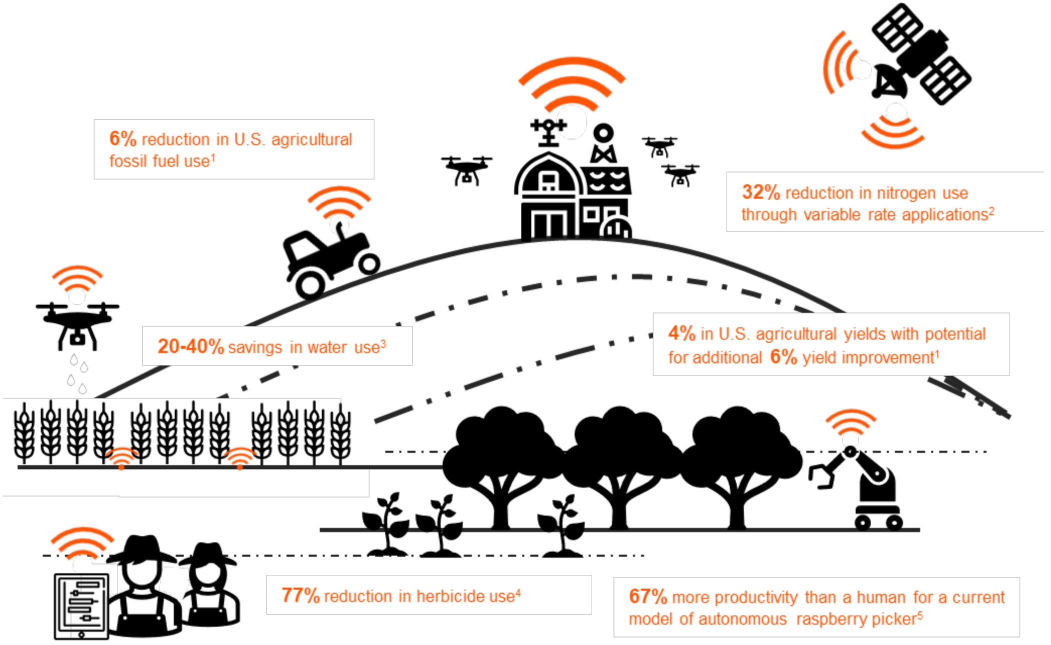
Sources: Text: 1. Food and Agriculture Organization, 2022; 2. USDA Foreign Agricultural Service, 2022; 3. Elkin, Smith, & Gross, 2022; Visual: Food and Agriculture Organization, 2022

AgTech: Precision Agriculture and Agricultural Robots Could Bring Farming Into the 21st Century

Precision agriculture seeks to maximize crop yields while conserving inputs, such as water, fertilizer, pesticides, and labor. It uses the Internet of Things (IoT), artificial intelligence (AI), and agricultural robots (AgRobots) to monitor and address the needs of specific crops and livestock.

Precision Ag & Robots Converge on Smart Farms

- **Sensors:** IoT-enabled sensors monitor pivotal factors such as moisture, nutrient levels, soil acidity, and plant and livestock health, and then relay the data to the application.
- **GPS:** Exact positioning metrics complement sensors to allow farmers and/or autonomous robots to apply data with geographic accuracy.
- **Software + AI:** Data accumulates from sensors/GPS to offer actionable advice for farmers or instructions for AgRobots that promote better agricultural outcomes.
- **AgRobots:** Autonomous machines, including tractors and drones, splice sensor and GPS data with AI to complete tasks such as tilling, mowing, and monitoring crops and livestock.



Sources: 1. Association of Equipment Manufacturers, et al., 2021 2. Castrignano, et al., 2020 3. Cleary, 2017 4. John Deere, 2021 5. Kollewe & Davies, 2019

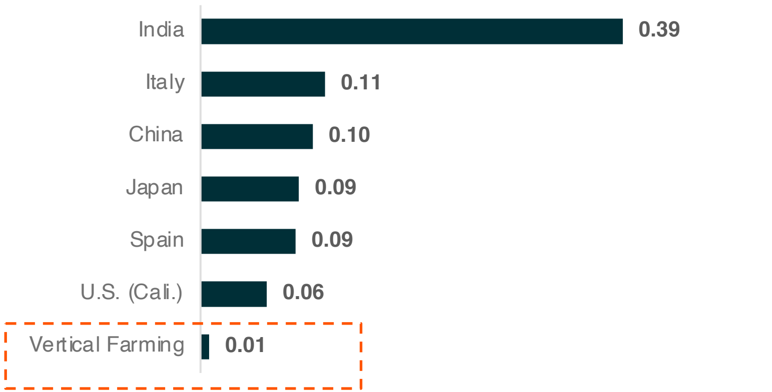
AgTech: Controlled Environment Agriculture (CEA) Helps Overcome Land and Resource Shortages

CEA is the cultivation of plants and their products in non-traditional environments. For example, vertical farms are indoor farms with vertically arranged stacks of crops, and container farms use shipping containers. Greenhouses and micro-farms are also examples.

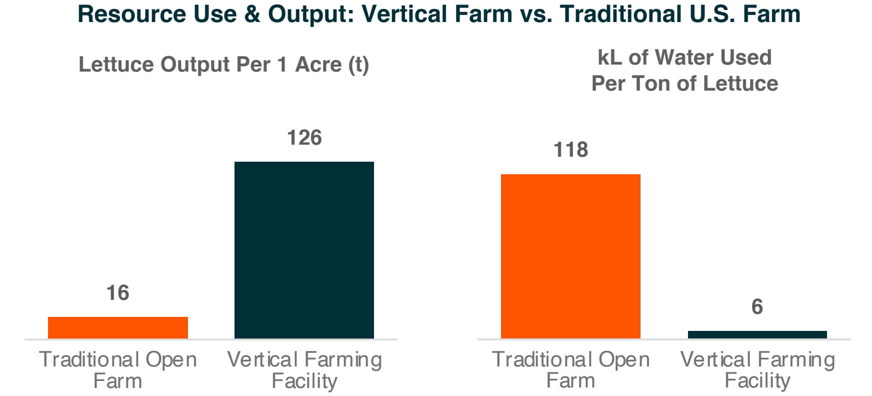
Potential Benefits vs. Traditional Methods

- **Geographic:** Saves space, can grow closer to the end consumer.
- **Less Inputs:** Uses less herbicide, land, and water (95% less).[1]
- **Quality/Productivity:** Year-round production, more crop turns, increased shelf-life.[2]
- **Less Waste:** Proximity to user allows for shorter supply chain and thus less waste.

Vertical farming can bolster agricultural efficiency and multiply potential output.



Vertical farms can produce more output while using fewer inputs than traditional farms.



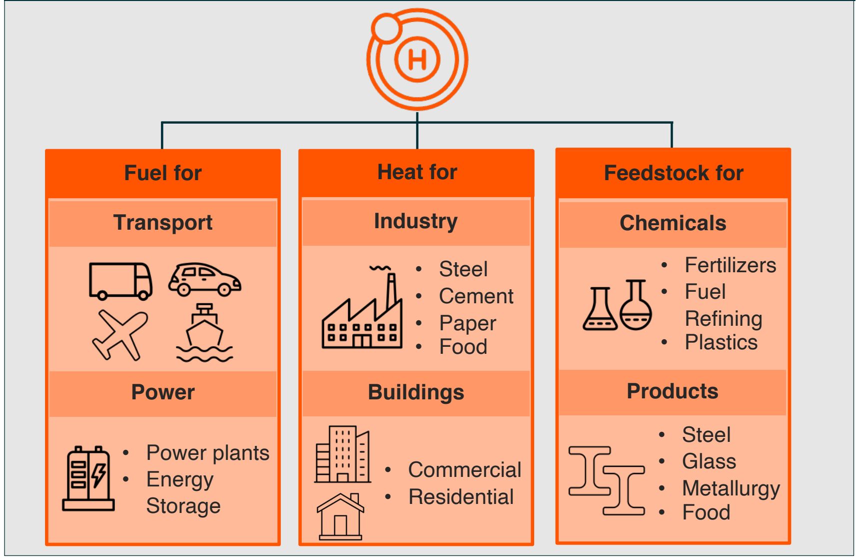
Note: Traditional farm yield based on U.S. 2020 average.

Sources: Text: 1. Gerretsen, 2020 2. S2G Ventures, 2020; Visuals: National Agricultural Statistics Service, 2021; Agrilyst, 2017; Gerretsen, 2020.; Burgos & Stapel, 2018; Hoekstra, 2008; Shatilov, Razin, & Ivanova, 2019

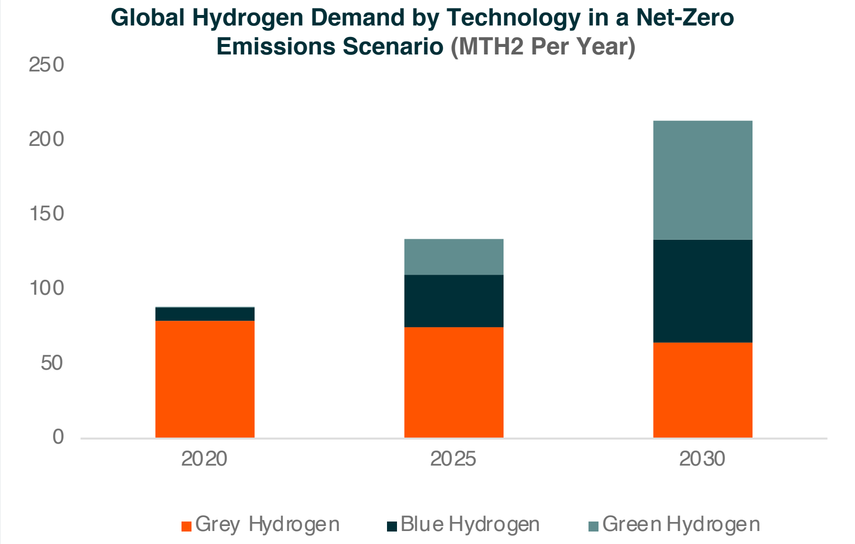
Low-Carbon Hydrogen Can Play a Central Role in Decarbonization Across Industries

Successful decarbonization requires addressing hard-to-electrify sectors such as petrochemical refining, aviation, and shipping. Hydrogen gas (H_2) can be a decarbonization tool. While nearly all the H_2 supply today comes from carbon-intensive grey hydrogen, the future of hydrogen is increasingly sustainable.

H_2 is 3x more energy-dense than gasoline and provides energy without direct emissions.[1]



By 2030, green and blue hydrogen need to account for two-thirds of hydrogen production to stay on track towards net zero by 2050.[2]

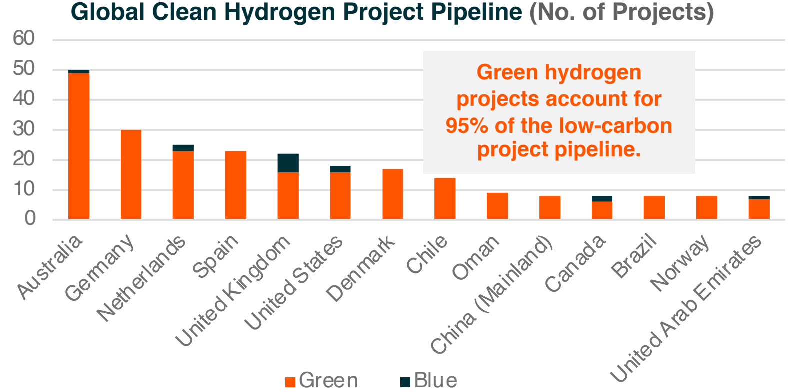


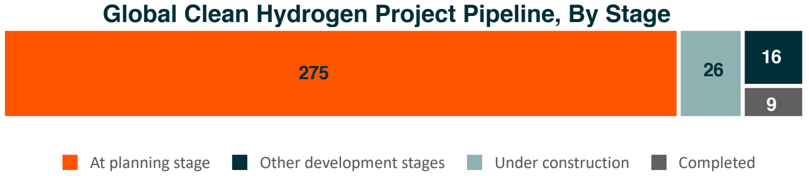
Sources: 1. U.S. Department of Energy, n.d.; 2. International Energy Agency, 2021; Visuals: Mathis & Thornhill, 2019; International Energy Agency, 2021

A Robust Pipeline and Favorable Cost Projections Point to the Creation of a New Global Industry

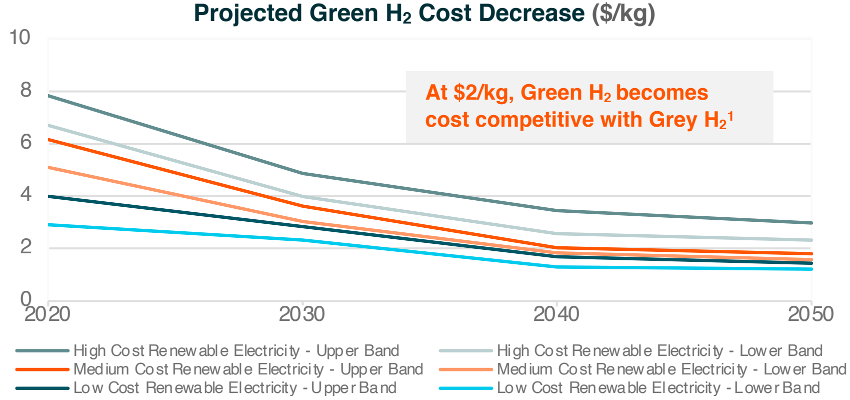
Green hydrogen is poised to become a powerful decarbonization tool across its potential use cases, particularly as electrolyzer costs decline with scale and renewable energy costs decline.

The low-carbon hydrogen project pipeline is expanding in many countries, with Australia and Germany the current outperformers.





The rapid scaling up of green hydrogen projects globally is a key factor in green hydrogen becoming cost-competitive with grey hydrogen.



- Green H_2 production must become cheaper than grey H_2 production for it to become a viable option for widespread use as a decarbonization tool.
- Cost parity could come sooner than projected in countries with the cheapest renewable energy prices, such as Chile, or highly favorable policies. The Inflation Reduction Act's Clean Hydrogen Production Tax Credit could lead green and blue hydrogen to become cost-competitive in the United States.

Sources: Visuals (LHS): Fitch Solutions, n.d.; Visual (RHS): World Energy Council, 2022

Government Policy, Developers, and Consumer Preferences Catalyzing Green Building Market

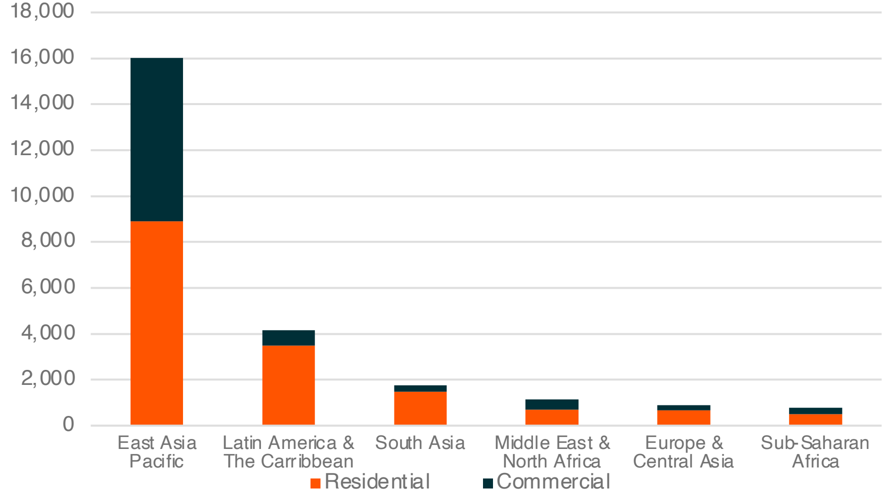
Buildings are responsible for up to 37% of energy-related carbon emissions and 50% of all extracted materials.[1] By 2050, nearly 70% of the world's population is projected to live in urban areas, which will require 2x the buildings stock.[2,3] Green buildings can address these needs more sustainably.

Green Buildings Represent a Multi-Trillion Dollar Opportunity

- Green buildings represent a $24.7 trillion investment opportunity from 2019 to 2030 in emerging markets (EMs) alone, driven by population growth in urban areas.[4]
- Retrofitting buildings to meet green building standards in EMs could be an additional $1.1 trillion opportunity.
- Retrofitting opportunities are likely even greater in developed countries in North America and Europe.[5] In Europe, more than 75% of buildings were built before green building legislation came into force.[6]
- Environmental regulations drive green building demand. Notably, 136 countries, 28 major cities, and 1000s of smaller cities include green building targets and/or initiatives within climate change mitigation plans.[7]

The East Asia Pacific and Latin America & Caribbean regions could be leaders in opportunities for new green building development.

New Green Building Investment Opportunity by Property Type and Region ($ Billions)



Sources: Text: 1. International Energy Agency, 2021; 2. Ibid.; 3. World Green Building Council, 2021; 4. International Finance Corporation, 2020; 5. International Finance Corporation, 2022; 6. Scott, 2021; 7. World Green Building Council, 2021; Visual: International Finance Corporation, 2020

Potential Benefits of Green Buildings Are Widespread

Green buildings have higher upfront costs, and the green designation requires the completion of a certification process, but they offer several potential benefits over traditional buildings.

From lower operating costs to healthier, more resilient communities, green buildings can benefit developers and occupants alike.

Increased environmental and financial resiliency: In their design, green buildings can boost resiliency against climate change and extreme weather events, and they can lower the risk of becoming stranded assets.

Access to preferential insurance premiums and green financing: Green building developers can often access preferential insurance and loan rates due to the lower risk of stranded assets and increased resiliency. In 2019, $66 billion in green bonds were issued globally for green buildings, accounting for 28% of all green bonds issued that year.

Lower operating costs: On average, green buildings in the United States use 25% less energy and have operating and maintenance costs that are 10–20% lower than traditional buildings.

Enhanced return on investment: Lower operation and maintenance costs can yield higher returns on investments compared to traditional buildings.

Improved health and wellbeing of building occupants and community: A green building can also boost the health and wellbeing of its occupants and the surrounding community. Notably, the COVID-19 pandemic accelerated the push for healthier buildings, including advanced air filtration systems.

Source: World Green Building Council, 2021

Power of Machine Learning in Climate Change Solutions

Azeem Azhar

From the monitoring of deforestation and emissions to the implementation of smart cities, machine learning is a powerful tool that can be used across a variety of climate change mitigation and adaptation solutions.

Machine learning can play a central role in many applications designed to reduce greenhouse gas emissions and improve climate resiliency.

Power & Industry

- Optimize operations
- Perform preventative maintenance
- Optimize supply chains and shipping routes
- Forecast electricity supply and demand
- Reduce waste

Cities & Buildings

- Model energy use across buildings
- Provide data for smart cities
- Utilize intelligent control systems in buildings
- Reduce transportation activity
- Improve disaster management

Agriculture & Land Use

- Optimize yields with precision agriculture
- Predict food demand and monitor food supply
- Manage forest fires and monitor deforestation
- Estimate carbon stock
- Utilize remote sensing to monitor emissions
- Improve ecological awareness and resilience

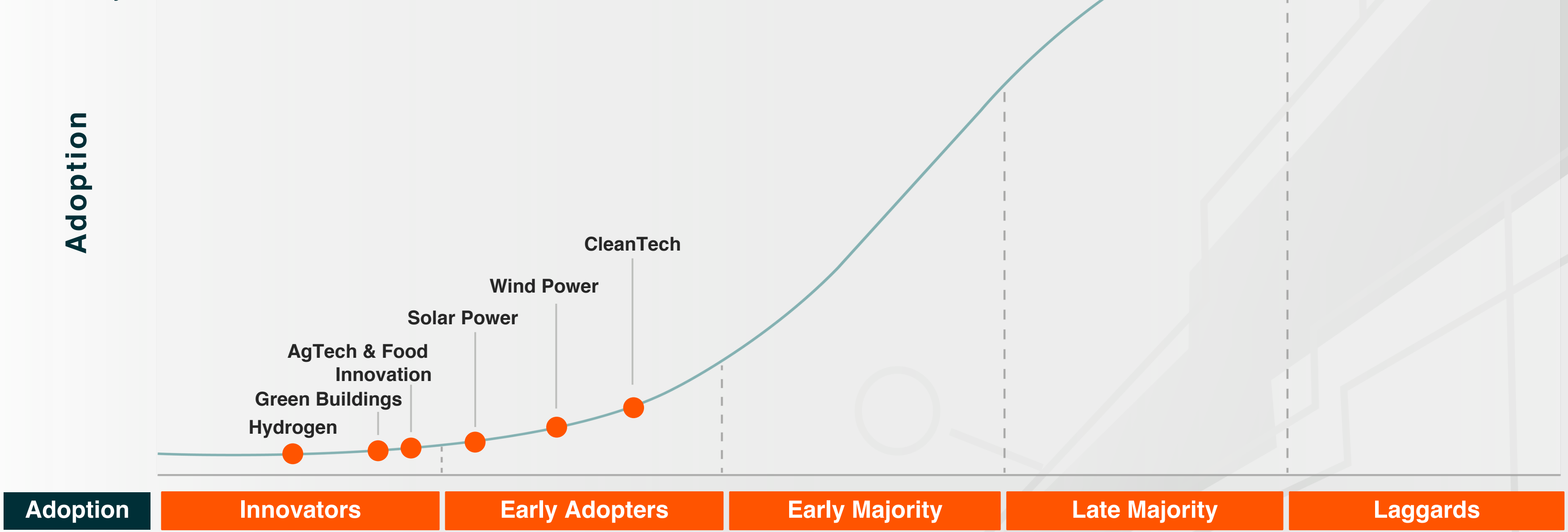
Renewable Energy

- Optimize system operation and maintenance
- Forecast wind and solar resources and power generation
- Accelerate materials science

Source: Rolnick, Donti, Kaack, Kochanski, Lacoste, Sankaran, Ross, Milojevic-Dupont, Jaques, Waldman-Brown, Luccioni, Maharaj, Sherwin, Mukkavilli, Kording, Gomes, Ng, Hassabis, Platt, Creutzig, Chayes, & Bengio, 2022

S-Shaped Curve of Adoption – Climate Change

Technology-driven solutions for climate change are still in the early stages of adoption. To keep global warming under 2°C, these technologies will need to scale rapidly, requiring up to an estimated $131 trillion in investments by 2050.[1] In the power sector, nearly 90% of generation could come from renewables in a net-zero economy.[2]



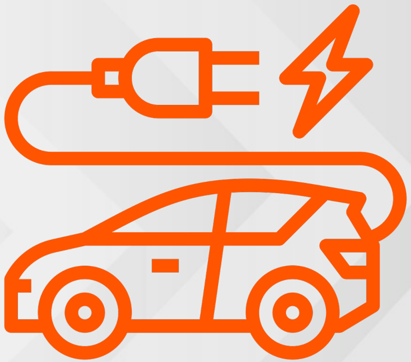
Sources: Text: 1. International Energy Agency, 2021a; 2. International Energy Agency, 2021b

Displayed for illustrative purposes. Curve shape not indicative of mathematical transformation

Chapter 05

Mobility

Accommodative government policy and technological improvement support rapidly increasing consumer adoption of electrified transportation options. This ongoing structural shift in mobility also draws attention to the importance of supply chains for critical materials, especially lithium.

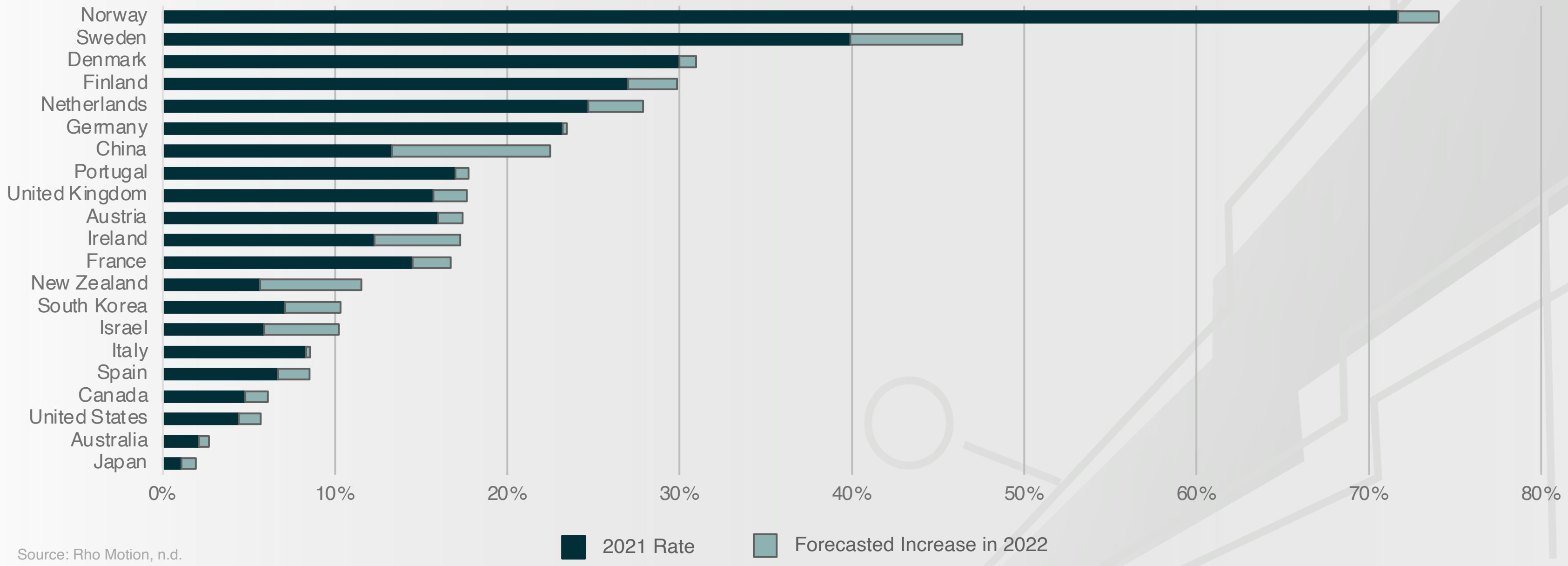


EV Market Penetration Could Continue to Expand in 2022

Adam Panayi

Adoption of passenger and light-duty electric vehicles (EVs) has increased dramatically in recent years. Despite a challenging economic backdrop and supply chain disruption, EV penetration rates are expected to increase in most major markets in 2022.

EV Passenger Cars and Light-Duty Vehicle (PC & LDV) Market Penetration Rates by Country, 2021 vs. 2022 (%)

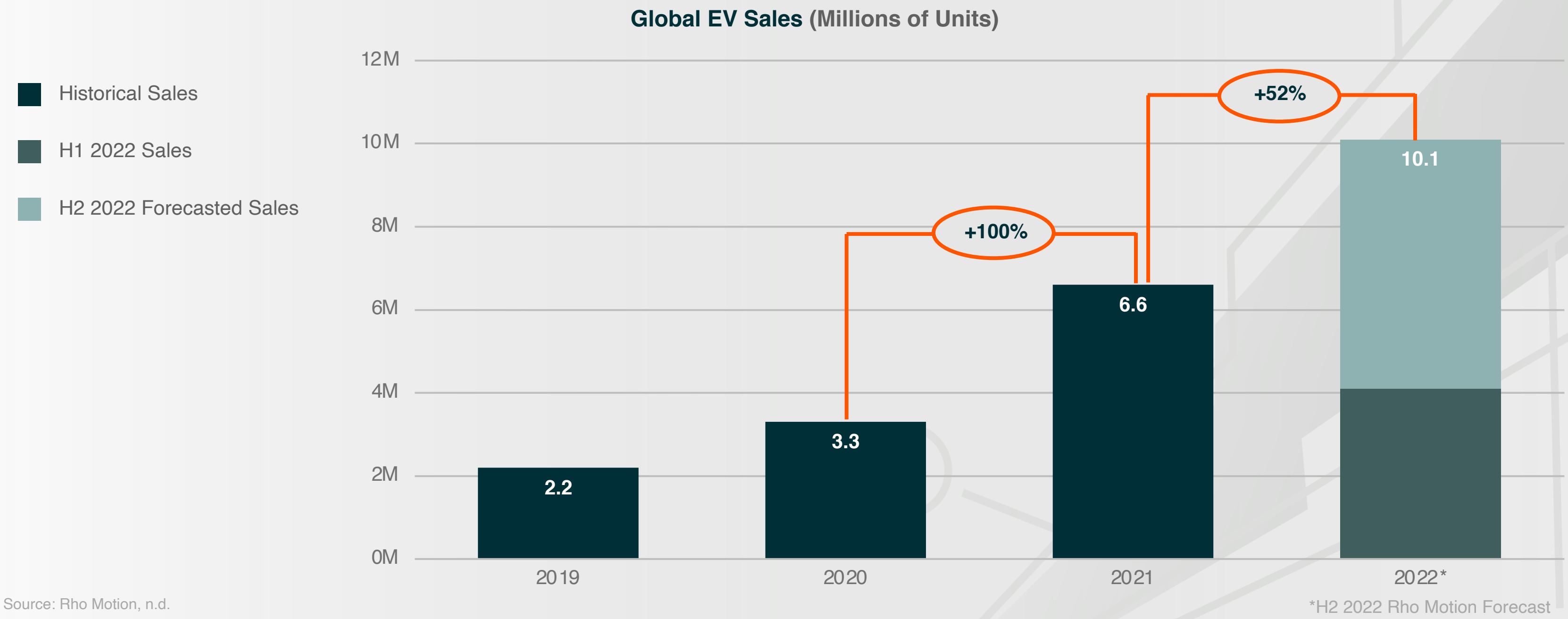


Source: Rho Motion, n.d.

Global EV Sales Poised to Continue Momentum

Adam Panayi

Total EV sales reached 4.1 million units in the first half of 2022, a 57% increase against the comparable 2021 period. Rising EV sales also come with the broader automobile market forecasted to decline 4% year-over-year.



Source: Rho Motion, n.d.

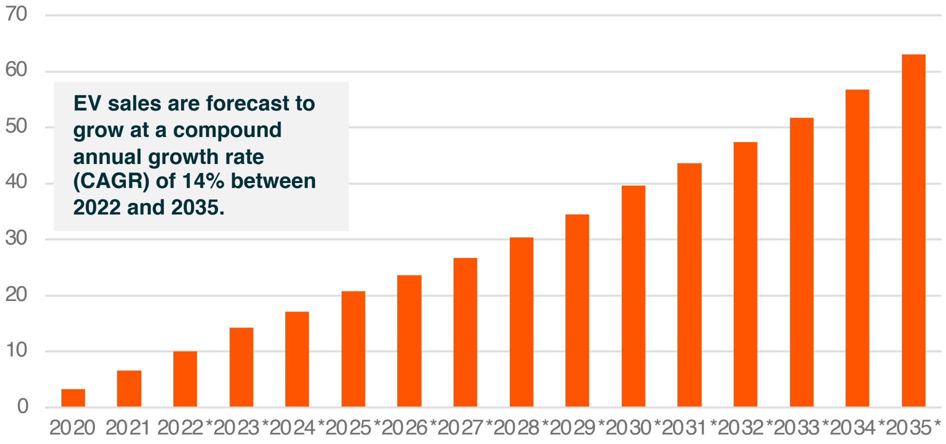
The Unstoppable Road to Electrification Is on the Fast Track

EV sales are reaching an inflection point as governments, auto manufacturers, and consumers accelerate the shift away from internal combustion engines. Expected technology innovations and the buildout of supportive EV charging infrastructure provide additional support for robust EV growth outlooks.

EVs, including battery EVs (BEVs) and plug-in hybrid EVs (PHEVs), are forecast to reach annual sales of 63.1 million units in 2035, up from a projected 10.1 million units in 2022.

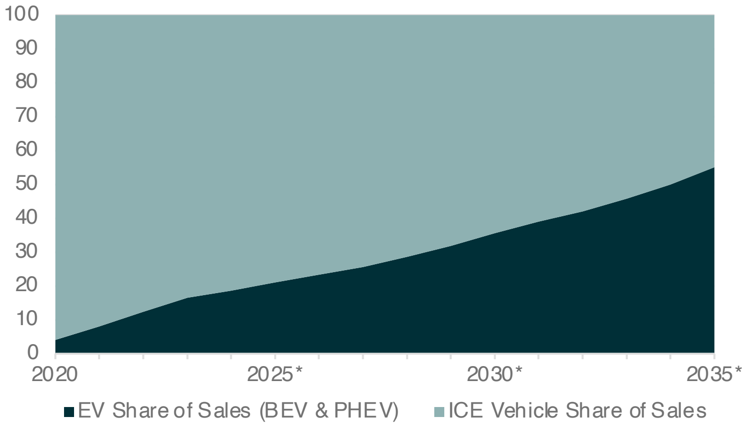
EVs could reach a combined 36% sales penetration rate by 2030 and 55% by 2035. In 2022, EVs are forecast to comprise 12.5% of sales.

Global Electric Vehicle Sales (Millions of Units)



Source: Global X analysis of information derived from Rho Motion, 2022.

Market Penetration Rate by Vehicle Type (%)



*Forecast

Increasingly Supportive Policy Landscape Bolsters Outlook for EV Adoption

Supportive policies in major auto markets like the United States, China, and Europe are accelerating EV adoption.

Europe

- **GERMANY:** In 2023, subsidies of up to €4,500 will be available until the €3.4 billion allocated sum for next two years' budget is spent.[1]
- **FRANCE:** In 2023, subsidies of up to €5,000 will be available for qualifying EV purchases.[2] Additionally, an incentive scheme for leasing EVs is set to launch in 2023 with €1.3 billion in funding.

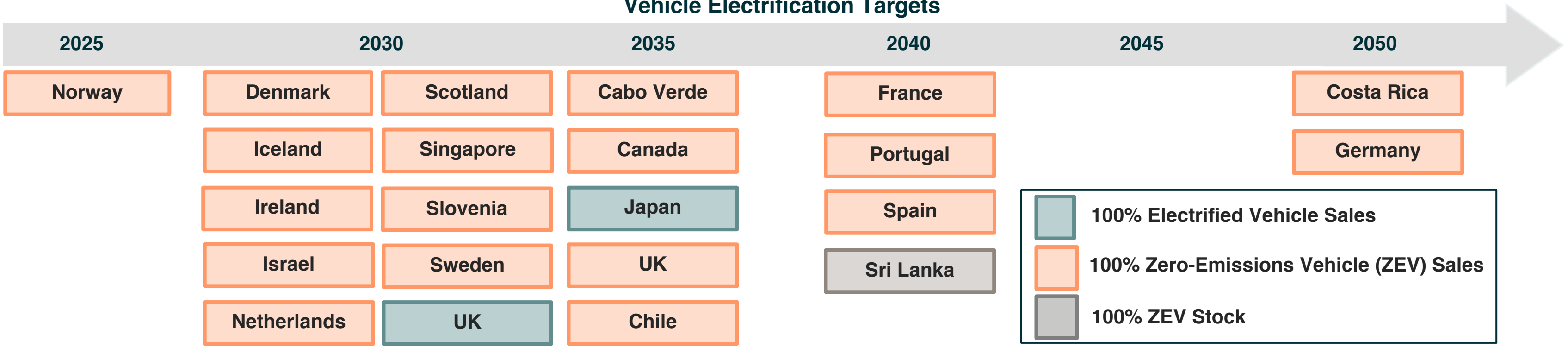
Asia

- **CHINA:** In 2022, China extended its vehicle purchase tax exemption for EVs through year-end 2023. Additional incentives are available at national and sub-national levels.[3]
- **INDIA:** In 2021, India extended its EV-focused FAME II Policy to 2024. The scheme includes subsidies for electric two-wheelers and cars.[4,5]

United States

- The **Inflation Reduction Act**, passed in August 2022, extends the $7,500 tax credit for new EVs and creates a tax credit for used EVs of up to $4,000.[6]
- The **Infrastructure and Investment Jobs Act (IIJA)**, passed in November 2021, allocates $7.5 billion to support the buildout of EV charging infrastructure.[7] The U.S. government is targeting 500,000 chargers by 2030.[8]

Vehicle Electrification Targets



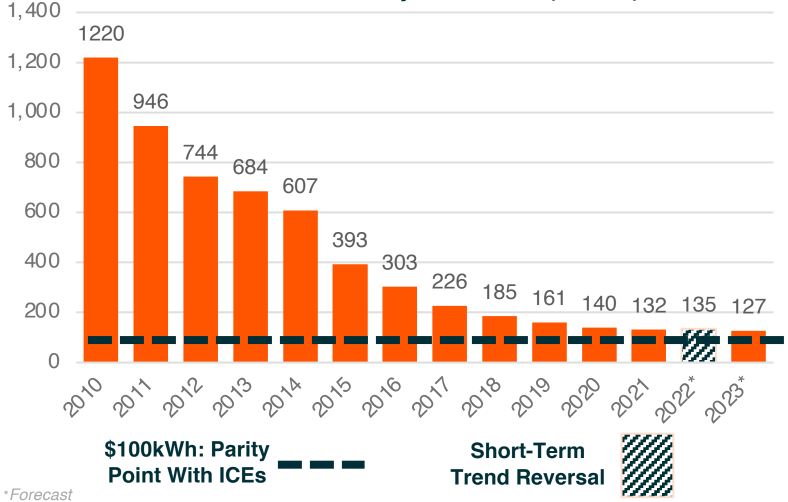
Sources: Text: 1. Roberts, 2022; 2. Morgan, 2022; 3. Rho Motion, 2022; 4. Ibid.; 5. International Energy Agency, 2022; 6. Senate Democrats, 2022; 7. U.S. Department of Transportation, 2022; 8. The White House, 2021; Visuals: International Energy Agency, 2021; International Energy Agency, 2022; Rho Motion, 2022

EV Battery and Vehicle Costs Are Expected to Increase in 2022 but Decline Over the Long Term

Lithium-ion battery prices fell 89% between 2010 and 2021, bringing EV prices close to parity with ICE vehicles.[1] While higher materials costs and supply chain challenges are likely to result in slight increases in battery pack and EV prices in 2022, cost declines are expected over the long term.[2]

Rising commodities prices and component costs increased EV battery pack and EV prices in 2022.[3]

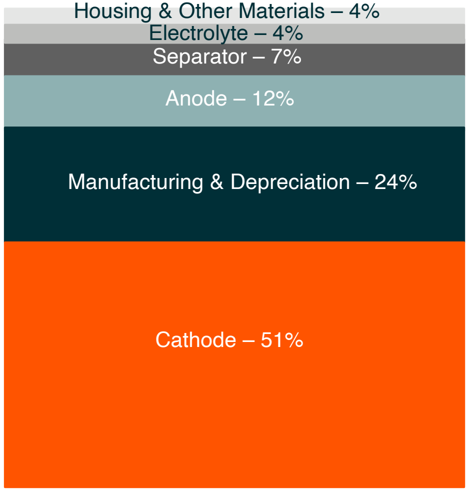
Lithium-Ion Battery Pack Price ($/KWH)



*Forecast

EV battery & EV costs can fall as tech advances, cell chemistry shifts, economies of scale take effect, and manufacturing improves.[4]

Share of Battery Cell Cost, by Component

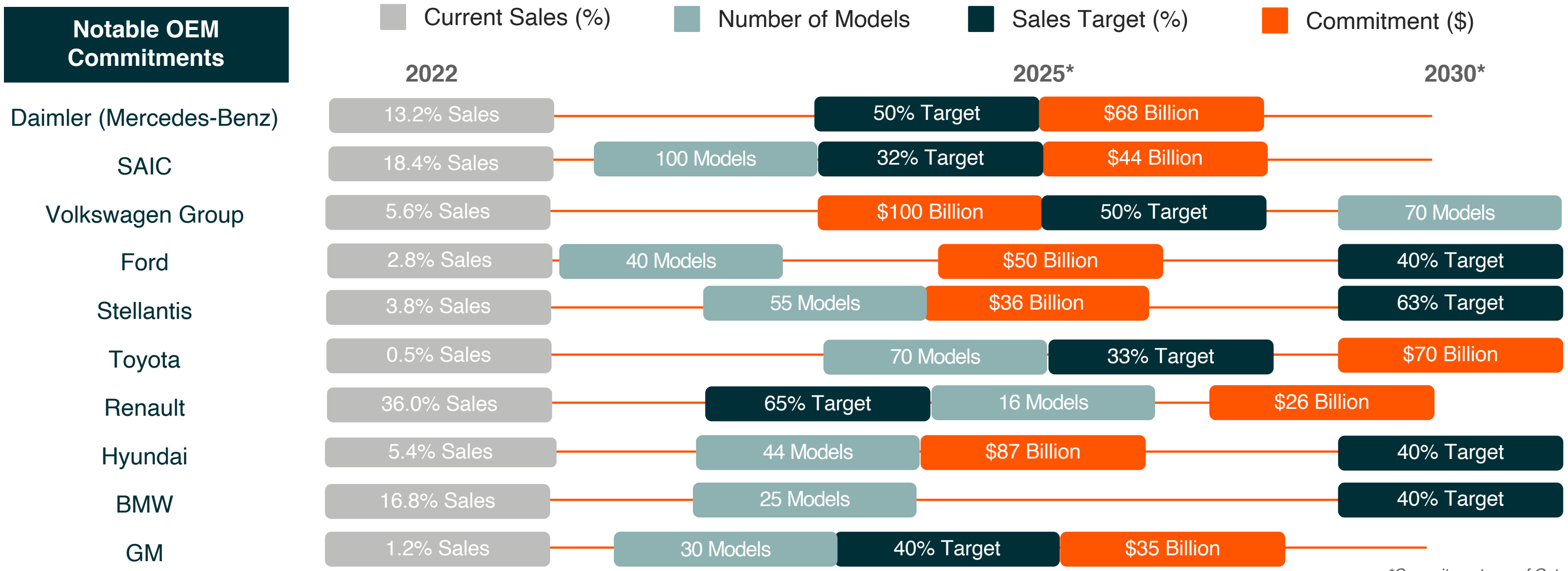


Note: Percentages may not add up to 100% due to rounding

Sources: Text: 1. Bloomberg NEF, 2022; 2. Ibid.; 3. Ibid.; 4. Bloomberg NEF, 2021; Visuals: Bloomberg NEF, 2022; Bhutada, 2022

Traditional Auto OEMs Shifting Towards Electric Future

With EV sales growth outpacing ICEs, traditional auto original equipment manufacturers (OEMs) are offering a wider range of EV models, committing billions of dollars of investment capital to retool factories, and targeting higher percentages of EV sales.



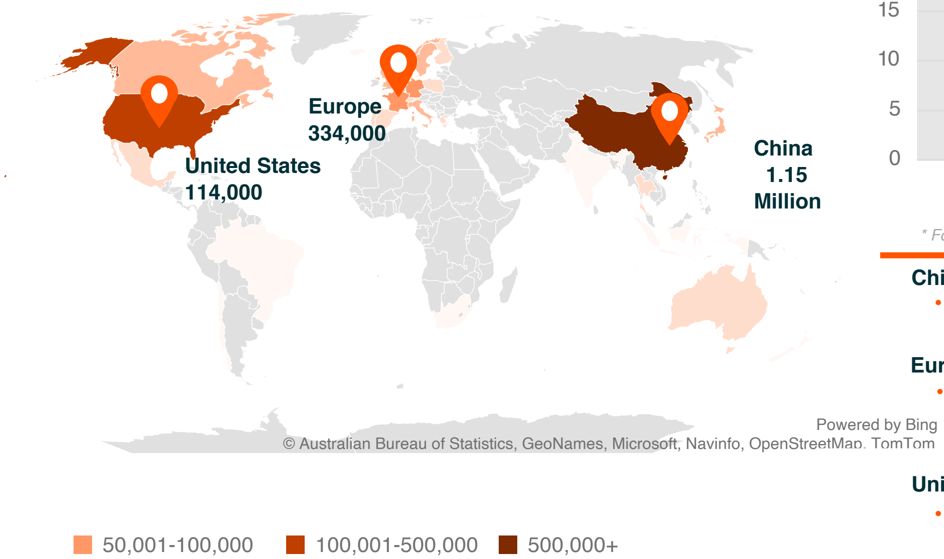
**Commitments as of October 2022.*
EV Sales Share as of most recent reportable period, as of publishing date.

Sources: See Appendix: Sources – Mobility

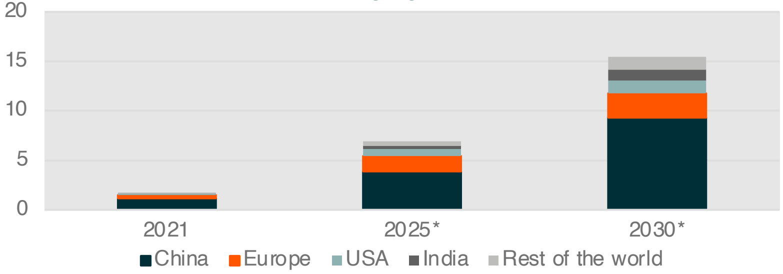
Growth in EV Charging Infrastructure Can Encourage Adoption

While EV range remains a concern due to limited charging networks, countries are working to build out charging points. More robust networks could play a key role in boosting consumer sentiment and EV adoption in China, Europe, the United States, and India.

Number of Battery EV Charging Points by Country (2021)



Number of EV Charging Points (Millions)



** Forecasts based on IEA's Announced Policies Scenario.*

China[1]

- China's government aims to build out charging infrastructure to meet demand for 20 million EVs by 2025.

Europe[2]

- The EU proposed billions in support to build out an EV charging network. The EU targets 1 million electric and hydrogen vehicle charging stations by 2025.

United States[3,4]

- The U.S. government aims to build out a network of 500,000 EV chargers by 2030 with $7.5 billion in funding through the IIJA.

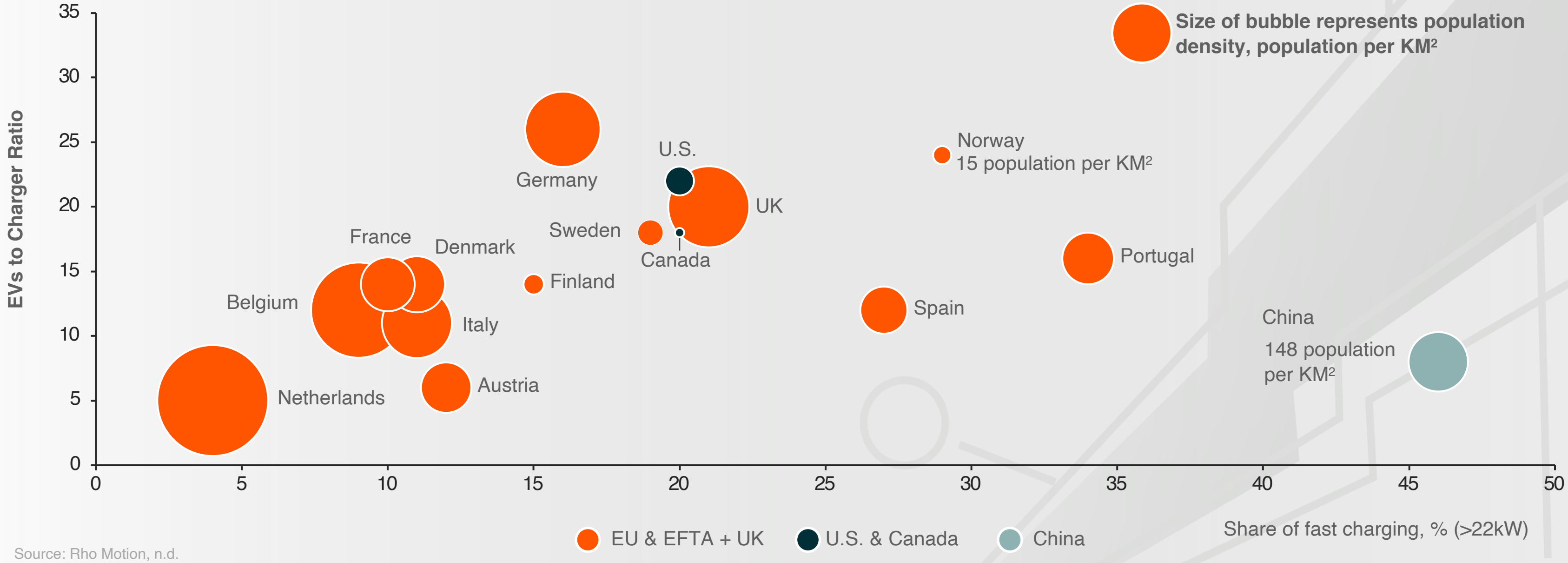
Sources: Text: 1. Conrad, 2022; 2. Virta Global, 2022; 3. U.S. Department of Transportation, 2022; 4. The White House, 2021; Visuals: International Energy Agency, 2022

EV Charging Station Needs Vary by Market

Adam Panayi

Several key market dynamics shape public EV charging demand. Charger availability and faster charging times generally support the adoption of EVs; however, there is nuance. For example, due to low population density, Norway finds success with a lower charging station count relative to the total number of EVs.

The Number of EVs to Charging Points by Country, % of Fast Charging (YTD as of August 2022)



Source: Rho Motion, n.d.

GLOBAL X by Mirae Asset

Exploring the Electric Mobility Landscape: Upstream

Raw lithium extracted from brine or spodumene deposits must be chemically processed before it can be used in a battery. These steps constitute the upstream segment of the electric mobility landscape.

1 Raw Material Extraction

The main sources of raw lithium are underground deposits of brine and spodumene, a hard rock mineral.

Major Companies[1]

- **SQM** (20% market share 2021)
- **Ganfeng** (18% market share 2021)
- **Albemarle** (18% market share 2021)

2 Chemical Processing

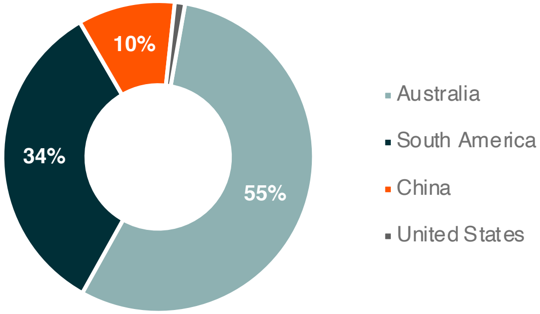
Preparing lithium for battery use requires chemical processing to produce lithium carbonate or lithium hydroxide with minimal contaminates.

Lithium Carbonate: Produced from hard rock (spodumene deposits) or lithium brines.

Lithium Hydroxide: Can be extracted from mineral deposits or converted from lithium carbonate.

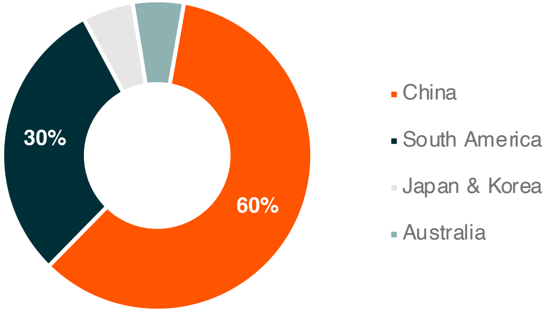
Mining is the only component of the lithium value chain where China does not have a dominant share.

Lithium Mining Market Share by Country (%)



Limited lithium refining expertise exists outside of China, Argentina, Bolivia, and Chile.

Lithium Chemical Processing Market Share by Country (%)



Sources: Text: 1. Jephcott, 2022; Visuals: Norris, 2022; Rho Motion, 2022

Exploring the Electric Mobility Landscape: Midstream

The next component of the electric mobility value chain involves the manufacturing of lithium-ion batteries. This process requires activity on the battery component space and cell assembly side. China has dominant shares in the midstream segment.

3 Cathode & Anode Production

Lithium carbonate or hydroxide is inserted into the battery's cathode, determining its capacity and voltage.

Common Lithium-Ion Battery Chemistries

- **Nickel Cobalt Manganese (NCM) 622 and 811**
- **Lithium Iron Phosphate (LFP)**

4 Lithium-Ion Cell Manufacturing

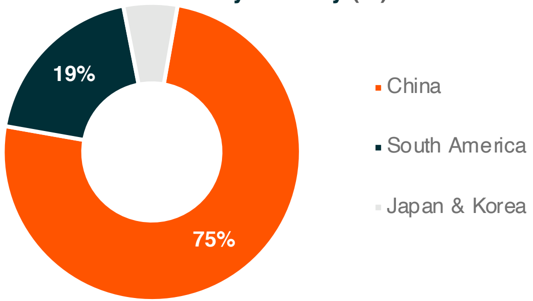
Cell assembly and electrolyte filling and formation results in the final lithium-ion battery product.

Major Companies[1]

- **CATL** (34% market share 2022)
- **LG Energy Solution** (17% market share 2022)
- **BYD** (14% market share 2022)

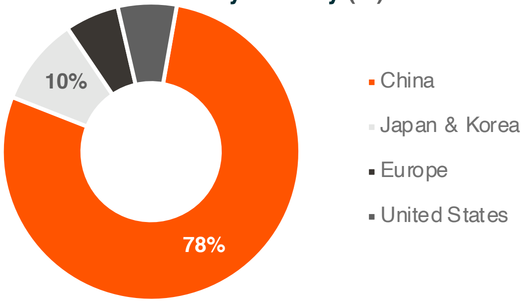
In recent years, China gained market share in the cathode and anode production space to effectively control the midstream segment.

Cathode and Anode Production Market Share by Country (%)



Although China is expected to maintain a strong advantage in battery manufacturing, Europe and the United States could gain market share.

Lithium-Ion Cell Manufacturing Market Share by Country (%)



Sources: Text: 1. Jephcott, 2022; Visuals: Norris, 2022; Rho Motion, 2022

Exploring the Electric Mobility Landscape: Downstream

EVs and other electrified transportation end uses constitute the downstream segment of the electric mobility landscape. Ultimately, the structural shift towards these vehicle options drives demand for lithium and lithium-ion batteries.

5 EV Sales and Other Electrified Mobility

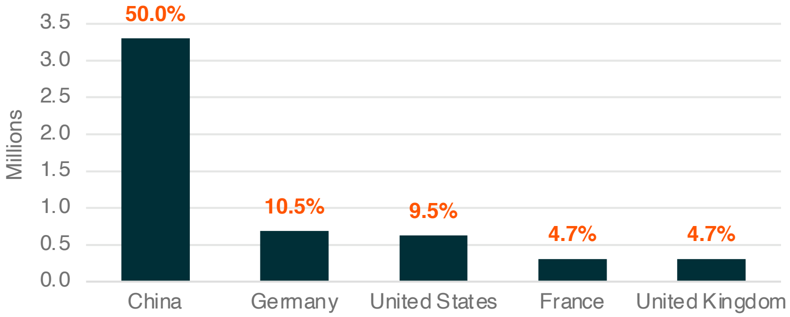
Rechargeable lithium-ion batteries power EVs, providing the most common form of end-use electric mobility. This segment also includes options ranging from e-bicycles, motorcycles, hoverboards, scooters, and other forms of electrified transportation.

Most Popular Fully Electric Models Globally (H1 2022)[1]

1. Tesla Model Y
2. Tesla Model 3
3. Wuling HongGuang
4. Volkswagen ID.4
5. BYD Dolphin
6. BYD Yuan Plus
7. Chery QQ Ice Cream
8. Hyundai Ioniq 5
9. Changan Benni
10. Chery eQ1

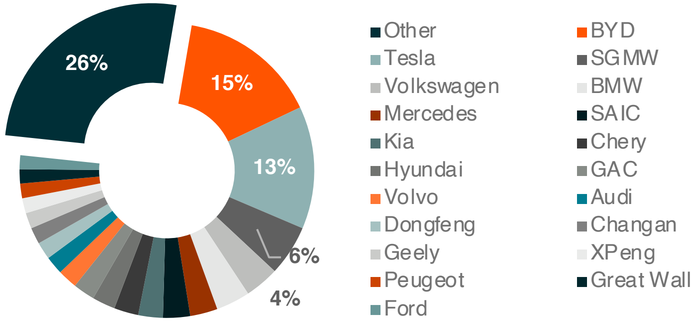
The top five countries in EV sales accounted for almost 80% of the global market in 2021.

EV Sales by Country (Millions) and Global Market Share (%)



The global EV market is highly competitive, led by dedicated EV makers BYD and Tesla.

H1 2022 Top 20 EV Producers Global Market Share (%)



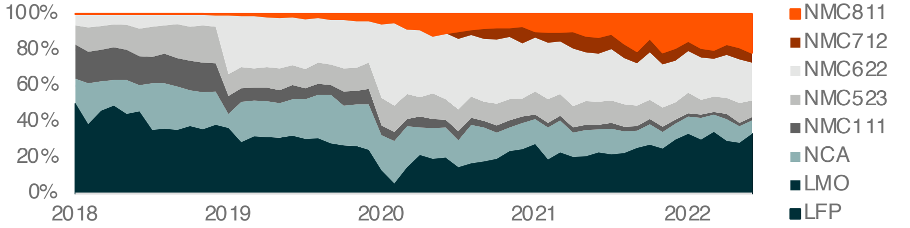
Sources: Text: 1. Pontes, 2022; Visual (LHS): International Energy Agency, 2022; Visual (RHS): EV Volumes, 2022

Battery Material Content: Lithium-Ion Batteries and Beyond

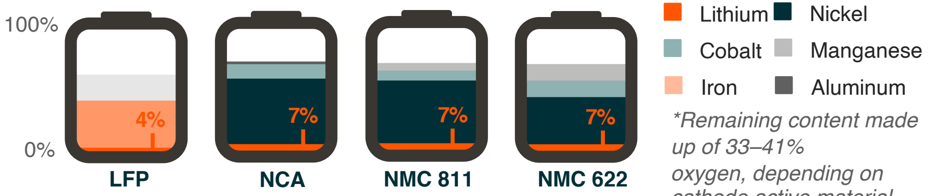
Lithium-ion chemistries vary widely, and battery makers continue to experiment with different combinations to optimize their use in EVs. Lithium is the common thread to currently viable battery types and next-generation battery tech.

The most common EV battery chemistries are currently lithium iron phosphate (LFP), nickel cobalt aluminum (NCA), and nickel manganese cobalt (NMC).

Average EV Battery Cathode Chemistry Across All Vehicle Classes (%)



Metal Content by Battery Chemistry (Weight %, Excluding Oxygen Content*)



**Remaining content made up of 33–41% oxygen, depending on cathode active material*

Most solid-state batteries are expected to require lithium metal, particularly for the anode.

Solid Power Proposed Lithium Metal EV Cell Design[1]

Quantumscape Proposed Lithium Solid State-Battery Design (Charged)[2]

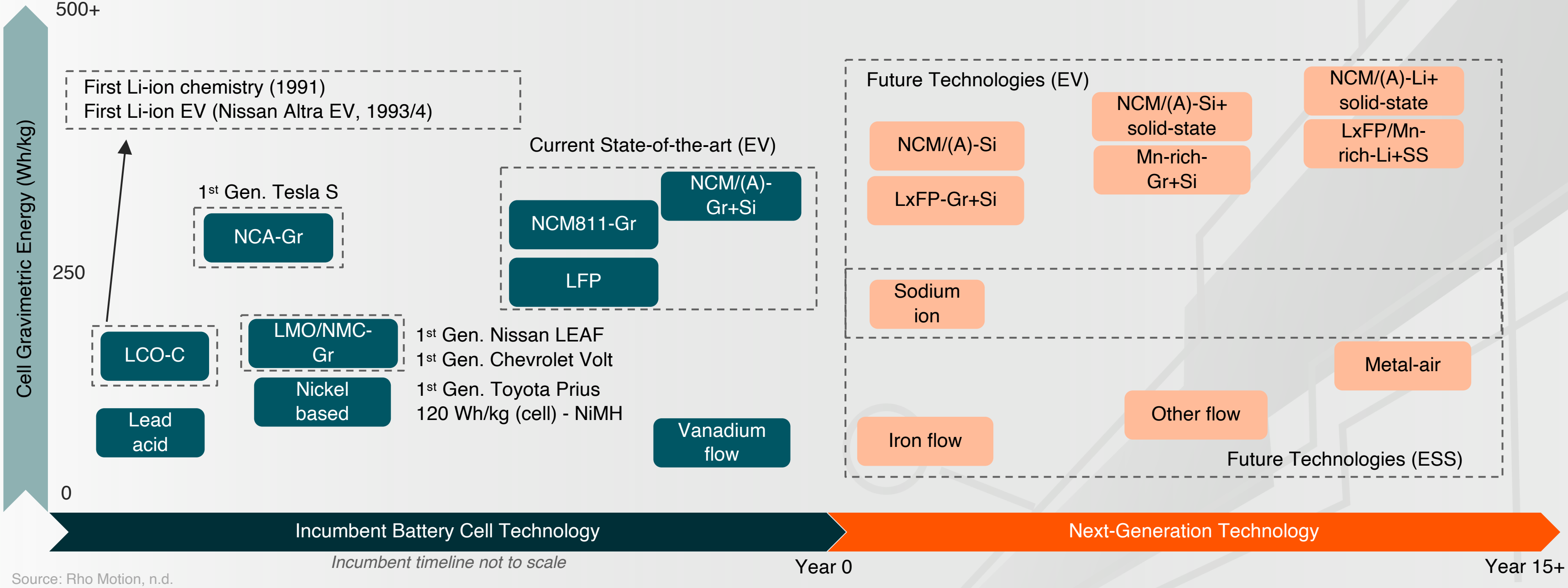
Solid-state technology could help lower EV costs, reduce charge times, and improve safety.

Sources: Text: 1. Solid Power, n.d.; 2. Miller, 2021; Visuals: Kresse, Bastian, Bookhagen, & Frenzel, 2022; Rho Motion, 2022

Battery Technologies for EV: Technical Roadmap

Adam Panayi

Most EVs are powered by advanced lithium iron phosphate (LFP) and nickel cobalt manganese (NCM). Future technology is expected to improve upon, but not entirely replace, these battery archetypes. Innovations such as solid-state technology will seek to deliver light-weight batteries capable of storing and delivering more energy.



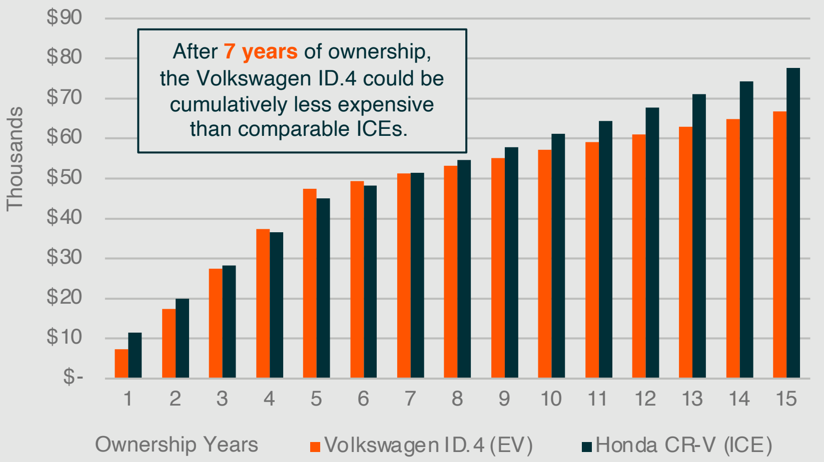
Source: Rho Motion, n.d.

EV vs. ICE Ownership Cost Comparisons in the United States

As EV costs approach cost parity with ICEs, EVs could become more accessible to consumers. Tax credits and relatively low maintenance and fueling costs already present enticing value propositions for EV ownership.

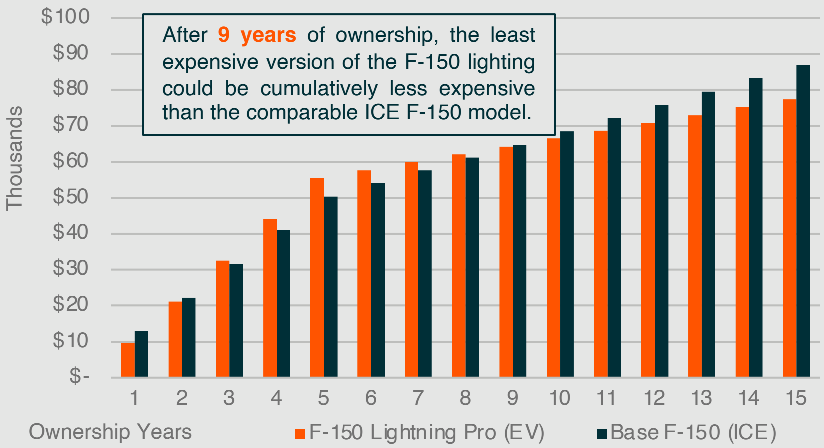
Cumulative costs for traditional compact SUVs could quickly catch up to their EV counterparts in the United States.

Cumulative Cost of Ownership by Year, Volkswagen ID.4 vs Honda CR-V (2022 Models, EV Tax Credit Applied)



After years of ownership, the least costly electric F-150 could be more cost effective than base models of America's best-selling vehicle.

Cumulative Cost of Ownership by Year, F-150 Lightning Pro vs Base F-150 (2022 Models, EV Tax Credit Applied)



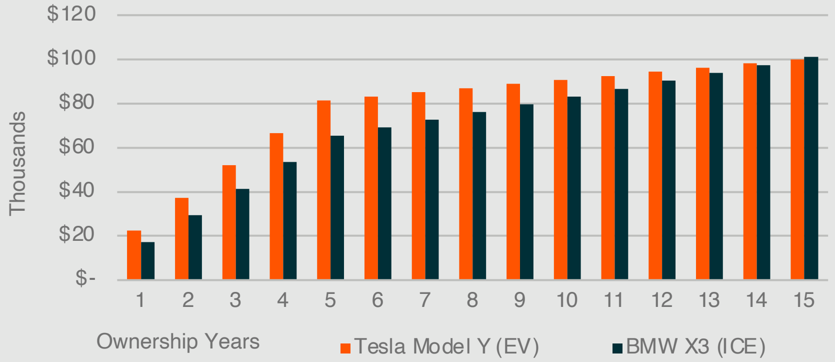
Sources: Both Visuals: Alternative Fuels Data Center, n.d.; Marticio, 2022; Cagatay, n.d.; Valdes, 2022; U.S. Energy Information Administration, n.d.; Witt, 2022; Bradley, 2022; Covington, 2022; Brady & Adams, 2022; Visual (LHS): Bornhop, 2022; Kurczewski, 2022; Visual (RHS): Brandt, 2022; Brooks, 2022

EV vs. ICE Ownership Cost Comparisons in the United States: Tax Credit Implications

Tax credits carry powerful implications for EV ownership costs. In the United States, EV tax credits will reconfigure under the Inflation Reduction Act from 2023 onward. For 2022, a maximum of $7,500 in tax credits apply to most EVs.

Companies like Tesla and GM are ineligible for tax credits after selling 200,000 vehicles in the United States.

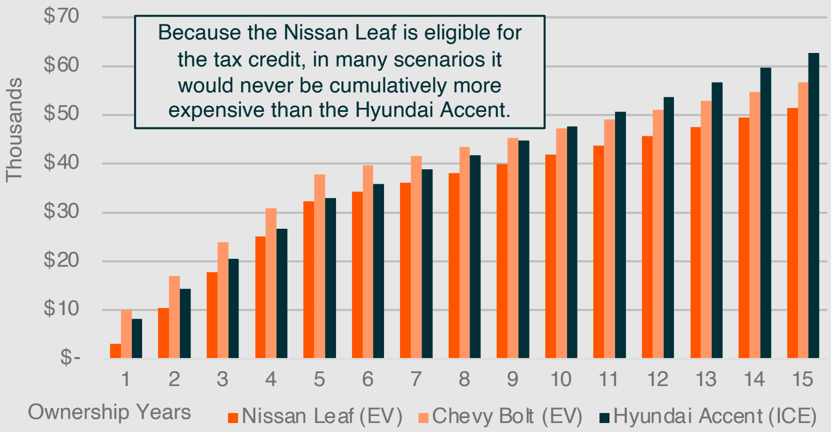
Cumulative Cost of Ownership by Year, Tesla Model Y vs BMW X3 (2022 Models, Ineligible for EV Tax Credit)



It can take **15 years** before ownership of the Tesla Model Y produces cumulative savings against comparable ICEs. Resumed eligibility for the tax credit could cut this time down to 9–10 years.

Eligibility for the tax credit plays an outsized roll in cumulative savings at lower EV price points.

Cumulative Cost of Ownership by Year, Nissan Leaf & Chevy Bolt vs Hyundai Accent (2022 Models, EV Tax Credit Applied to Nissan Leaf)



Sources: Both Visuals: Alternative Fuels Data Center, n.d.; Marticio, 2022; Cagatay, n.d.; Valdes, 2022; U.S. Energy Information Administration, n.d.; Witt, 2022; Bradley, 2022; Covington, 2022; Brady & Adams, 2022; Visual (LHS): Brandt, 2022; Visual (RHS): Brandt, 2022-a; Ryan, 2022a; Ryan, 2022b

Fuel Cells 101

Adam Panayi

A fuel cell creates the conditions for an electrochemical reaction to occur between oxygen and hydrogen that yields electricity. If this supply of hydrogen is sourced sustainably, fuel cells could be used to cut greenhouse gas emissions in transportation.

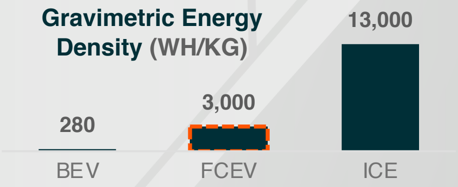
The What?

Fuel cell electric vehicles (FCEVs) are electric vehicles that operate using compressed hydrogen gas as fuel and whose only tailpipe emission is water vapor and heat.

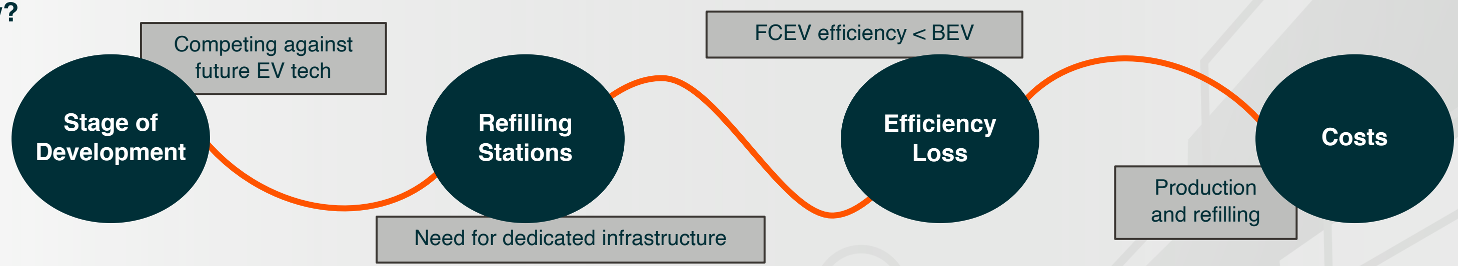
Hydrogen + Oxygen → Electricity + Water

The Why?

- ↑ Energy Density
- ↓ Refill Time
- ↑ Hydrogen Production



The How?



The When?

FCEV development will likely be in markets not directly competing with EVs, primarily long-haul commercial, medium-duty bus, and coach.

Sources: Text: Johnson & Cox, 2022; Visual: Dealroom, Co.

Hydrogen Fuel Cell EVs Create Opportunity to Decarbonize Medium- and Heavy-Duty Vehicles

Battery EVs (BEVs) accounted for a robust 71% of sales in 2021, while hybrid EVs made up roughly 28% and fuel cell EVs (FCEVs) less than 1%.[1] FCEV technology is an attractive zero-carbon emission option for buses, trucks, and heavy industry vehicles.

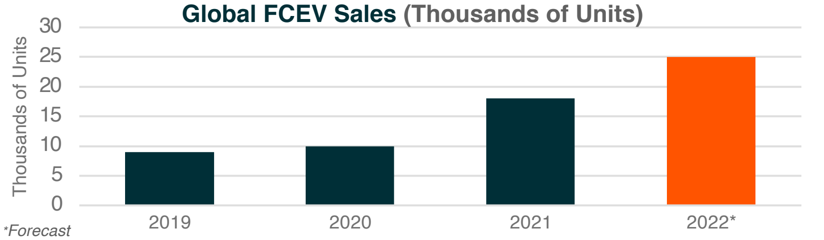
FCEVs offer three key potential advantages over BEVs for buses, long-haul trucking, and heavy industry uses.

1. Higher energy storage density[2]: For a 500-mile range truck, the hydrogen fuel cell powertrain can be 2 tons lighter than the battery electric powertrain.

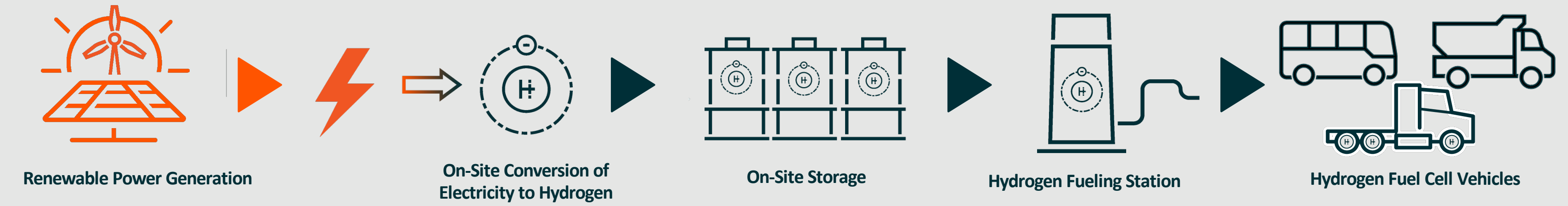
2. Shorter refuel time[3]: Hydrogen fueling stations are similar to gas stations. FCEV trucks can be refueled in a few minutes, significantly shorter than the charging time required for similarly-sized BEVs.

3. Better performance in cold weather conditions[4]: On average, battery electric buses lose 37.8% of their range when the temperature falls from 50–60˚F to 22–32˚F, compared to just 23.1% for hydrogen fuel cell buses.

Total FECV sales are forecast to increase in 2022, led by growth in the heavy-duty vehicle segment.



Wind and solar power can be used to produce zero-carbon green hydrogen, which then can be used as a primary fuel source for hydrogen FCEVs.[5]



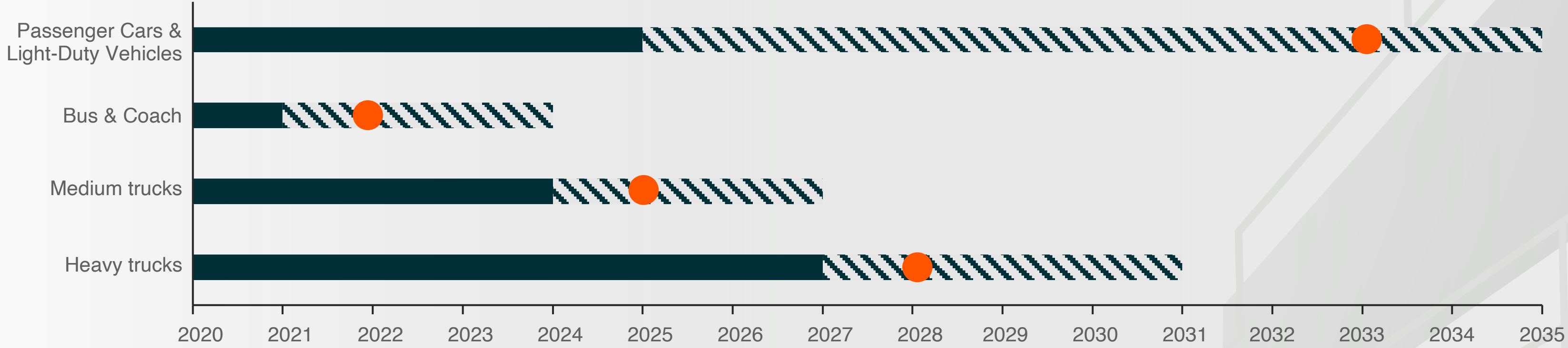
Sources: Text: 1. Irle, n.d.; 2. Hirano, 2021; 3. Julin, 2021; 4. Center for Transportation and the Environment, 2019; 5. Muoio, 2016; Visuals: Muoio, 2016; Global X Visual with data from Rho Motion, 2022.

FCEV Opportunities Are Developing on Different Timeframes

Adam Panayi

As the size of a vehicle increases, the advantage of a light-weight fuel with higher energy density scales accordingly. Therefore, the market opportunity for transportation fuel cells is likely greater and more imminent for larger vehicles than light-duty vehicles.

Fuel Cell Development Timeline by Vehicle Class



Commercialisation process: Here we identify the period that we expect FCEV development, testing and OEM qualification, and vehicle design and concept. For passenger cars and light-duty vehicles (PC and LDV), cost has been the key barrier to commercialization. As a result, many OEMs are focusing on BEV development. There is more commitment and development in the heavier vehicle classes.

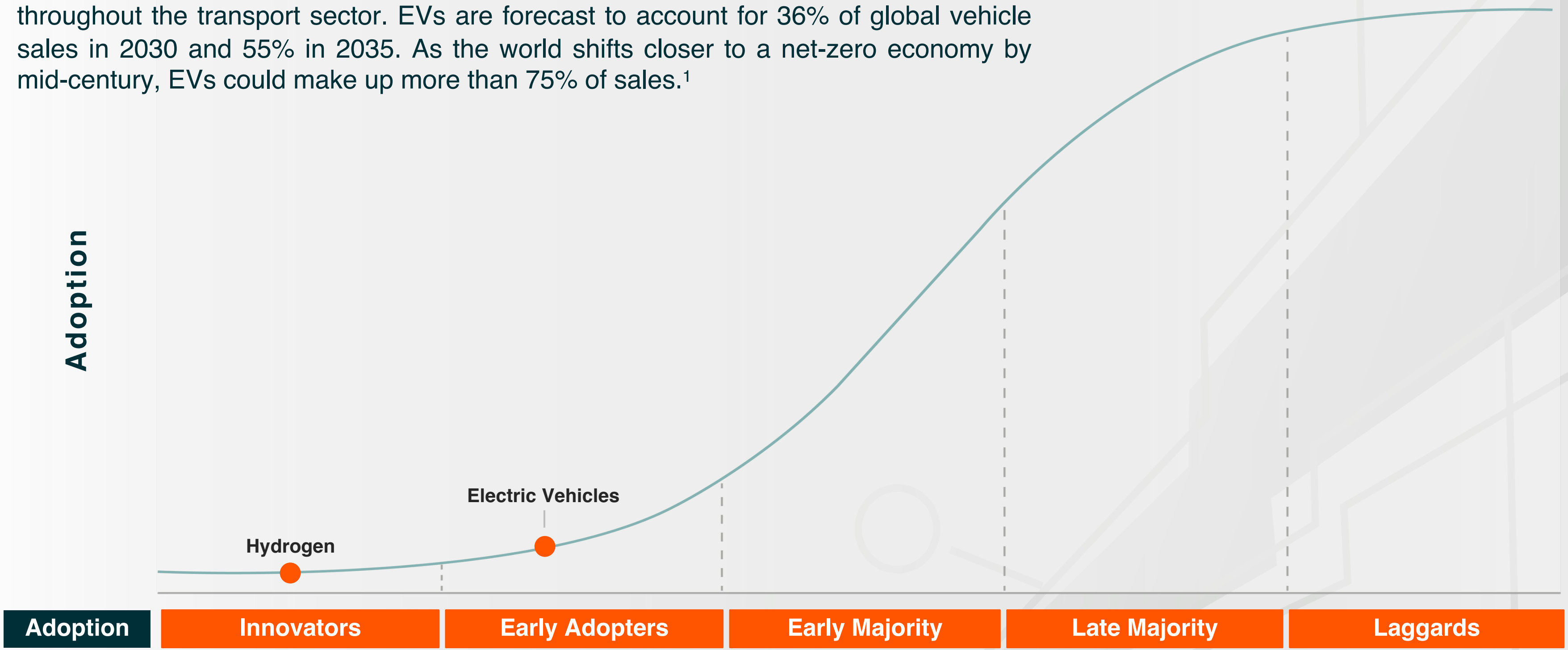
Market acceptance: We define as FCEV sales >1% of total car sales when aggregating sales from EU & EFTA & UK, China, Japan, Korea, and U.S. & Canada.

Downside: Due to the stage of FCEV development, downside risks include advances in battery chemistry technology over the coming decade, refilling station scaling, and ongoing challenges over FCEV efficiency and costs. We do not expect an upside where technology for FCEV applications advances at a quicker rate.

Source: Rho Motion, n.d.

S-Shaped Curve of Adoption – Mobility

The adoption of EVs is the primary pathway for reducing greenhouse gas emissions throughout the transport sector. EVs are forecast to account for 36% of global vehicle sales in 2030 and 55% in 2035. As the world shifts closer to a net-zero economy by mid-century, EVs could make up more than 75% of sales.[1]



Sources: Global X analysis of information derived from Rho Motion, 2022

Displayed for illustrative purposes. Curve shape not indicative of mathematical transformation

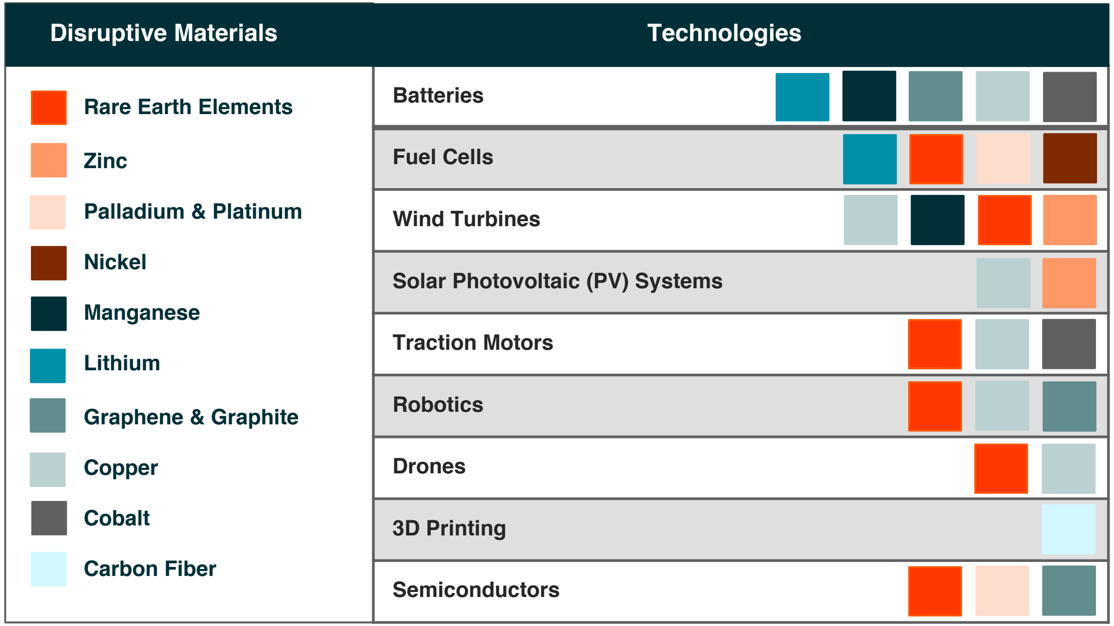
Chapter 06

Disruptive Materials

The world is rapidly embracing digital and clean technologies such as renewable energy, hydrogen fuel cells, electric vehicles, and traction motors. Core to these technologies' designs are materials like lithium, which is vital to today's electric vehicle batteries and battery energy storage systems. Copper is a key metal for wind and solar power systems. Uranium is another disruptive material that can advance a clean energy future.

Disruptive Materials Are Essential to Emerging and Clean Technologies

Metals, minerals, and materials are the critical but often unheralded ingredients fueling the advancement of disruptive technologies that can help slow climate change, improve productivity, and connect people around the world.



Highlighted Disruptive Materials

- **Rare Earth Elements:**[1] Neodymium, praseodymium, terbium, and dysprosium are among the rare earth elements used to manufacture permanent magnets for wind turbines, traction motors, robotics, and drones.
- **Zinc:**[2] Among its use cases, zinc can be a coating to protect wind turbines and solar panels from rust. The metal can also be used in batteries and galvanized steel.
- **Graphene & Graphite:**[3,4] Often described as a wonder material, graphene is the thinnest known material but also the strongest, being 100x stronger than steel. End-use markets include auto and transportation, aerospace, and construction.
- **Copper:**[5] High conductivity and resistance to corrosion make copper a key component of renewable energy systems, including wind and solar power.

Sources: Text: 1. Patricia, Silvia, Samuel, & Beatrice, 2020; 2. Venditti, 2022; 3. Russell, 2019; 4. Pistilli, 2022; 5. Copper Development Association Inc., n.d.; Visuals: Global X ETFs with information on required materials derived from International Energy Agency, 2021

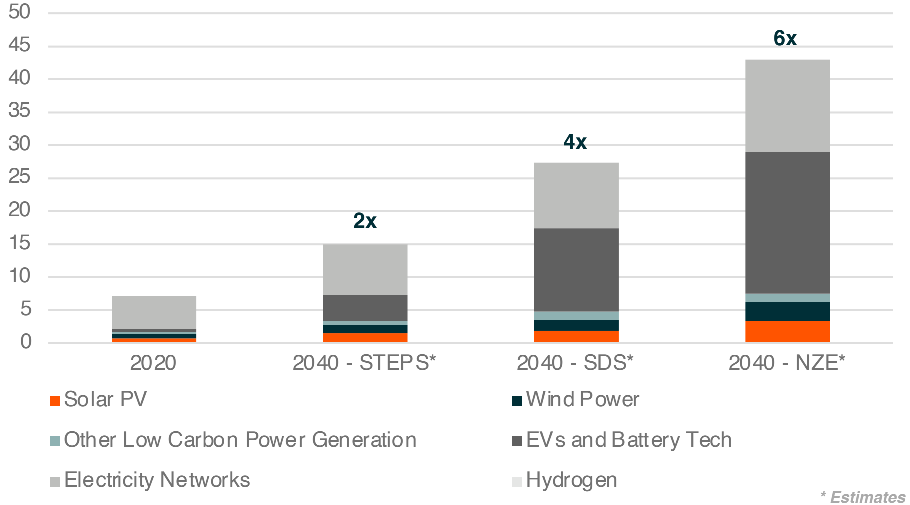
Clean Technologies Present Significant Potential Growth Opportunities for Disruptive Materials

Disruptive materials are critical to the decarbonization of the power and transport sectors. The International Energy Agency's (IEA) climate change scenarios provide glimpses into potential demand for disruptive materials.

The IEA projects disruptive materials production to multiply by 2–6 times from 2020 levels over the coming decades.

CleanTech Related Disruptive Materials Demand by Policy Scenario (Mt)

- **Stated Policies Scenario (STEPS):** Takes a conservative approach to the implementation and achievement of existing climate change goals. It does not consider any significant measures beyond what policy makers had in place as of 2021.
- **Sustainable Development Scenario (SDS):** Assumes all current net-zero pledges are achieved in full, with the developed economies reaching net zero emissions by 2050, China around 2060, and every other country by 2070.
- **Net Zero Emissions By 2050 Scenario (NZE):** The best-case scenario in which net-zero emissions are reached by 2050, limiting the global temperature increase to 1.5°C.



** Estimates*

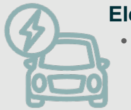
Source: International Energy Agency, 2022

Demand for Disruptive Materials Building with CleanTech's Rise

The emergence of clean technologies could create unprecedented demand for certain metals and materials, potentially resulting in shortages and rising prices. For example, lithium demand could be anywhere from 13–42 times higher than 2020 levels.[1]

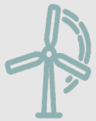
Emerging and clean technologies could support years, if not decades, of strong demand for disruptive materials.

Disruptive Materials Requirements by Clean Technologies



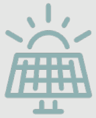
Electric Vehicles

- The lithium-ion battery pack in each electric vehicle requires roughly 8 kilograms (kg) of lithium, 35kg of nickel, 20kg of manganese, and 14kg of cobalt.[2]



Wind Turbines

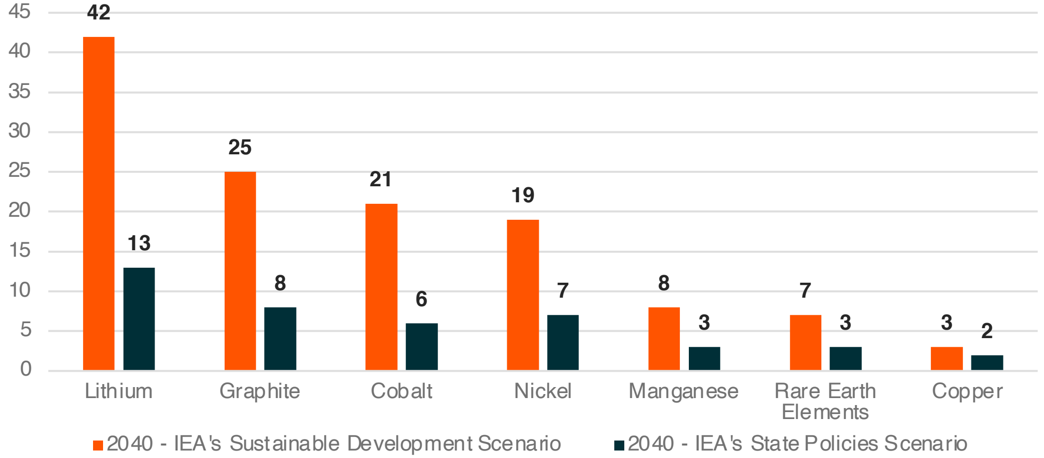
- Each megawatt (MW) of onshore wind power capacity requires an average 2,900kg of copper. Offshore wind systems require 8,000kg/MW of copper.[3]
- Onshore and offshore systems require roughly 790kg/MW of manganese and 5,500kg/MW of zinc.[4]



Solar PV Systems

- Each megawatt of solar PV capacity requires 2,822kg of copper and 30kg of zinc.[5]

Estimated Disruptive Materials Growth by 2040 (Growth Multiples Relative to 2020)



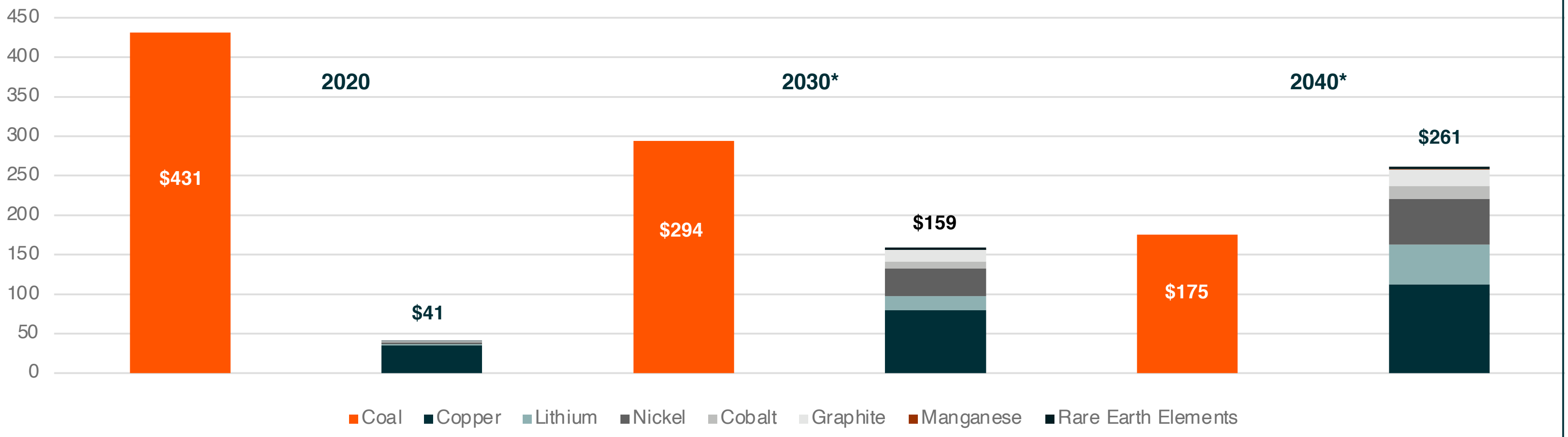
Sources: Text: 1. International Energy Agency, 2022; 2. Castelvecchi, 2021; 3. International Energy Agency, 2022; 4. Ibid.; 5. Ibid.; Visuals: International Energy Agency, 2022

Disruptive Materials In, Fossil Fuels Out

Disruptive materials are likely to replace fossil fuels as the key raw materials that run the 21st-century economy.

As companies move further into disruptive materials, we expect revenue profiles to shift significantly. According to one estimate, mining revenue from disruptive materials could increase fivefold to over $250 billion by 2040, while coal mining revenues decline by 59%.

Mining Revenue ($ Billions)

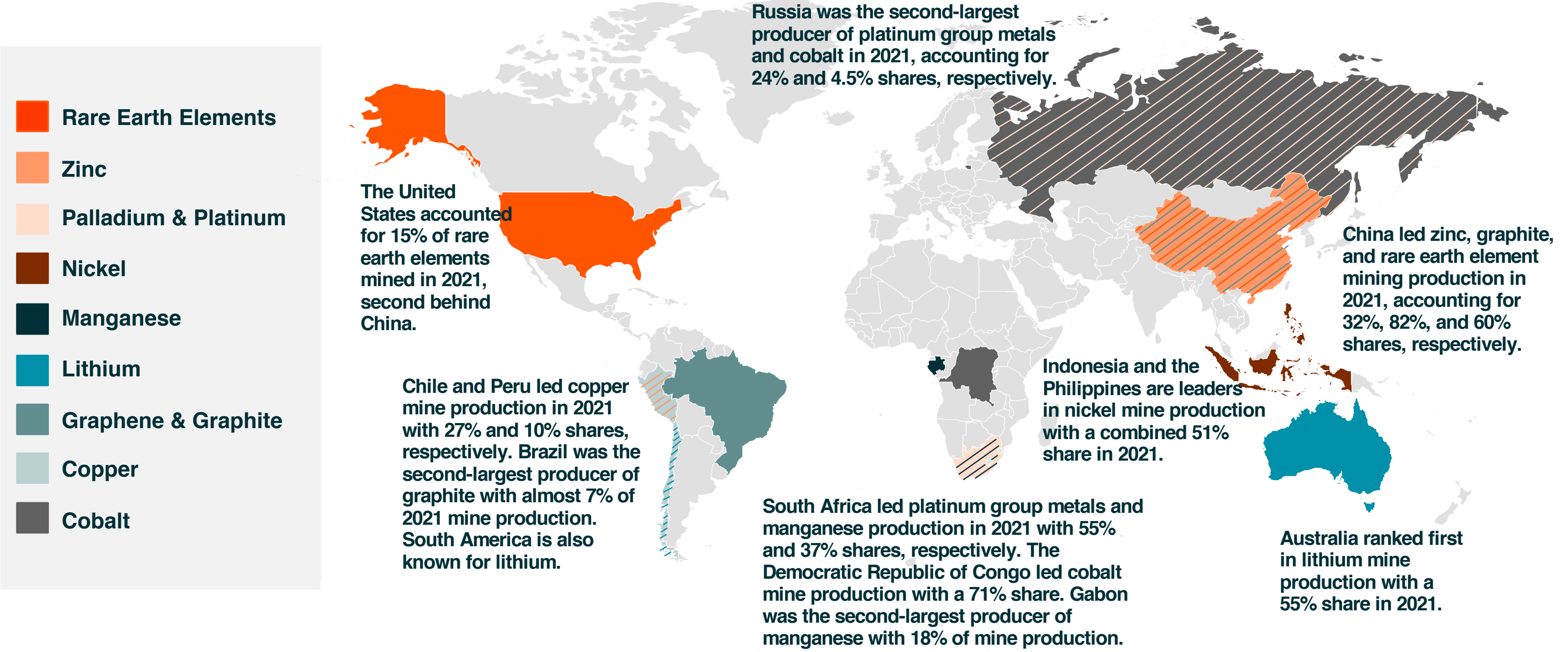


** Estimates*

Source: International Energy Agency, 2022

A Future Dominated by Disruptive Materials Points to Opportunities Across Regions

The mining and processing of disruptive materials is more concentrated than oil and natural gas, but the top markets span the globe.



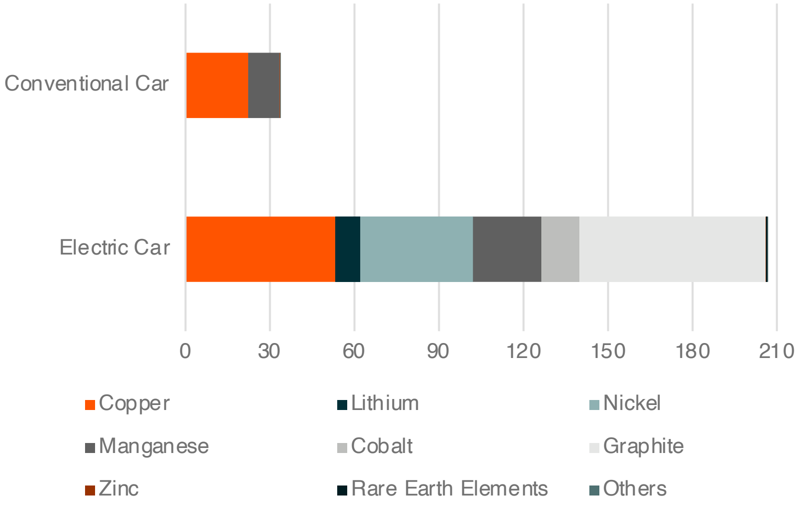
Sources: Cordier, 2022; Flanagan, 2022; Jaskula, 2022; McRae, 2022; Olson, 2022; Schnebele, 2022; Schulte, 2022; Shedd, 2022; Tolcin, 2022

Lithium in Focus: Transition From Conventional Vehicles to EVs Set to Be Main Driver of Demand

An electric vehicle requires six times more disruptive materials than a traditional internal combustion engine (ICE) vehicle.[1] As a result, EVs are expected to be a significant driver of demand for a variety of materials, particularly lithium.[2,3]

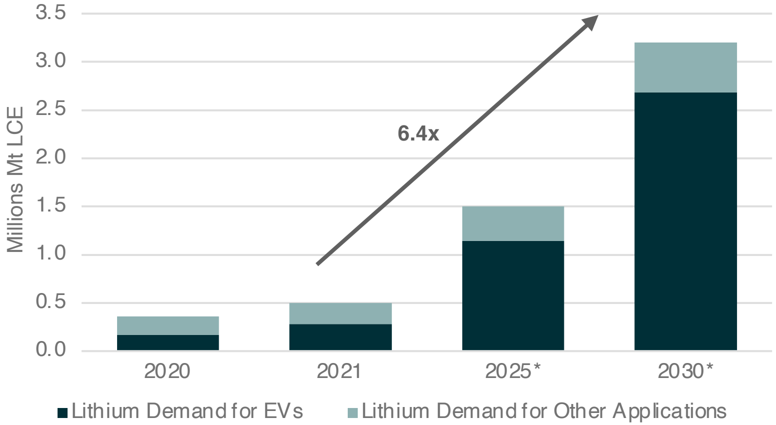
Lithium, graphite, copper, nickel, cobalt, and manganese are just a few of the disruptive materials EVs use.

Disruptive Materials Used in EVs vs. ICE Vehicles (kg/vehicle)



EVs are forecast to account for most of the growth in demand for lithium. Battery energy storage is another notable source of demand.

Lithium Demand by Application
(Millions of Metric Tons per Annum of Lithium Carbonate Equivalent)



*Forecast

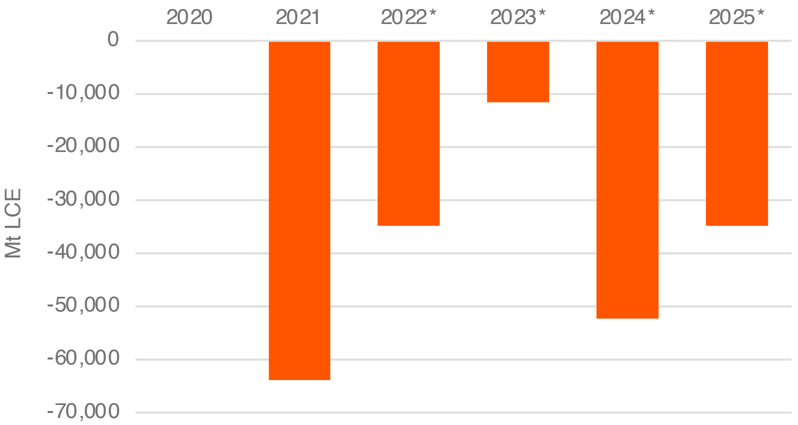
Sources: Text: 1. International Energy Agency, 2022; 2. Ibid.; 3. Norris, 2022; Visual (LHS): International Energy Agency, 2022; Visual (RHS): Norris, 2022

Lithium in Focus: Supply/Demand Imbalance Poses Risks to Electric Vehicle Adoption

Underinvestment in lithium mining could pose risks to auto OEMs' ambitious EV goals. We expect a lithium deficit for the next several years, with the market stabilizing after 2025. These deficits are expected to support higher lithium prices.[1]

New lithium mining operations can take 3–5 years (or more) to complete, making the undersupply forecast for 2025 an urgent issue.

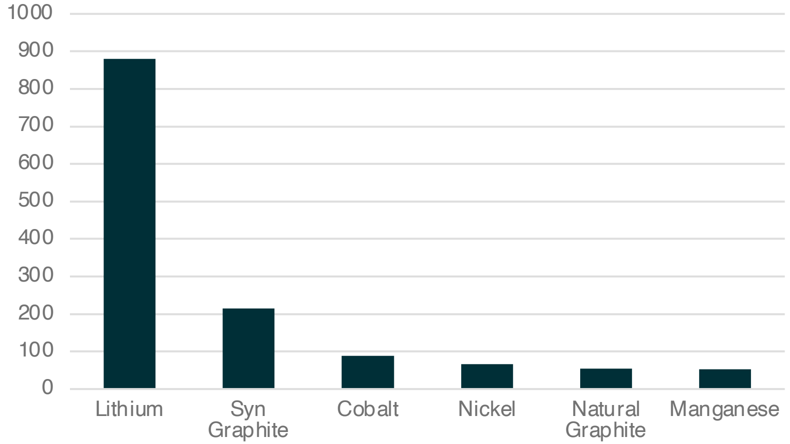
Lithium Supply Balance
(Metric Tons per Annum of Lithium Carbonate Equivalent)



Note: *Negative number indicates shortage. Supply and demand were effectively balanced in 2020. *Forecast*

Demand for lithium from the EV sector and supply disruptions from heat waves and power outages in China have prices at record highs.[2]

Percentage Increase in Critical Battery Raw Materials Costs Since January 2020 (as of August 25, 2022)



Sources: Text: 1. Benchmark Mineral Intelligence, 2022; 2. Ibid.; Visual (LHS): Benchmark Mineral Intelligence, 2022a; Benchmark Mineral Intelligence, 2022b; Visuals (RHS): Benchmark Mineral Intelligence, 2022a; Benchmark Mineral Intelligence, 2022b; Benchmark Mineral Intelligence, 2022c

Lithium in Focus: Prices Remain Well Above Historical Levels

The inelastic nature of lithium supply combined with growth in EV demand supports higher lithium prices. In September 2022, Chinese lithium carbonate hit an all-time high of $71,315 per ton even as commodities markets moderated.[1] Global prices increased 226% between September 2021 and September 2022.[2]

Lithium Carbonate Prices (USD/t)

Note: As of September 2022

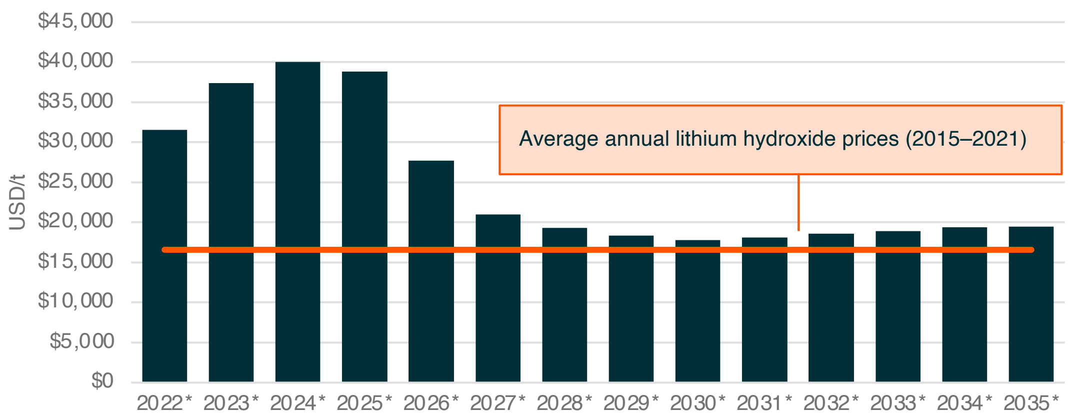
Sources: Text: 1. Lee, 2022; 2. Benchmark Mineral Intelligence, n.d.; Visual: Sigma Lithium, 2022

Lithium in Focus: Elevated Pricing Could Support Capacity Expansion

Traditionally, lithium miners have been hesitant to boost capacity, fearing the impacts a surplus would have on lithium pricing. However, with established demand dynamics and price projections that are well above historical averages, miners are making robust commitments to boost capacity.

Strong demand and delays in available new supply are likely to keep lithium prices high near-term. Even after the market stabilizes, prices are projected to remain above recent averages.

Forecasted Prevailing Global Prices for Battery Grade Lithium Hydroxide (USD/t)



**Forecast*

Recent Lithium Miner Expansion Announcements

SQM: In Q2 2022, announced a lithium carbonate production goal of 210,000 tonnes by early 2023, more than double 2021 levels.

Albemarle: In Q3 2022, announced a U.S. processing plant and a goal to increase overall lithium capacity fivefold to 500,000 tonnes by 2030.

Ganfeng: In Q3 2021, announced a plan to boost lithium carbonate capacity fivefold to 600,000 tonnes on an undefined timeframe.

Sources: Text: 1. Mckenzi, 2022; 2. Cambero, 2022; 3. Scheyder, 2022; 4. Daly & Orlofsky, 2021; Visual: Sigma Lithium, 2022

Uranium in Focus: A Material Increasingly Viewed as Key to the Energy Transition

Uranium is a heavy, dense, and radioactive metal, making it a potent source of concentrated energy. Uranium fuel enables nuclear power plants to generate electricity, and nuclear power can be a key clean energy source in the transition towards net zero.

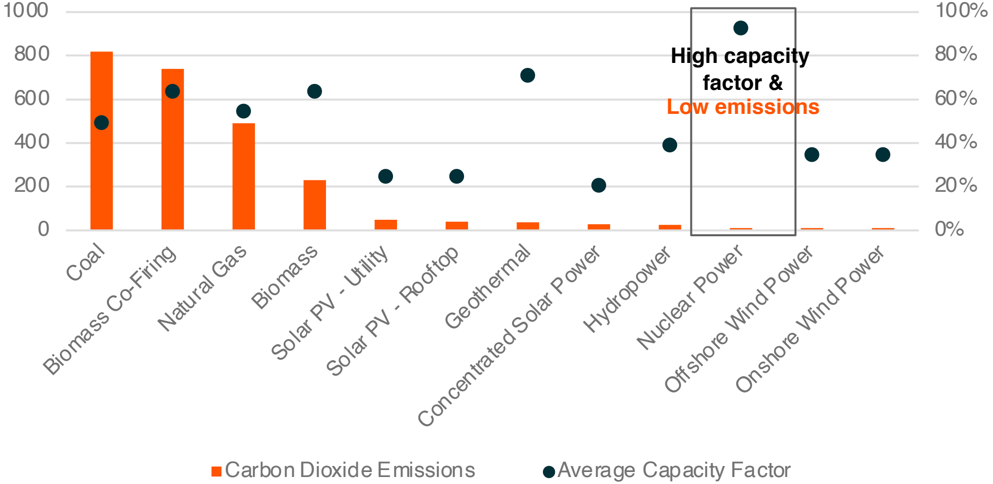
Nuclear power emits far less CO2 than fossil fuels. At 12 grams of CO2 per kW/h, uranium's emissions are the same as offshore wind energy.[1]

Uranium and Nuclear Power, Explained

- Nuclear power is the biggest source of uranium demand globally. Nuclear power reactors generate electricity by producing immense heat as they split uranium-235 atoms in the process of nuclear fission.
- Nuclear power is one of the few sources of electricity that combines large-scale baseload power output and low greenhouse gas emissions.
- With an average capacity factor of 92.7%, nuclear is the most dependable power source.[2]
- Construction costs of nuclear power plants can be high, but ongoing fuel costs tend to be quite low given the minimal amount of uranium needed to power a plant.[3]

Note: Capacity factor averages for U.S. power sources in 2021.

Carbon Dioxide Emissions (Left – GCO2 Equivalent per KWH) & Capacity Factor (Right — %), by Power Source



Sources: Text: 1. World Nuclear Association, n.d.; 2. U.S. Energy Information Administration, 2022; 3. World Nuclear Association, 2022; Visual: World Nuclear Association, n.d.; U.S. Energy Information Administration, 2022

Uranium in Focus: Increasing Government Support for Nuclear Energy

Recent policy developments and a robust project pipeline point to a positive growth outlook for nuclear power. Major power markets, including the United States, China, and the EU, are looking for ways to maintain current nuclear power fleets and add new capacity to address climate change and boost energy security.

Favorable policies could boost demand for uranium. In 2021, nuclear power generation reached 2,653TWh, requiring 62,496 tonnes of uranium.[1]

United States

- The Inflation Reduction Act includes tax credits for existing nuclear power plants and incentivizes advanced nuclear power deployment.[2]
- The Infrastructure Investment and Jobs Act includes $6 billion in funding for a program to preserve the existing U.S. fleet of nuclear power reactors.[3]

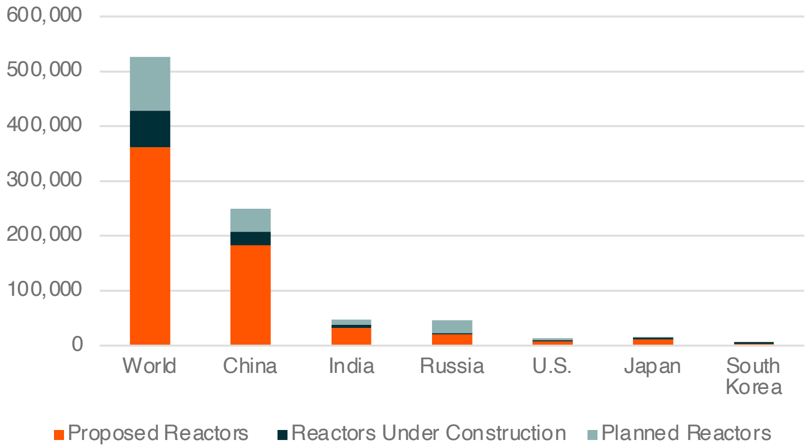
China

- China aims to construct at least 150 new reactors in the next 15 years, which would be more than the rest of the world has built in the past 35 years. The colossal plan is estimated to cost at least $440 billion.[4]

European Union

- The European Commission formally adopted the REPowerEU plan, which aims to rapidly reduce EU dependence on Russian fossil fuels. The plan states that nuclear power will need to play a role in boosting energy security within the region.[5]

Nuclear Power Capacity in the Planning & Development Stages (MW)



Sources: Text: 1. International Atomic Energy Agency & U.S. Energy Information Administration, 2022; 2. Huff, 2022; 3. Lovells, Fishman, & Roma, 2021; 4. Murtaugh & Chia, 2021; 5. World Nuclear News, 2022; Visual: World Nuclear News, 2022

Uranium in Focus: Small Modular Reactors (SMRs) Becoming Essential to Nuclear Power Sector

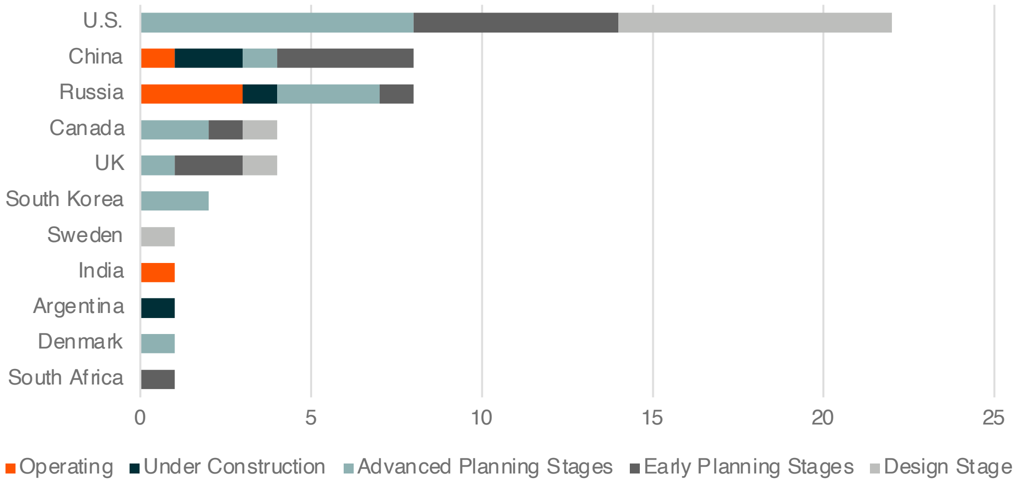
SMRs are advanced nuclear reactors with power capacity of up to 300MW per unit, or one-third of the generating capacity of traditional reactors. Their smaller size provides several benefits, and many governments see them as the future of nuclear power.[1]

Over 50 SMRs are in the development stages around the world, with the United States, China, and Russia leading the project pipeline.[2]

Benefits of SMR Technology[1]

- **Small Footprint:** Given their smaller footprint, SMRs can be sited on locations not suitable for larger nuclear power plants.
- **Modularity:** Prefabricated units of SMRs can be manufactured and then shipped and installed on site, simplifying the construction process.
- **Cost Savings:** The smaller size and modularity of SMRs generally result in much lower development costs and shorter construction timelines than traditional nuclear power plants.
- **Enhanced Safety:** SMR designs can include safety and security enhancements that are not possible for larger traditional nuclear power plants.

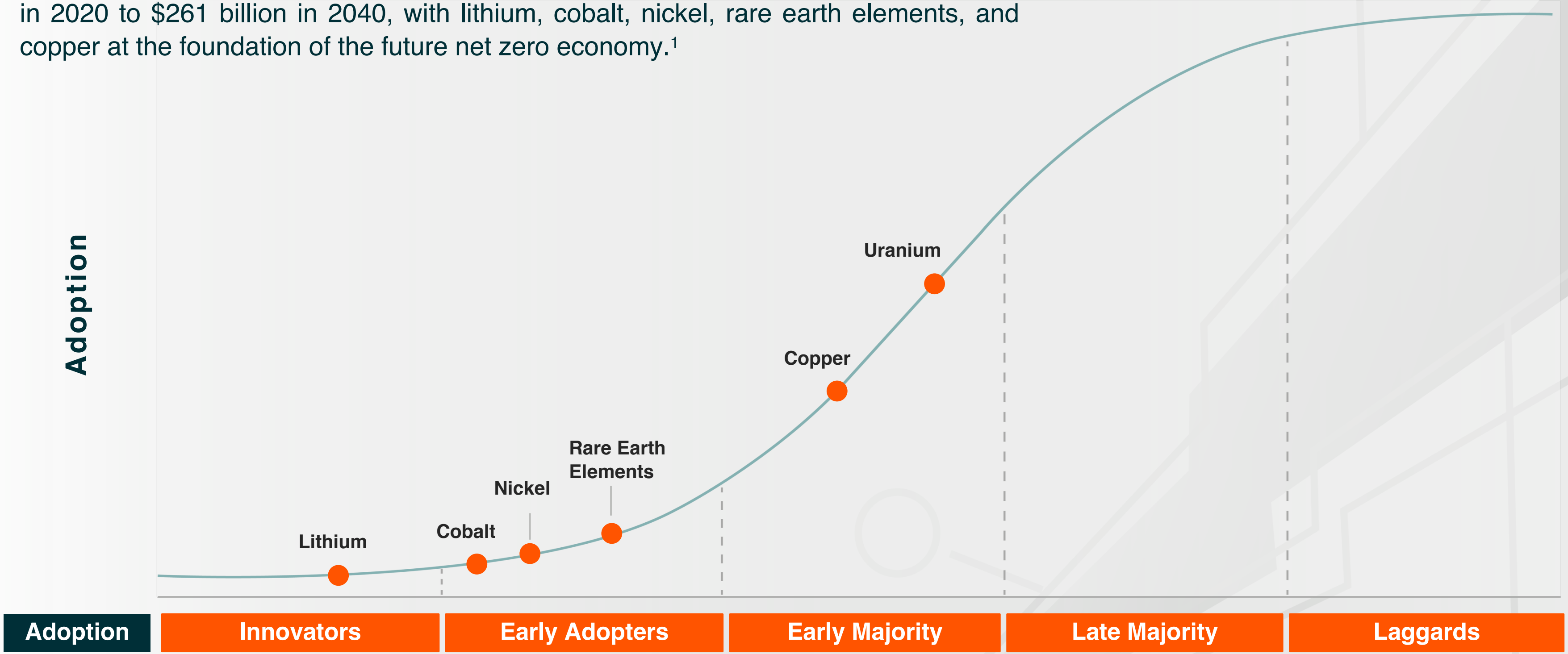
SMRs Across Project Development Stages (# of Reactors)



Sources: Text: 1. Office of Nuclear Energy, n.d.; Visual: World Nuclear Association, 2022

S-Shaped Curve of Adoption – Disruptive Materials

Mining revenue for cleantech-related disruptive materials could grow from $41 billion in 2020 to $261 billion in 2040, with lithium, cobalt, nickel, rare earth elements, and copper at the foundation of the future net zero economy.[1]



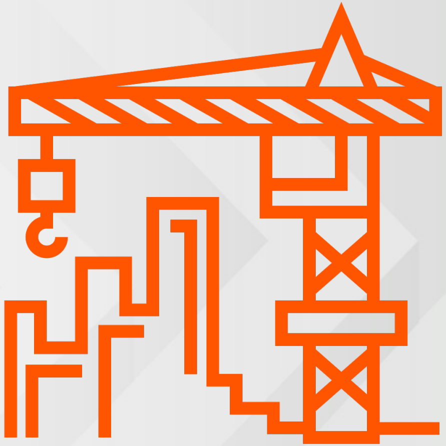
Source: 1. International Energy Agency, 2022

Displayed for illustrative purposes. Curve shape not indicative of mathematical transformation

Chapter 07

U.S. Infrastructure Development

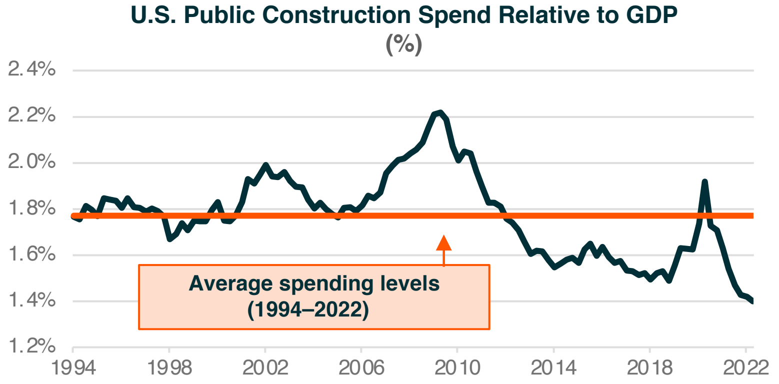
After decades of use and neglect, U.S. infrastructure struggles to accommodate current societal needs and is underprepared for future dynamics. However, attention is returning to traditional and next generation infrastructure. The passage of the Infrastructure Investment and Jobs Act in late 2021 could begin to close the chronic gap in domestic infrastructure funding.



U.S. 21st-Century Infrastructure Is Defined by Structural Trends, Not Classical Definitions

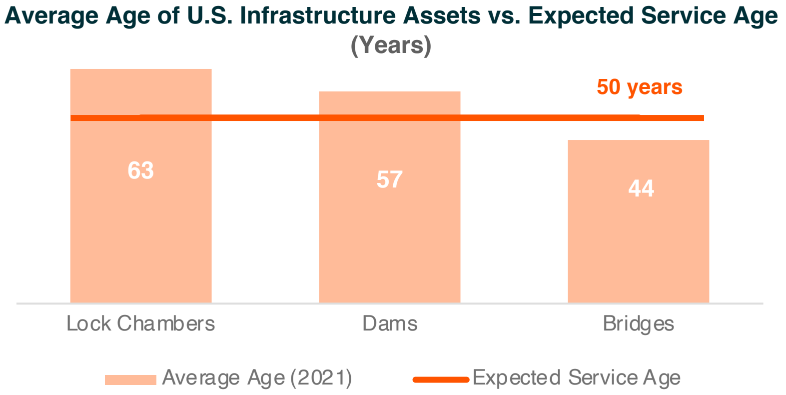
Trends Requiring Infrastructure Improvement in the United States	• **Depreciation of Current Assets:** Useful life of infrastructure assets is stretched thin by years of use and relatively low federal spending in recent times. • **Climate Risk:** Increasingly noticeable externalities present risks to freshwater supplies, real estate, transportation, and energy grids.

In recent years, public construction spending has declined relative to historical levels, halting maintenance and progress on newer projects.



Note: GDP data from St. Louis Fed, construction spending from US Census, seasonally adjusted annual rates.

In many cases, infrastructure assets in the United States are quickly approaching or already past their expected life spans.



Sources: Visual (LHS): U.S. Bureau of Economic Analysis & U.S. Census Bureau, 2022; Visual (RHS): American Society of Civil Engineers, 2021

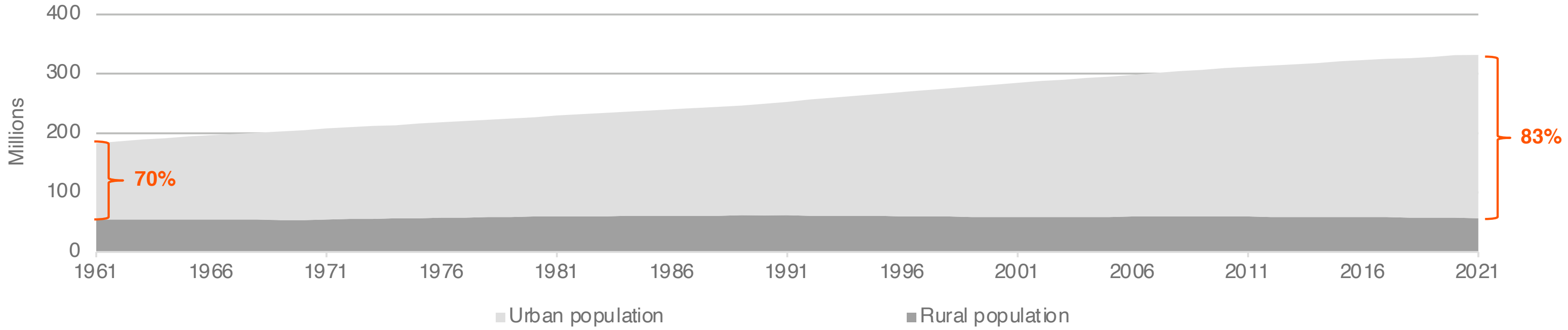
U.S. 21st Century Infrastructure Is Defined by Structural Trends, Not Classical Definitions

Trends Requiring Infrastructure Improvement in the United States

- **Demographics:** Overall population growth and uneven distribution toward urban areas strains existing infrastructure.
- **Technology/Consumer Preferences:** Technology fundamentally changes infrastructure use/design, often leaving rural areas unaccommodated.

About 83% of the U.S. population is concentrated in urban areas, up from 70% six decades ago, placing disproportionate stress on infrastructure assets in population centers.[1]

U.S. Urban and Rural Populations (Millions) and 2021 Population Breakdown (%)



Sources: Text: 1. World Development Indicators, 2022; Visual: World Development Indicators, 2022

U.S. Infrastructure: Just How Bad Is It Really?

Segment	Current State	Economic/Social Impact
Roads & Bridges[1]	• 43% of roads were in poor or mediocre condition as of 2019 • 7.5% of U.S. bridges were structurally unsound as of 2019 • Roads and bridges have a $786 billion project backlog	• Traffic delays cost $166 billion in productivity and fuel (2017) • Traffic fatalities increased 60% between 2009 and 2019 • Poor road condition cost drivers $130 billion a year in car repairs
Water Utilities 1, 2, 3, 4	• 9% of drinking water systems serve 80% of U.S. population • 6 billion gallons of drinking water are lost to leaky pipes daily • Up to 22 million Americans drink water delivered by lead pipes • 20% of U.S. households are not connected to public sewers	• $7.6 billion in drinking water was lost to leaks in 2019 • 63 million people exposed to unsafe drinking water in the U.S. • 500,000+ U.S. children have elevated lead levels
Electric Utilities 1, 5, 6	• 70% of U.S. transmission lines are at least 25 years old • 60% of circuit breakers are at least 30 years old • 6% of electricity providers serve 72% of U.S. customers	• 2018's Camp Fire was partially caused by faulty power lines and caused $16.5 billion in damages • Power outages cost the U.S. $28–169 billion annually • Distribution infrastructure issues cause 92% of outages
Rail + Public Transit 1, 7, 8, 9, 10	• U.S. passengers took 32.5 million trips on Amtrak in 2019, 18.8 million of which were in the Northeast Corridor (NEC) • Average age of major NEC backlog projects is 110 years old • 45% of Americans have no access to public transit	• Only 73% of Amtrak trains were on time in 2018 • Amtrak's 2018 operating losses were $171 million, partially due to delays • Public transit delays could cost riders $1.2 billion over the next 10 years

43% of roads were in poor or mediocre condition in 2019

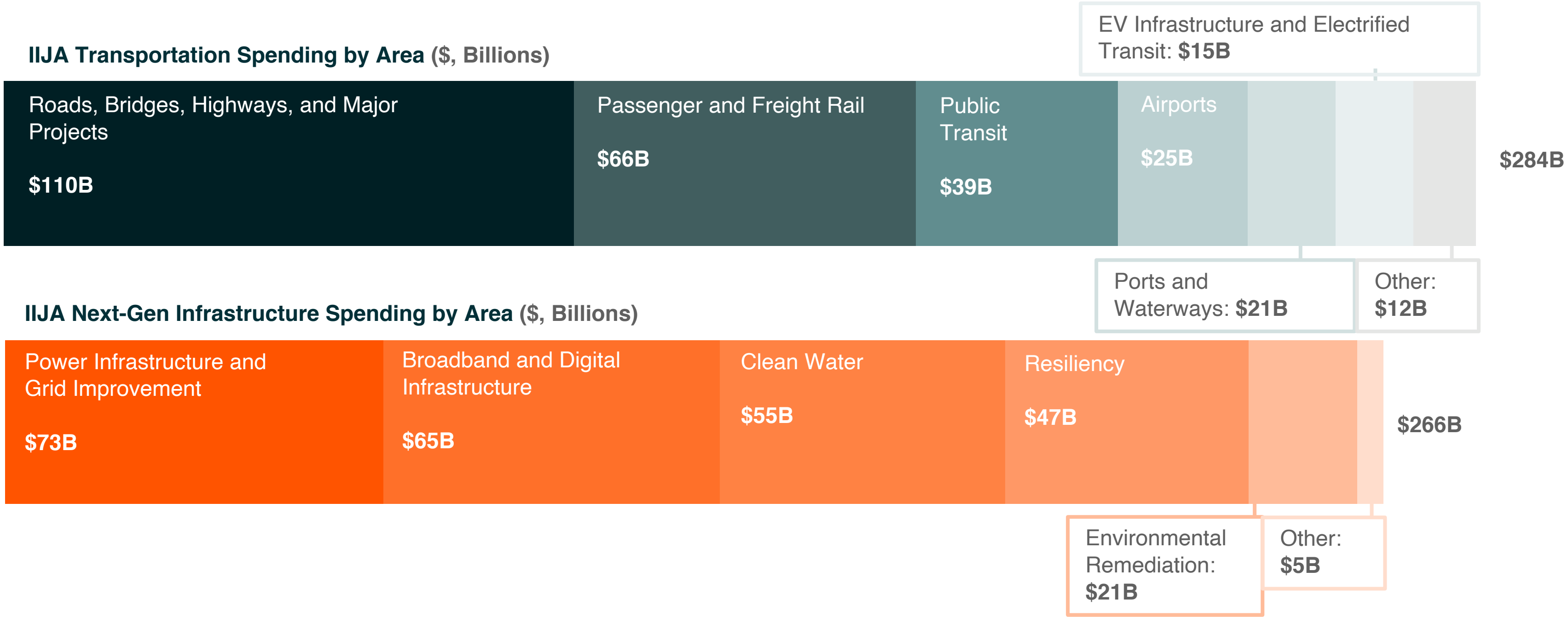
9% of drinking water systems serve 80% of the population

70% of transmission lines are at least 25 years old

Sources: 1. American Society of Civil Engineers, 2020 2. Rosenthal & Craft, 2020 3. Philip, et al., 2017 4. Mayans, 2019 5. Aniti, 2018 6. Rice, 2019 7. American Society of Civil Engineers, 2017 8. Morrison, 2019 9. Mann, 2019 10. American Society of Civil Engineers, 2021

U.S. Infrastructure: From Wishlist to Reality, the Infrastructure Investment and Jobs Act (IIJA)[1]

President Biden signed the bipartisan IIJA into law on November 15th, 2021. The $1.2 trillion package includes $550 billion of spending across a wide range of 21st-century infrastructure areas that could transform the United States.



Sources: 1. DeFazio, 2021

U.S. Infrastructure: Spending Takes Time, as Does Its Benefits

Infrastructure spending is not instantaneous, nor are its benefits. Only over time does spending translate to revenues, economic growth, and social impact.

Federal Aid Highway Act of 1956[1]

- Investment: $25B ($252B in 2021 dollars) to build 41,000 miles of interstate highway.
- Construction: Work concluded in 1992, with total costs amounting to $129B (more than $500B adjusted for inflation).
- Outcome: As much as 25% of the country's productivity gains from 1950 to 1989 and 3.9% of current real GDP can be traced back to the act.

American Recovery and Reinvestment Act 2009 (ARRA)[2]

- Transportation: Authorized $48.1B in spending for the Department of Transportation.
- Deployment: Though nearly 70% of spending occurred in 2011, ARRA-related transportation spending averaged $1.6B annually from 2013–2019.
- Outcome: Initial spending boosted employment as intended, with related economic growth kicking in by 2015.

After 5 years, the federal government could distribute 51% of total authorized IIJA spending. After 10 years, the government could distribute 86% of total authorized IIJA spending.[3]

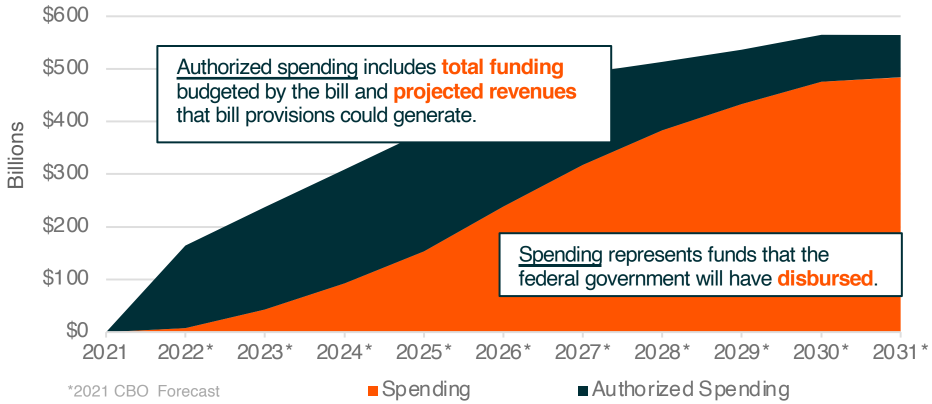
Planning Timelines

Prior to construction, infrastructure projects must undergo extensive planning and review. This phase translates to revenues for consultants and infrastructure specialists.

Construction Timelines

Over time, spending translates to revenue for contractors, engineers, and consultants before eventually reaching component/equipment manufacturers and producers of materials.

Available Infrastructure Investment & Jobs Act Spending Over Time ($B)



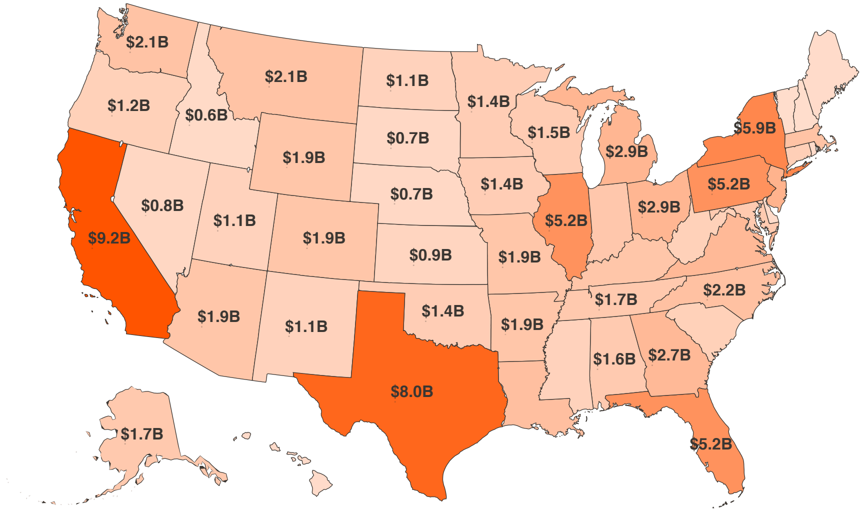
*2021 CBO Forecast

Sources: Text: 1. Phelps, 2021; 2. Mallett, 2020; 3. Congressional Budget Office, 2021; Visual: Congressional Budget Office, 2021

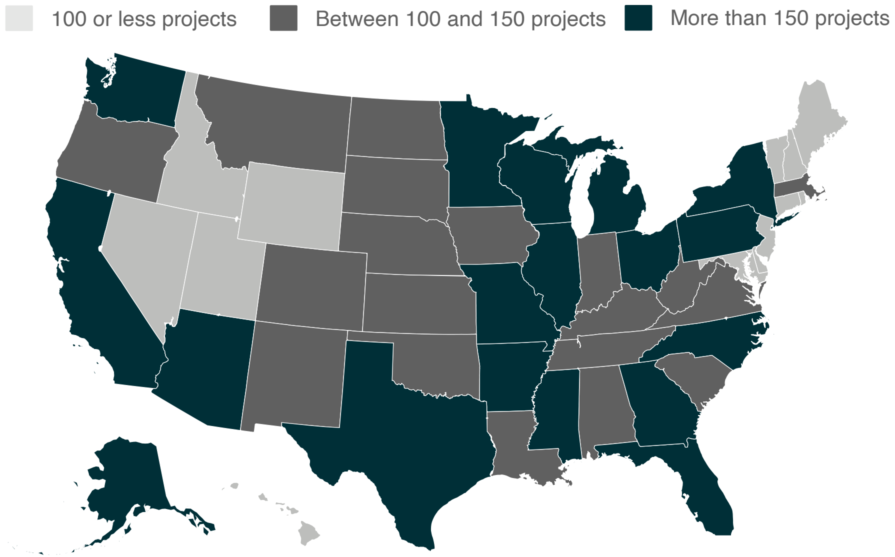
U.S. Infrastructure: State-by-State Progress of the Infrastructure Investment and Jobs Act[1]

Rollout of the IIJA remains in its early stages, but more than $105 billion in funding has been announced at the state level and over 7,000 IIJA-related projects have been announced.

Announced IIJA Funding by State ($ Billions)



Announced IIJA Projects by State (#)*



*Announced projects represent a small subset of total projects that will be funded by the IIJA

Source: The White House, 2022

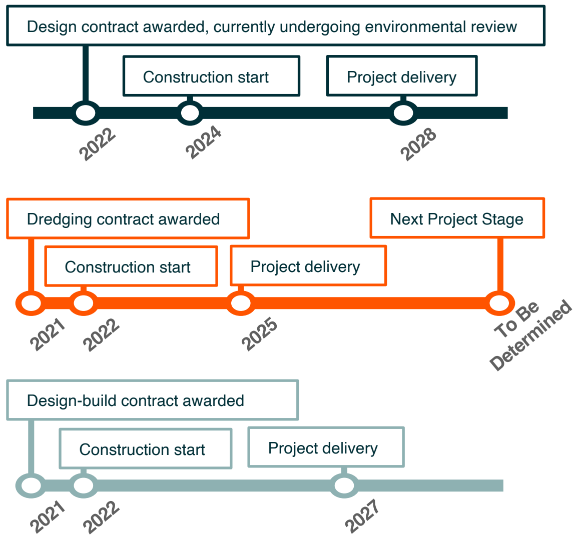
U.S. Infrastructure: IIJA-Funded Project Highlights

IIJA funding is already making a difference at the preexisting project level. Some long-stalled projects are moving forward, while others could use IIJA funds to advance on schedule. Major construction starts are expected to accelerate toward 2025.

Project Description	IIJA Funding	Companies Involved[7]*
Denver International Airport Expansion (CO): Construction of a new seventh runway at the Denver International Airport that could cost $1.2B[1]	$59M allocated to Denver International Airport projects in FY 2022[2]	**Jacobs Engineering** (Design Consulting) **AECOM** (Project Management)
Houston Ship Channel Project 11 (TX): $1B project to widen and deepen a segment of the Houston Ship Channel due to increasing volumes[3]	$142M provided by the Army Corps of Engineers to keep project on schedule[4]	**AECOM – Gahagan & Bryant Associates** (Planning) **Great Lakes Dredge & Dock Corp** (Dredging)
Penn Station Access (NY): Connection of Metro-North Railroad to Penn Station in Manhattan that is expected to cost $2.9B[5]	$500M tapped from Amtrak's federal funding[6]	**Jacobs Engineering** (Prime Designer) **Halmar International** (Design Builder)

*List of companies is not exhaustive.

Project Timeline[8]



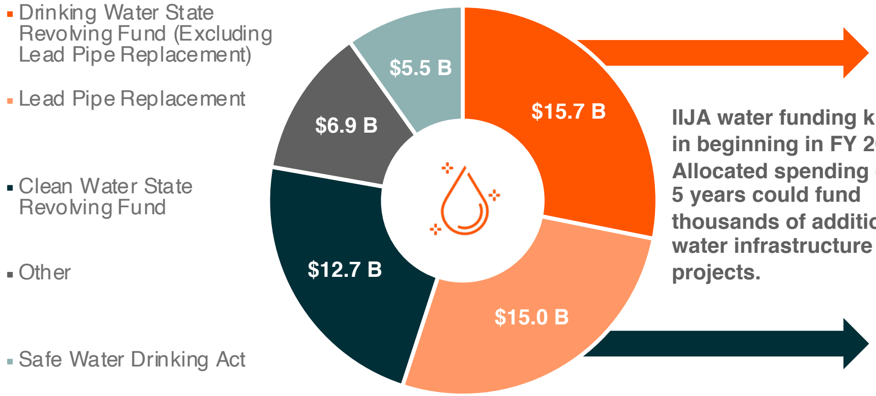
Sources: 1. Murray, 2021; 2. Federal Aviation Administration, n.d.; 3. Leggate, 2022; 4. Ibid.; 5. McGeehan, 2021; 6. Ibid.; 7. Fitch Solutions, n.d.; 8. Ibid.

U.S. Infrastructure: Water Projects Receive Boost from IIJA

In recent years, the annual capital spent on water infrastructure in the United States fell more than $80 billion short of the estimated need.[1] This annual gap in funding need and availability could reach $136 billion by 2039.[2] Fortunately, about 10% of IIJA spending is dedicated to water initiatives.[3]

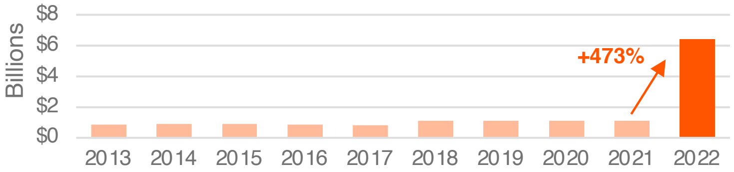
The Drinking Water State Revolving Fund (DWSRF) and the Clean Water State Revolving Fund (CWSRF) are the primary mechanisms for water funding. The DWSRF targets lead service-line replacement and drinking water projects. The CWSRF targets current and future water pollution.

Infrastructure Investment and Jobs Act Water Initiative Allocations 2022–2026 ($Billions)

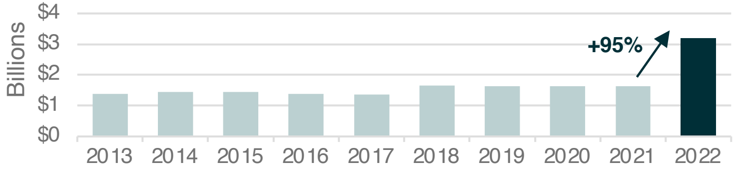


IIJA water funding kicks in beginning in FY 2022. Allocated spending over 5 years could fund thousands of additional water infrastructure projects.

Drinking Water State Revolving Fund (DWSRF) Annual Allotments ($Billions)



Clean Water State Revolving Fund (CWSRF) Annual Allotments ($Billions)



**Federal Fiscal Years*

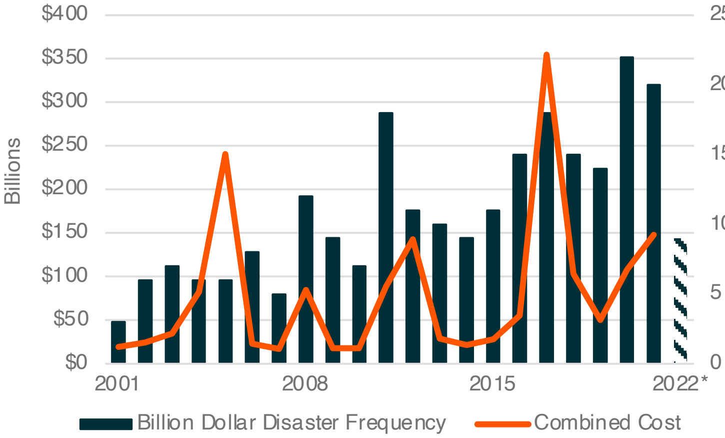
Sources: Text: 1. Prouty, 2022; 2. Ibid.; 3. Bielenberg, Brody, Dunn & Kumar, 2022; Visual (LHS): DeFazio, 2021; Visual (RHS): United States Environmental Protection Agency, 2022a; United States Environmental Protection Agency, 2022b

U.S. Infrastructure: Adapting to Climate Change With Resilient Infrastructure

Mother nature appears to be harsher than ever, with natural disasters occurring at unprecedented rates. U.S. infrastructure must be built or modified to withstand these events and other climate change-related impacts.

Damages from natural disasters could trend upward if the effects of climate change continue to intensify.

Combined Cost of Billion Dollar Disasters in the United States ($B, LHS) and Frequency of Such Disasters (#, RHS)



*Data as of first half of 2022
Source: NOAA National Centers for Environmental Information (NCEI)

Population Centers

Rising sea levels could displace 13 million people in the United States by 2100.[1]

Transportation Infrastructure

The Pacific Northwest's 2021 wildfires caused thousands of miles of freight train reroutes.[2]

Water Infrastructure

In 2021, Hurricane Ida disrupted access to clean water for over 2 million people in Louisiana and Pennsylvania.[3,4]

Energy Infrastructure

Drought in the western U.S. threatens power for tens of millions as reservoirs approach water levels unusable for hydroelectric generation.[5]

PROTECT Formula Program: Promoting Resilient Operations for Transformative, Efficient, And Cost-Saving Transportation[6]

The IIJA allocates $8.7 billion toward the PROTECT Formula Program to defend transportation infrastructure against rising sea levels, flooding, extreme weather events, and other natural disasters. States can access funding for these eligible activities:

- Planning: Design/development of tools to simulate transportation disruption scenarios, boost state capacity to increase responsiveness, and evacuation planning/preparation.
- Resilience Improvements: Modifications to existing transportation assets to withstand one or more elements of climate change, such as flood or wildfire.
- At-Risk Coastal Infrastructure: Enhancements/relocation of highway, bridge, road, pedestrian walkway, and bicycle lane assets to bolster infrastructure that is disproportionately susceptible to coastal impacts of climate change.

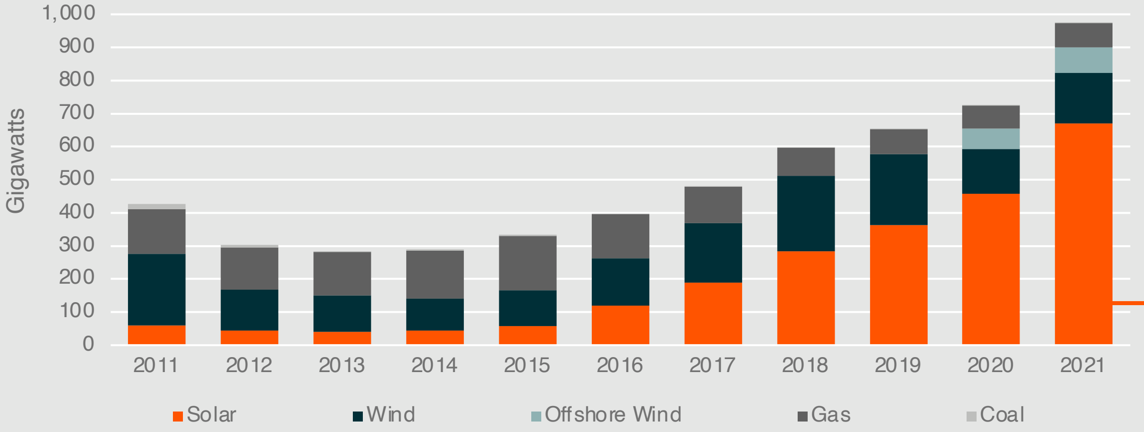
Sources: Text: 1. University of Southern California, 2020; 2. Gormley, 2021; 3. Maykuth, 2021; 4. Rubiano, 2021; 5. UN News, 2022; 6. Federal Highway Administration, 2021; Visual: National Centers for Environmental Information, 2022

U.S. Infrastructure: Outdated Grid Is Not Yet Suited for the Energy Transition

As the U.S. energy mix shifts toward renewable energy, developers must work with antiquated power systems. Hundreds of gigawatts (GWs) of renewable energy projects are waiting to connect to the grid; however, aging grid infrastructure and the lack of high-voltage transmission lines and energy storage creates delays.

New electric generation projects must apply for interconnection to the grid. It is estimated that only 25% of the queued projects in 2021 will come online due to outdated infrastructure and congested interconnection processes.

Total Capacity in U.S. Interconnection Queues by Energy Source (GW, Gigawatts)



The U.S. Interconnection Queue is the pipeline of proposed electric generation projects that are seeking approval before connecting to one of the major regional power systems. Although many projects in the queue are never built, it is considered a strong indicator of near-term electrical development trends.

Solar accounted for almost **70%** of the interconnection queue in 2021, up dramatically from 14% in 2011.

Note: Solar category includes both standalone solar systems and solar systems with batteries

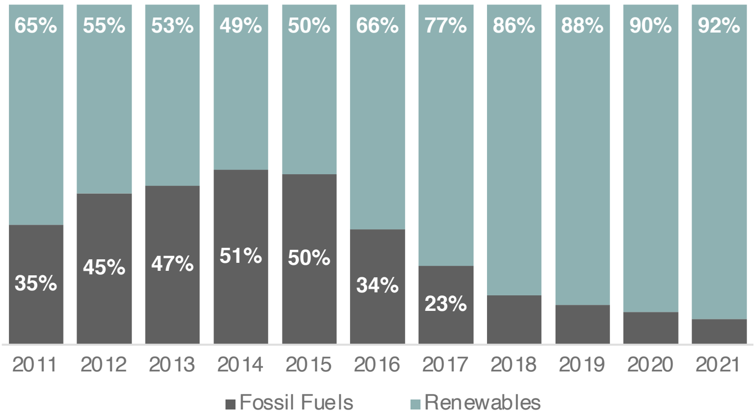
Source: Electricity Markets & Policy, n.d.

U.S. Infrastructure: Renewable Energy Pipeline Could Create Demand for Supportive Infrastructure

An outsized share of interconnection queues include renewable energy projects. Queued renewable capacity is several times more than the total U.S. capacity, creating demand for supportive transmission, distribution, and storage infrastructure.

Since the mid-2010s, the share of natural gas and coal projects waiting to connect to the grid fell dramatically. The fall is a function of declining fossil fuel capacity additions and a surge in proposed renewables projects.

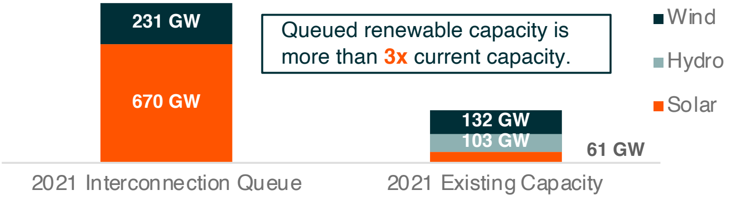
Renewables vs. Fossil Fuels Share of Interconnection Queues (%)



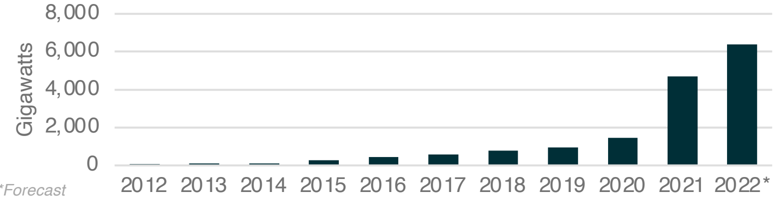
Note: Excludes proposed energy storage projects

Supportive infrastructure such as high-power voltage lines and energy storage could accommodate more renewable energy capacity. Only recently have energy storage projects been added to the grid in earnest.

2021 Capacity in Interconnection Queues and Existing Capacity by Energy Source (GW, Gigawatts)



U.S. Cumulative Battery Storage Capacity (GW, Gigawatts)



**Forecast*

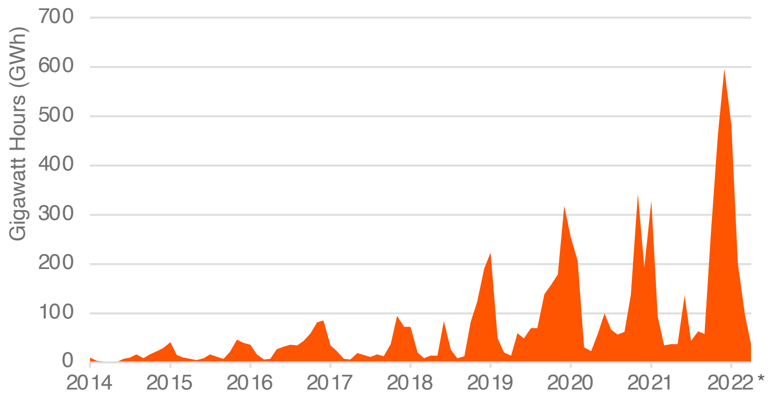
Sources: 1. Electricity Markets & Policy, n.d.; 2. U.S. Energy Information Administration, 2022

U.S. Infrastructure: Utilities Could Continue to Invest More in Transmission and Distribution

In some cases, more renewable energy is produced than the grid can accommodate. These incidents can lead to curtailment of energy generation, which is costly for the producer and system operator alike. U.S. utilities are increasing investments in the supportive infrastructure that could mitigate this dynamic.

Renewable energy curtailment has trended upwards in many markets as capacity expands rapidly.

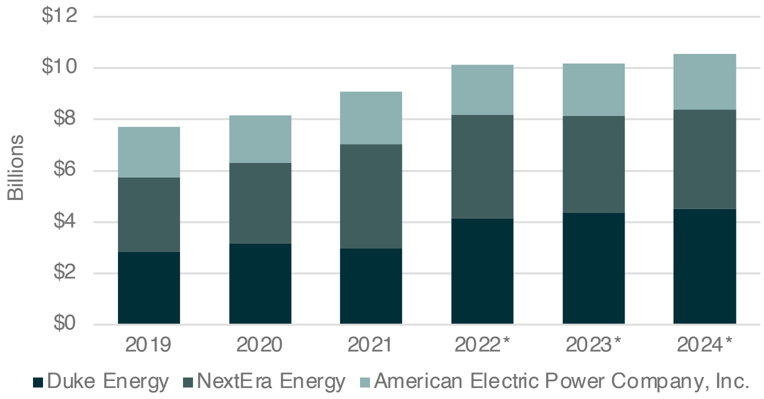
Curtailment of Wind and Solar Energy by the California Independent System Operator (CAISO) (Gigawatt Hours)



*2022 data through August 2022

CAPEX on transmission and distribution projected to increase as utilities position for the energy transition.

U.S. Electric Utilities Budgeted CAPEX on Transmission and Distribution ($, Billions)



*Indicates forecast

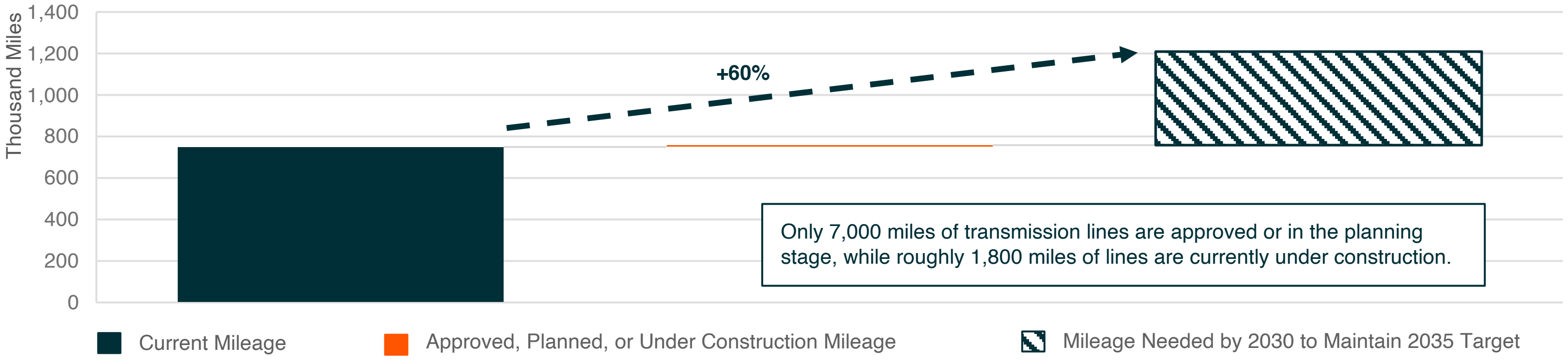
Sources: Visual (LHS): California ISO, 2022; Visual (RHS): American Electric Power Co., 2019; American Electric Power Co. 2020; American Electric Power Co., 2021; American Electric Power Co., 2022; Duke Energy, 2019; NextEra Energy, 2021

U.S. Infrastructure: Grid Modernization Needs Heavily Outweigh Project Pipeline

A well-connected grid is key to accommodating higher levels of renewable energy generation. Transmission lines, especially high-voltage variants, give operators flexibility to transport electricity throughout the grid when renewable output fluctuates. Recent policy shifts could help boost the transmission project pipeline.

The Department of Energy suggests that electricity transmission capacity must expand 60% by 2030 to accommodate a U.S. goal of reaching 100% clean electricity by 2035.[1] Currently, the transmission line project pipeline is limited. Only 5,000 miles are on track for delivery by 2025.[2]

Projected U.S. Transmission Line Expansion Needed to Reach 100% Clean Electricity by 2035 (Thousand Miles)



Note: Mileage needed based on Department of Energy Guidance

Average voltage for transmission pipeline is 375 kilovolts (kV).[3] Voltage exceeding 500kV is preferred for high-power voltage lines in a renewably powered grid.[4]

Sources: Text: 1. U.S. Department of Energy, 2022; 2. American Clean Power, 2022; 3. Fitch Solutions, n.d.; 4. EMF Portal, n.d.; Visual (LHS): GeoPlatform ArcGIS Online, n.d.; Fitch Solutions, n.d.; U.S. Department of Energy, 2022; Visual (RHS): Edison Electric Institute, 2022

U.S. Infrastructure: Leveraging Technology for Smarter Infrastructure

In today's digital age, connectivity is ubiquitous and data volumes are growing exponentially. To support the integration of newer technologies, the next generation of infrastructure must be built with next-gen networks in mind.

Key Technologies for Smart Infrastructure

Smart cities feature tech-enabled infrastructure collecting data to manage assets, preserve resources, and improve efficiency.

- **Connected sensors** embedded in roads, buildings, vehicles, and other infrastructure collect data in real time
- **Data clouds & AI** store and process data from sensors and other sources, generating instructions for infrastructure.
- **Next-gen networks** are the lifeblood of connected infrastructure, enabling the transmission of data and instructions in real time.

	4G / 4G LTE	5G
Frequency / Capacity	< 6GHz	> 6GHz
Bandwidth	100MB/s–1GB/s	10–20GB/s
Latency	~10ms	~1ms

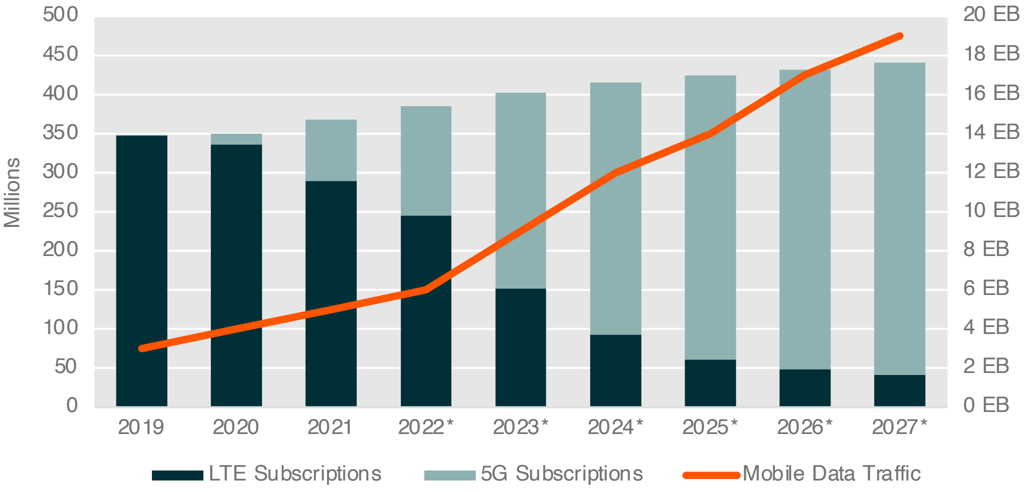
100x capacity for connected devices and sensors

>5x increase in network responsiveness

10–100x increase in network speed

As data volumes swell in North America, 5G networks are expected to become standard.

Projected North American Mobile Subscriptions by Technology (#, Millions, LHS) and Mobile Data Traffic (EXABYTE / Month, RHS)



*Indicates forecast

Source: Ericsson Group, n.d.

U.S. Infrastructure: Addressing Weaknesses in Digital Infrastructure

Many Americans still experience low internet speeds, in part because the effectiveness of 5G is hindered by dynamics such as outdated infrastructure. The IIJA directs $65 billion toward broadband deployment and development.[1]

Digital Infrastructure Categories

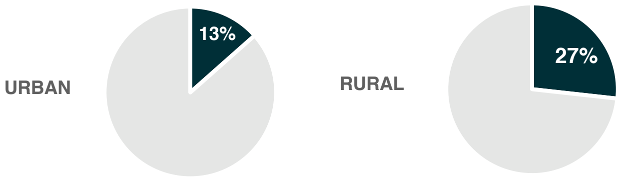
Fiber Optics: Installation of fiber optic cables could support increasing intensity of newer networks. Fiber optics improve on legacy copper systems by offering higher speeds, elevated bandwidth, longer transmission distance, and immunity from electromagnetic interference, among other qualities.

Cell Towers: More towers could facilitate stronger internet performance. Conventional cell towers and “small cell” towers for 5G are needed. Newer 5G cells emit high frequency millimeter waves, which have limited range. These devices must be placed in high density over a given area to maximize the benefits of 5G.

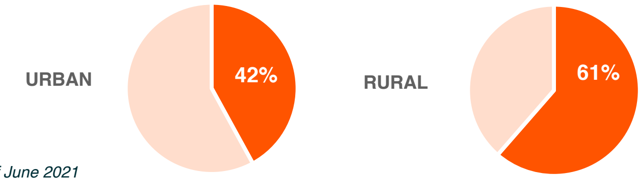
Data Centers: Data centers are networks of computing and storage resources that allow the delivery of software or data. These infrastructure assets are critical to the daily digital processes of companies and consumers. Nearly 2,700 data centers are already in place around the United States, but more are needed to handle future data volumes.[2]

The FCC considers download speeds of 25/3 Mbps as “high-speed.” This level could soon be raised to 100/10 Mbps.[3] Many people lack access to high-speed internet, with a large divide between rural and urban populations.

Percent of U.S. Population Without a Provider of Fixed Wireless or Cable Broadband Capable of Speeds of 25/3 Mbps



Percent of U.S. Population Without a Provider of Fixed Wireless or Cable Broadband Capable of Speeds of 100/10 Mbps



**As of June 2021*

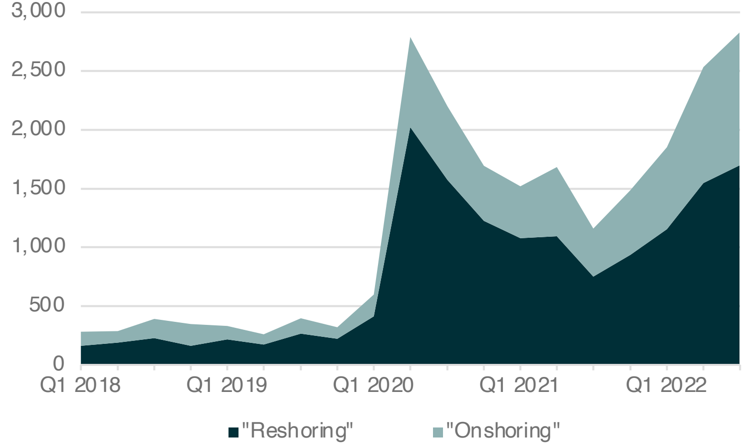
Sources: Text: 1. DeFazio, 2021; 2. Cloudscene, n.d.; 3. Howard, 2021; Visual: Federal Communications Commission, 2021

U.S. Infrastructure: Supply Chain Reshoring Could Boost Domestic Construction

Recent black swan events prompted U.S. companies to reconsider their decentralized supply chains. Many management teams hope to build out domestic manufacturing capacity, which could create opportunities throughout the U.S. infrastructure space.

Supply chain localization is an increasingly common topic in corporate presentations and news stories. A 2021 survey found that 92% of U.S. executives expressed positive sentiments toward reshoring efforts.[1]

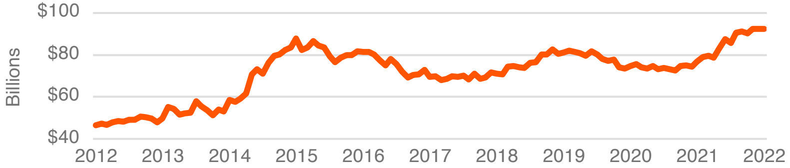
Prevalence of Supply Chain Reorientation Buzzwords in News Stories (#, Stories)



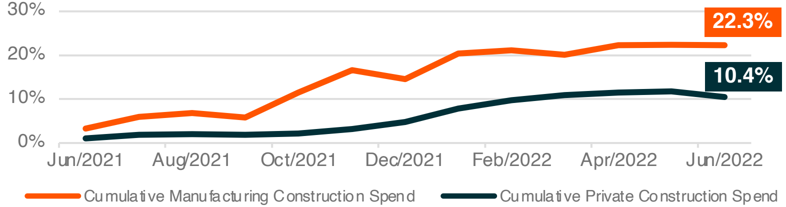
Note: Includes social media stories

U.S. spending on manufacturing capacity is high relative to history and outpaced growth in private construction in recent quarters. Newly started projects in the West are projected to increase 47% YoY for 2022.[2]

U.S. Private Manufacturing Construction Spending ($, Billions)



Cumulative Increase in U.S. Manufacturing Construction vs. Other Private Construction Spending Last 12 Months (%)

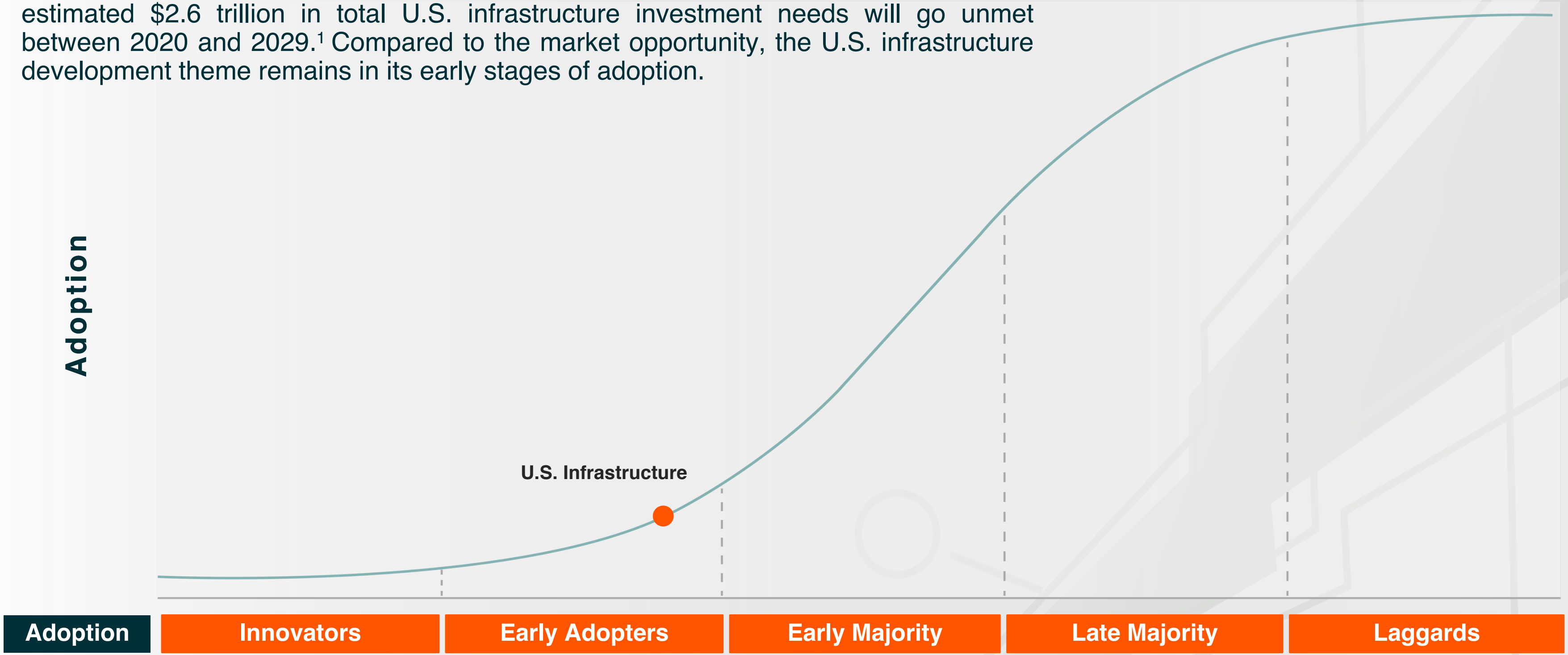


Source: U.S. Census Bureau

Source: Text: 1. Bossche, Ehrig, Troncoso, & Luo, 2022; 2. Obando, 2022; Visual (LHS): Bloomberg, L.P., n.d.; Visual (RHS): U.S. Census Bureau, 2022

S-Shaped Curve of Adoption – U.S. Infrastructure Development

A total overhaul of U.S. infrastructure is many years and trillions of dollars away. An estimated $2.6 trillion in total U.S. infrastructure investment needs will go unmet between 2020 and 2029.[1] Compared to the market opportunity, the U.S. infrastructure development theme remains in its early stages of adoption.



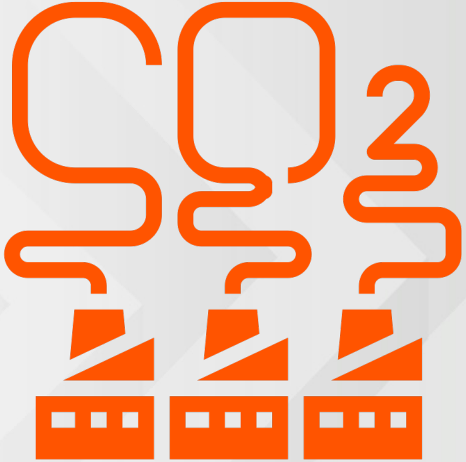
Source: 1. American Society of Civil Engineers, n.d.

Displayed for illustrative purposes. Curve shape not indicative of mathematical transformation

Chapter 08

Global Decarbonization

As the unequivocal threat of climate change endures, policymakers and companies must cooperate to align with the 2015 Paris Agreement. Climate change requires a meteoric rise in investments to reduce carbon emissions, including the development of more rigorous carbon markets and carbon capture technologies. We believe tightening deadlines to meet net zero and fresh policy incentives create a perfect storm for carbon markets and nascent carbon capture technologies to rise over the next decade.

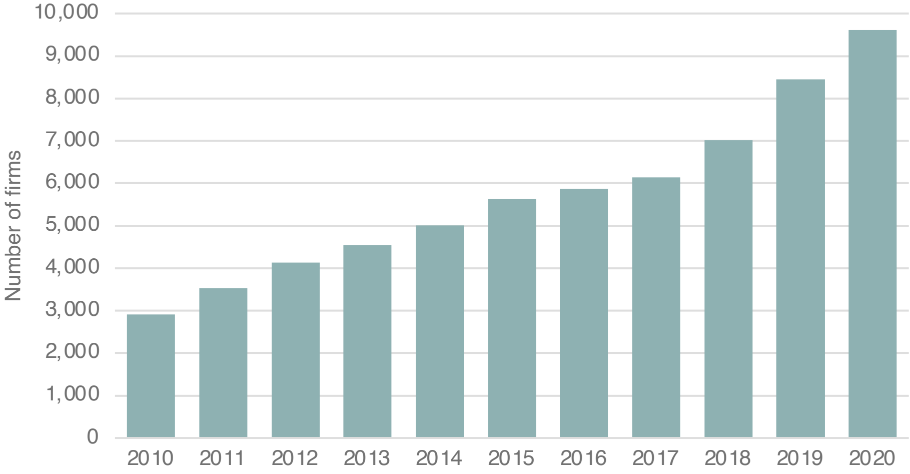


What's Driving Decarbonization Efforts From the Corporate Level

Decarbonization is now a top priority for company management due to pressure from corporate boards, investors, and customers. As climate targets set by the 2015 Paris Agreement approach, we expect greater demand for decarbonization solutions.

Firms Disclosing Emissions Through the Carbon Disclosure Project*

The Carbon Disclosure Project is a global disclosure system for environmental reporting with the most comprehensive dataset on corporate climate action. Disclosing companies represent over 50% of global market capitalization.

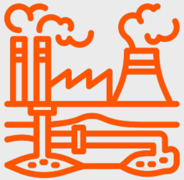


Source: Ruf & Frans, 2021

Corporate climate commitments drive increased activities towards decarbonization solutions.

Carbon Markets: Voluntary and Compliance

Trading volumes and prices have increased significantly in the compliance and voluntary carbon markets as the pressure to meet net zero builds. Increased trading and price activity highlight the growing demand for the development and standardization of robust carbon markets.



Carbon Capture, Utilization, and Storage (CCUS)

Incentives from the Inflation Reduction Act and advance market commitments led by big tech companies seek to jumpstart CCUS investment to reach a commercially viable stage as a decarbonization solution.

How the Carbon Markets Work

The compliance and voluntary carbon markets work in tandem, in separate ecosystems, to facilitate the pathway to decarbonization.

Governments & Regulators

Set the emissions cap and allocate allowances to covered industries

Carbon Allowances

The compliance carbon market consists of regional programs that regulate carbon allowances. Each allowance provides a company the legal ability to emit 1 ton of CO2. Companies that have excess emissions can purchase allowances from companies who have surplus allowances.

Emitter A

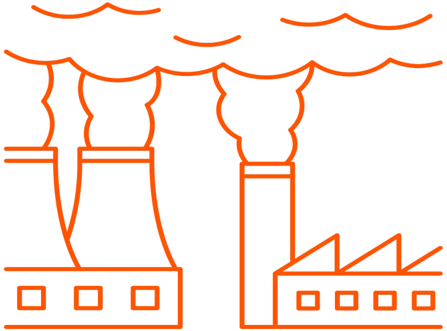
(Excess GHG emissions)

BUYS

Emitter B

(Reduced GHG emissions)

SELLS



Compliance Carbon Markets

Primary Market
Regulated companies trade carbon allowances after they are issued by regulators companies.

Secondary Market
Banks, trading companies, and other market participants trade exchange-listed carbon futures and derivatives to enhance liquidity, market efficiency, and allow regulated companies to hedge risk.

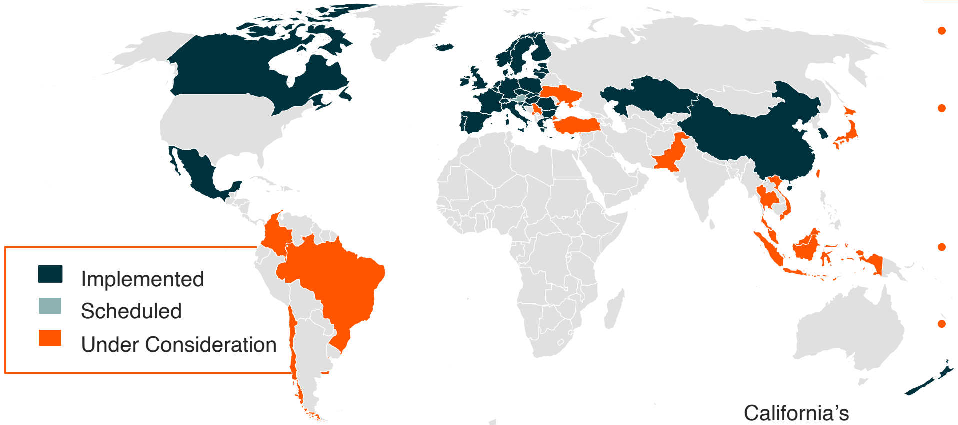
Voluntary Carbon Markets

Carbon credits in the voluntary carbon market generate emissions reductions and removals and are project-based. Therefore, carbon credits are offsetting emissions. Carbon offsets refer to instruments within the Voluntary Carbon Markets.

Carbon credits provide an opportunity to invest in nature-based solutions and drive investment into nascent green technologies.

The credits must be verified by a third party using a recognized carbon offset standard.

Regional and National Emissions Trading Schemes (ETS) Continue to Expand Globally



Global Compliance Carbon Markets Milestones

- **California:** In 2021, California Carbon Allowances (CCAs) reached a peak of 2.4 billion carbon allowances traded, up from 1.87 billion in 2020.
- **RGGI:** In 2022, Pennsylvania went to state court to defend its entry into the Regional Greenhouse Gas Initiative (RGGI), which would add significant supply to the market. Conversely, Virginia lawmakers have stated the RGGI's repeal is imminent.
- **European Union:** EU Allowances (EUAs) increased by 144% in value in 2021, accounting for 90% of global carbon allowance trading value.
- **China:** Launched in 2022, China's ETS is already the world's largest carbon market, over three times the size of the EU's. According to estimates, China's market can grow by 70% or more once heavy industry and manufacturing are added to the scheme.

1997 The Kyoto Protocol establishes the first international carbon market system.

2005 The EU ETS launches as the world's first international emissions trading scheme.

2005 The U.S. Regional Greenhouse Gas Initiative is formed as a consortium of states in the Northeast.

2008 The New Zealand ETS launches.

2013 California's cap-and-trade program launches and is now the largest scheme in North America.

2015 The Paris Agreement becomes a landmark international treaty on climate change.

2015 The South Korea ETS launches as the first in East Asia.

2021 Post-Brexit, the UK ETS launches.

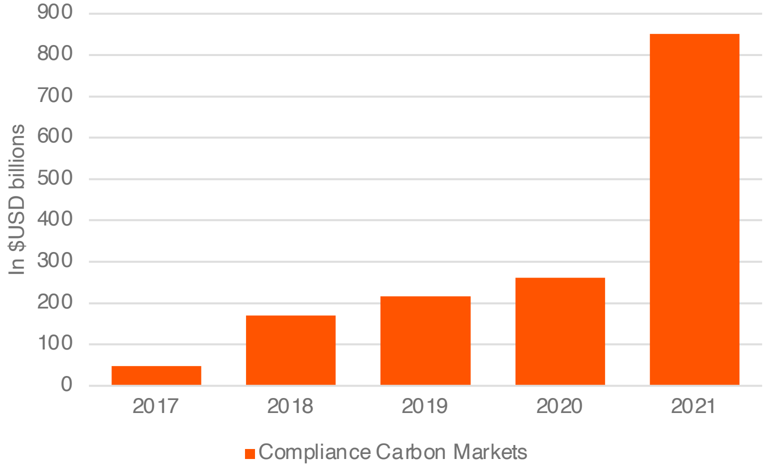
2022 China's ETS launches and becomes the world's largest carbon market.

Compliance and Voluntary Carbon Markets Will Be Essential to Achieve Net Zero

We expect demand for the compliance and voluntary carbon markets to increase significantly as corporations with net-zero commitments work toward meeting targets. We expect prices in these markets to rise with demand.

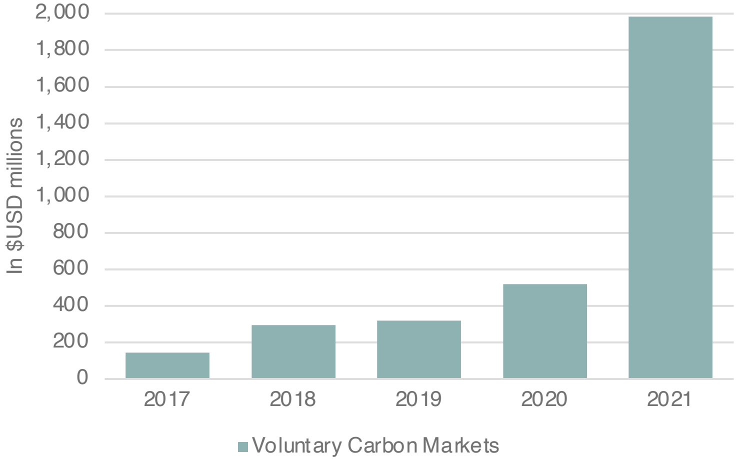
Expectations for tighter emissions caps, particularly in Europe, continue to push demand for carbon allowances globally.

Trading Volume of Compliance Carbon Markets



Voluntary carbon markets nearly quadrupled from 2020 to 2021, but their size pales in comparison to the compliance carbon markets.

Trading Volume of Voluntary Carbon Markets

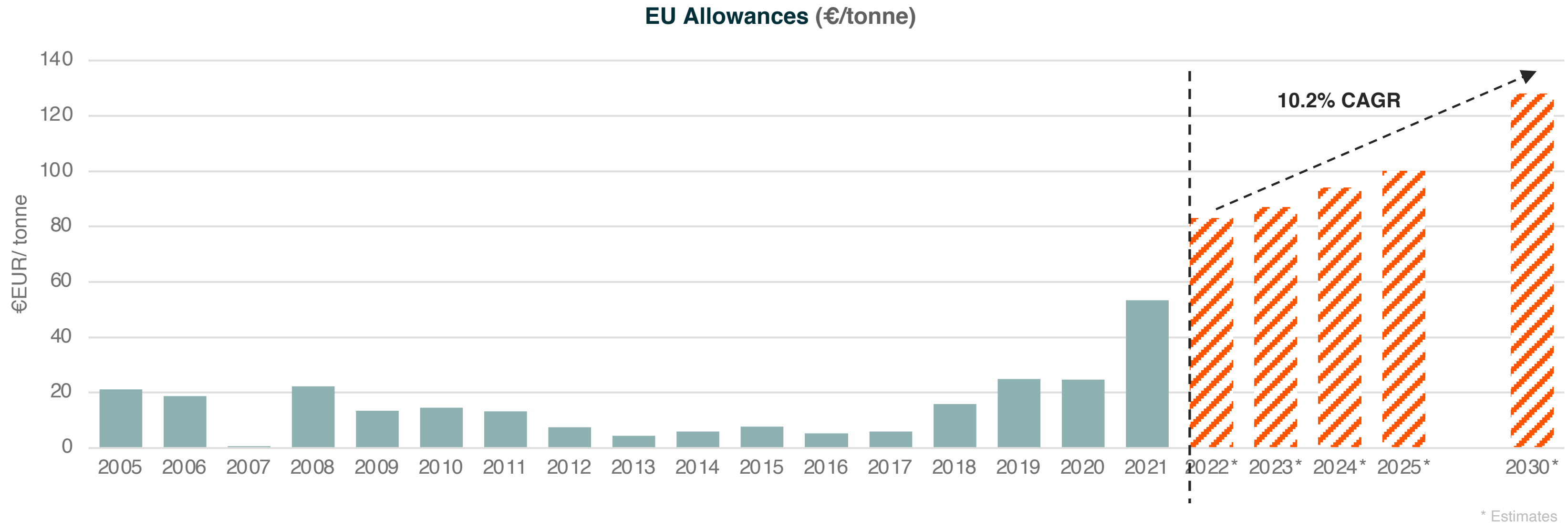


Sources: 1. Berkeley Lab, n.d.; U.S. Energy Information Administration, 2022

Compliance Carbon Markets Continue to Develop, Resulting in Increased Trading Volume

Tightening emissions budgets and stricter regulations will likely continue to drive prices higher. The EU ETS is a case study, as the European Commission's Fit for 55 package is expected to continually reduce the emissions cap and raise EU Allowances prices.

European climate ambitions are expected to remain robust over the longer term despite the energy crisis, surpassing €120/tonne.



Sources: Bloomberg NEF, 2022; The World Bank, n.d.; Engin, Amiot, Evans, Lord, & Burks, 2022

Urgency to Develop Voluntary Carbon Markets Gaining Momentum

The voluntary carbon markets offer a potential solution to purchase carbon credits to offset a company's emissions while financing nature-based solutions and driving investment into nascent green technologies.

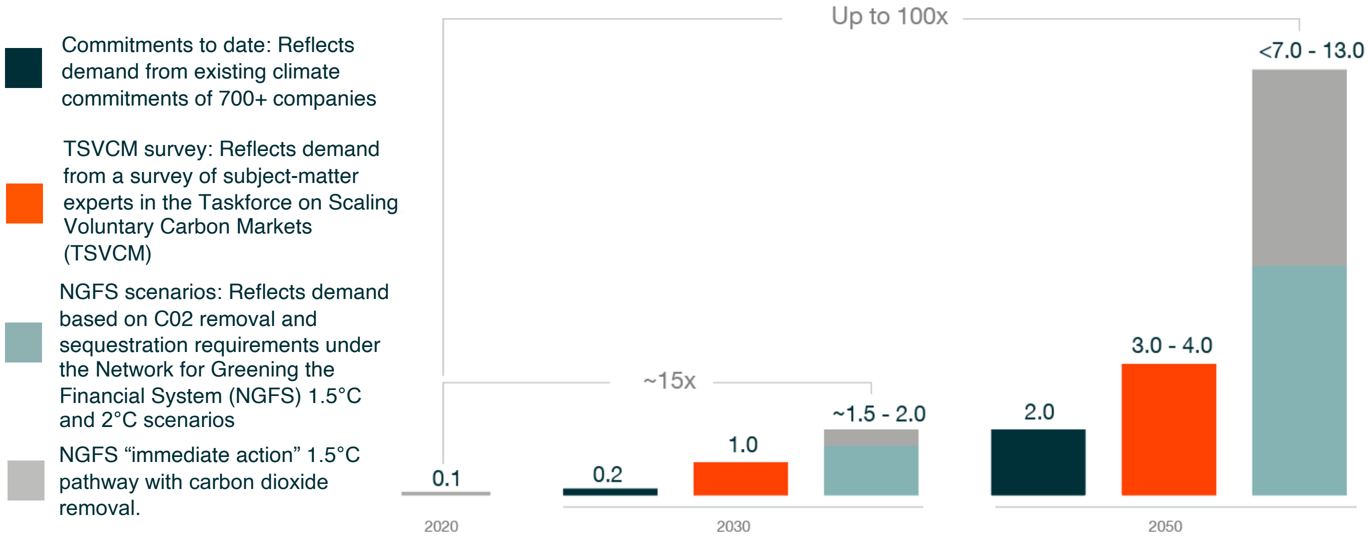
CHALLENGES

- Verification standards to ensure quality of carbon credits
- Lack of liquid and robust market

OPPORTUNITIES

- Assist in meeting corporate net-zero goals
- Drive investment in early-stage green technologies and nature-based solutions

Scaling the Carbon Voluntary Markets



Sources: Text: HSBC, 2021; Blaufelder, Levy, Mannion, & Pinner, 2021; Visual: Donofrio, Maguire, Myers, Daley, & Lin, 2021

Regenerative Finance (ReFi) Develops Rapidly After the Launch of the First Carbon Credit Tokens

Challenges are evident, but blockchain has the potential to improve verifiability, maintain transparency, and be a recordkeeping agent as voluntary carbon markets scale. Carbon credit tokens have garnered interest from policymakers, corporations, and development banks to direct capital to nature-based solutions.

2021

Moss Earth's MCO2 begins trading on Coinbase

After launching in March 2021, MCO2 became the first carbon credit token to trade on coinbase.

Toucan Protocol launches Basic Carbon Tonne (BCT)

In the first month after launch, BCT trading volume hit $2B+ and 150,000+ tokenized carbon credits were retired.

2022

Polygon goes carbon neutral

The Polygon network fulfilled its carbon-neutral pledge by retiring 104,794 tonnes in the form of BCT and MCO2 tokens.

Premier carbon registry, Verra, opens consultation for crypto

After rebuking crypto tokens initially, Verra opened a public consultation to third-party crypto instruments and tokens.

The IFC and partners launch Carbon Opportunities Fund

The World Bank affiliated International Finance Corporate (IFC) backed energy-focused platform Chia Network through $10 million in seed capital to support the development of a blockchain-based carbon credit trading platform.

The Future of ReFi

- Startups, development banks, and corporations like Salesforce work to develop carbon credit exchanges.
- Carbon offsetting through IMPT, a carbon token that partners with retailers, will work to measure individual carbon footprint while shopping, pushing the use case for carbon credits beyond corporate demand.

Sources: Holger, 2022; Carbon Credits, n.d.; The White House, 2022; Allied Offsets, n.d.; Moss Earth, 2021; IMPT,io, n.d.

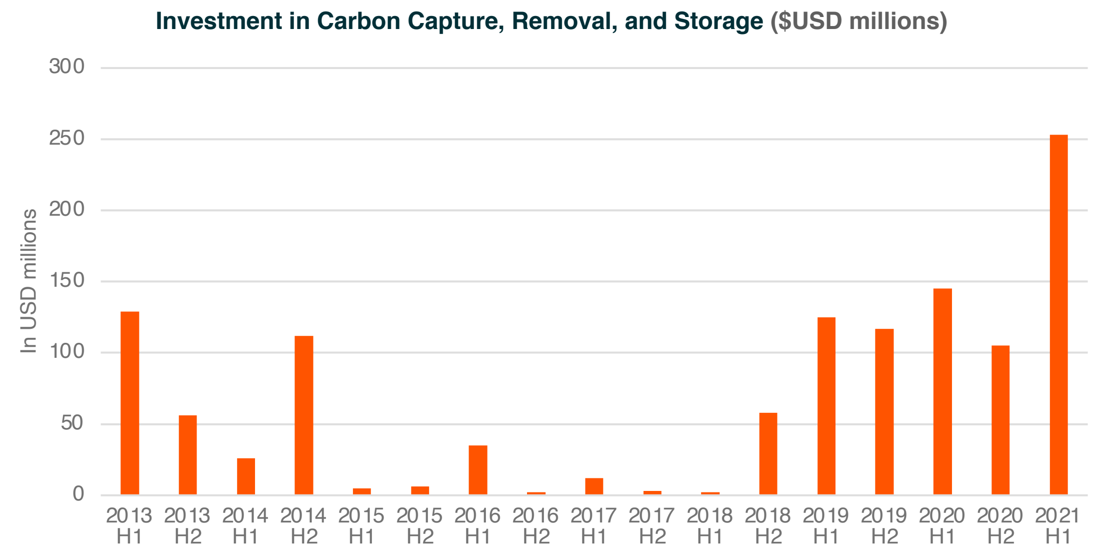
Carbon Capture, Utilization, and Storage (CCUS) Projects Receive Major Boost

Corporate interest in carbon capture technologies hit an inflection point with climate change targets approaching. Investment is rising, and companies are working together to advance the technology.

Corporate Climate Ambition

- Leading technology and consulting companies collaborate to accelerate research and development of carbon removal through an advance market commitment (AMC) called Frontier Climate.
- An AMC was piloted over a decade ago for vaccine development for low-income countries. The pilot incentivized research for a critical societal need, regardless of initial commercial viability. Companies used the same mechanism to commit an initial $925 million towards permanent carbon removal between 2022 and 2030.
- In 2022, Climeworks raised the largest-ever direct air capture (DAC) investment, equivalent to $650 million.
- United Airlines is investing directly in DAC. Microsoft purchases DAC removal from Climeworks, and it invested in Orca, the largest operating DAC plant.

The global carbon capture and storage market is expected to reach $5.35 billion by 2030.



Sources: Worford, 2022; Budinis, 2022; Johnson & Cox, 2022; Frontier, n.d.; Clear Air Task Force, 2022; Kovaleski, 2022

Newfound Policy Support for CCUS Technologies Creates Momentum

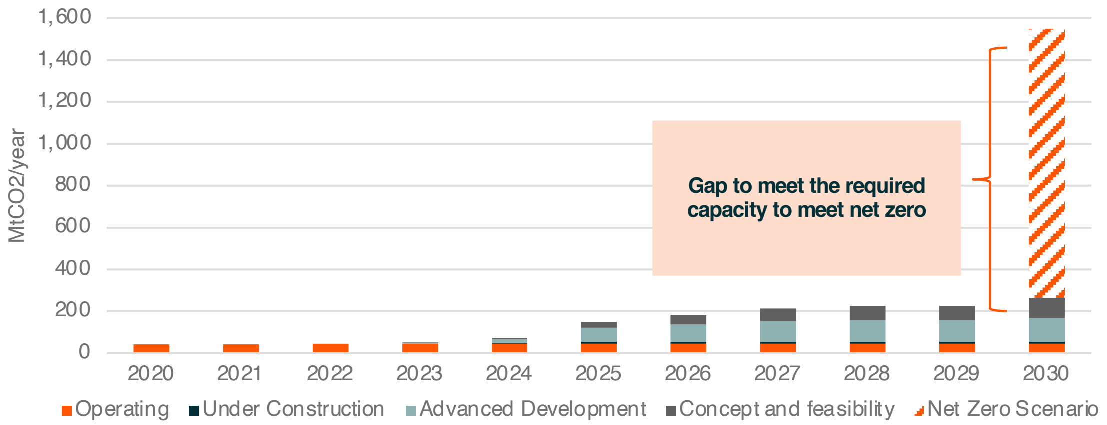
Historically, a lack of policy support and commercial incentives limited CCUS technologies to less than 0.5% of global investment in clean technologies. The Inflation Reduction Act's tax credits and Bipartisan Infrastructure Law funding make CCUS a priority.

Climate Policy Action

- **The Inflation Reduction Act includes incentives to boost CCUS:** The IRA includes enhancements and expanded benefits to the 45Q tax credit to incentivize the development of carbon capture and storage. The direct air capture credit increased from \$50 to \$180/tonne, with the goal to increase its potential to decarbonize hard-to-abate industrial sectors.
- **The Department of Energy allocates \$2.3 billion to carbon emissions reduction initiatives:** The first initiative allocated \$2.25 billion to accelerate geologic carbon storage projects capable of permanently storing at least 50 million metric tons of captured CO2. The second initiative allocated \$45 million towards onshore and offshore carbon storage. The third initiative allocated \$46 million towards technologies that remove, capture, convert, or store carbon dioxide from utility and industrial sources or the atmosphere.

While over 200 new capture facilities are set to be operational by 2030, capacity remains well short of the International Energy Agency's forecasted Net Zero Scenario.

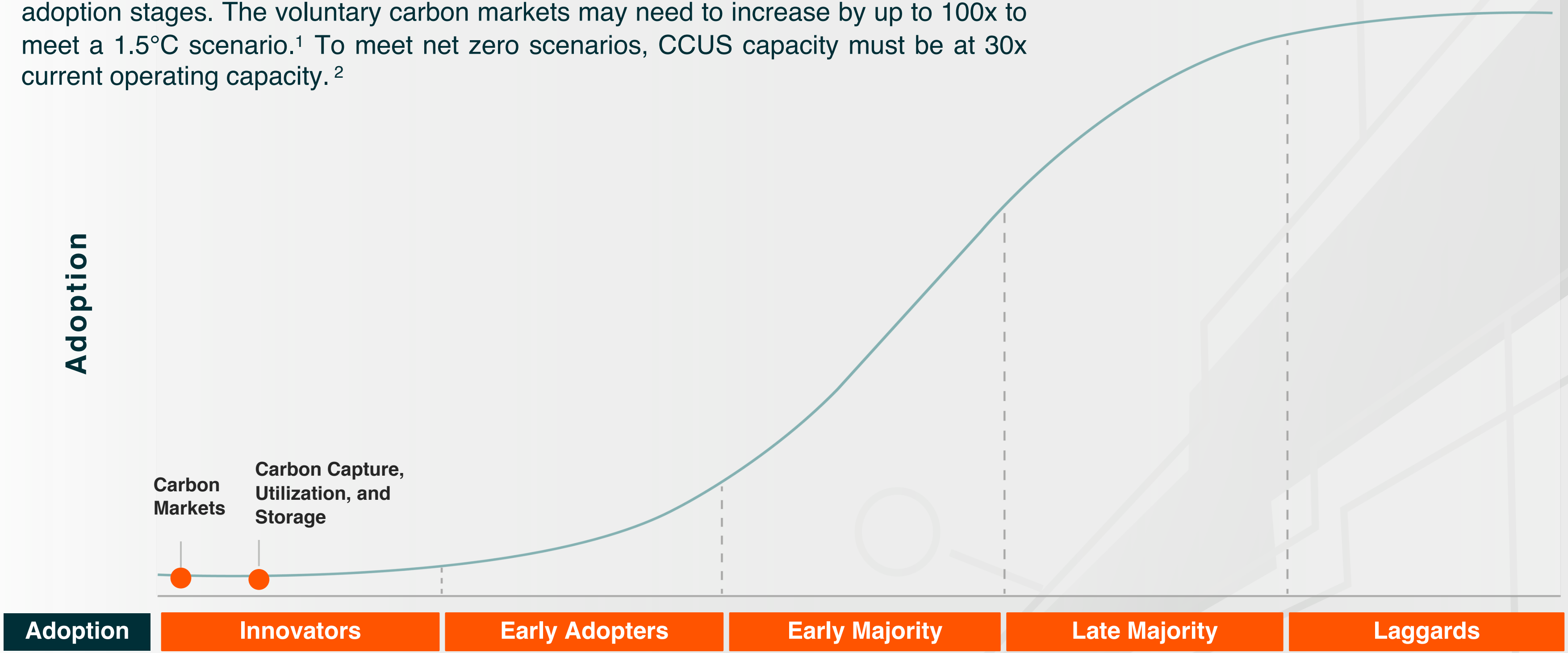
Capacity of Large-Scale CO2 Capture Projects, Current and Planned, vs. the International Energy Agency's Net Zero Scenario (2030)



Sources: International Energy Agency, 2020

S-Shaped Curve of Adoption – Global Decarbonization

To meet climate targets, carbon markets must grow exponentially from nascent adoption stages. The voluntary carbon markets may need to increase by up to 100x to meet a 1.5°C scenario.[1] To meet net zero scenarios, CCUS capacity must be at 30x current operating capacity.[2]



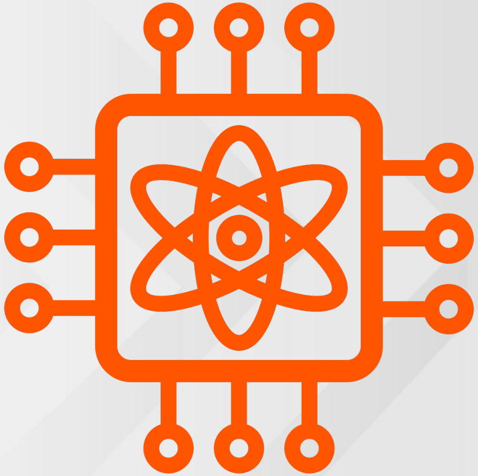
Sources: Blaufelder, Levy, Mannion, & Pinner, 2021; Valle, 2022

Displayed for illustrative purposes. Curve shape not indicative of mathematical transformation

Chapter 09

Big Data & Saas

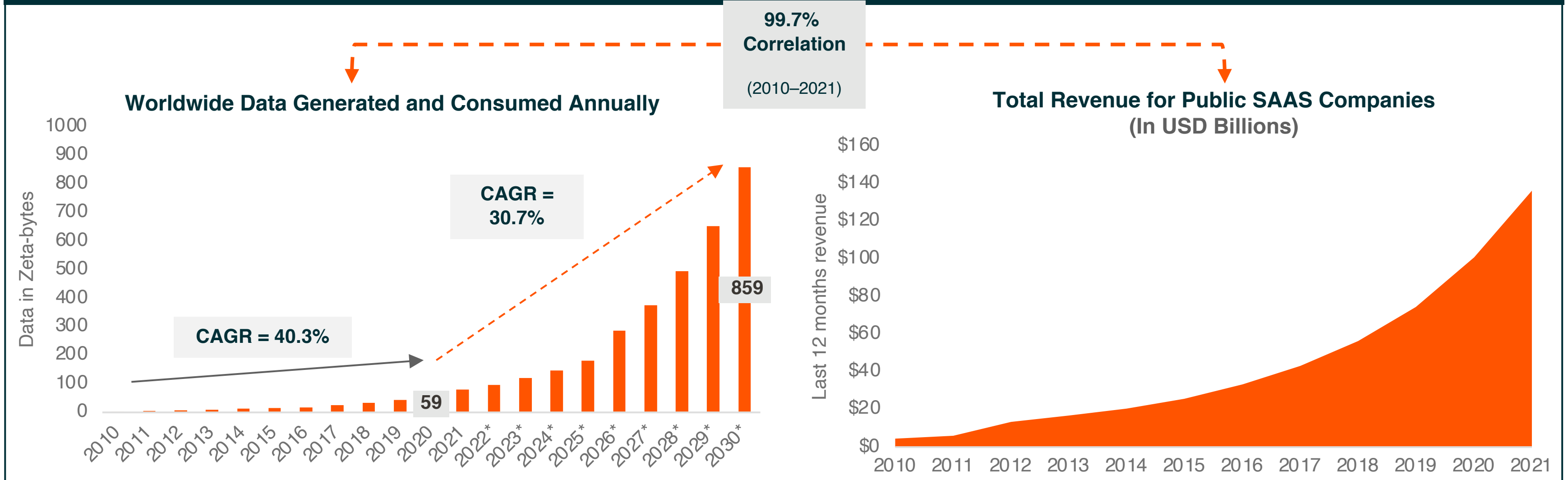
The exponential growth of data generated, stored, and processed continues unabated. For the digital economy to flourish, the development of centralized hyperscale processing, delivered through large-scale datacenters, is critical. Modern enterprise applications are being built natively on the cloud. Edge networks are working with hyperscale infrastructure to enable low-latency, media-rich experiences. And to make digital participation safe, cybersecurity continues to evolve with aggressive investment.



The Global Data Expansion Is in Full Force

The result of exponential growth of devices, applications, and endpoints is the creation of massive amounts of data downstream. An average connected person is expected to record over 4,900 data interactions per day by 2025.[1]

More than 180 zeta-bytes of data will be processed (created, stored, and consumed) worldwide by 2025—nearly 3x that of 2020. A result of the rise in processed data is the rise in consumption of cloud-deployed software as businesses struggle to store, process, and understand their data.



*Indicates forecast; Forecasted using exponential fitting

Shows TTM Sales for 75 public SaaS stocks

Sources: Text: 1. Reinsel, Gantz, & Rydning, 2018; I-Scoop, n.d.; Visual (LHS): Statista Research Department, 2022; Djuraskovic, 2022; Visual (RHS): FactSet Research Systems, n.d.

Big Tech Giants Are Aggressively Investing in Hyperscale Buildouts

Alphabet, Apple, Amazon, Microsoft, and other big tech platforms are becoming infrastructure suppliers to address their own needs and turn excess compute into profitable ventures. Big tech-run hyperscale facilities are also becoming hotbeds for computational innovation, pioneering architectural innovation aimed at redesigning the compute stack to lower costs and improve performance.

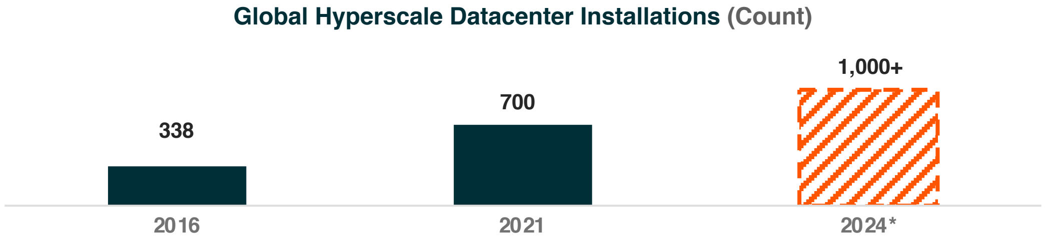
Hyperscale Datacenters Are Driving Computational Innovation

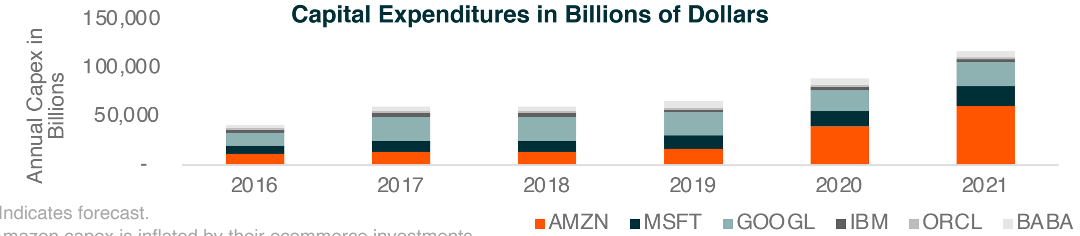
Specialized processors
The on-premise era drove a boom in x-86 processors. In the data era, the role of a powerful CPU is diminishing. Meanwhile, the bulk of the processing is being offloaded to GPUs coupled with low-power ARM processors.

High speed networking
Heavy streams of data sent to the cloud forced hyperscalers to reinvent networking. Their redesign of adapters, switches, software, and cables gave rise to specialized vendors like Mellanox, and fueled an industry wide shift to software-defined networks (SDNs).

Modular databases
Relational databases that dominated the early web broadly lack the suitability for instant read-write requirements of the real-time era. Data pipelines and tooling evolved to store, read, and write information more efficiently.

The Hyperscale Datacenters installed base is expected to grow at a 12.6% CAGR through 2024, supporting a parallel explosion in data and user activity. Capital expenditures from the major hyperscalers have doubled in the last 5 years.





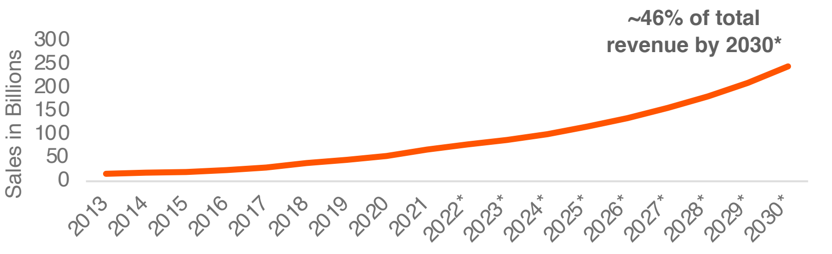
*Indicates forecast.
Amazon capex is inflated by their ecommerce investments.

Sources: Visual (Top): Synergy Research Group, 2022; Miller, 2022; Statista Research Department, 2022a; Statista Research Department, 2022b; Visual (Bottom): FactSet Research Systems, n.d.

Platforms Powered by Hyperscale Infrastructure Are Emerging as Gatekeepers of the Digital Economy

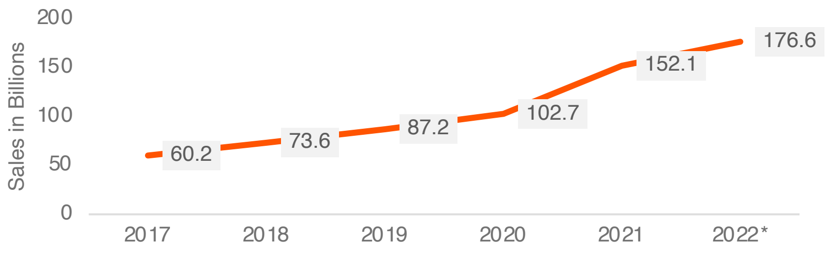
Consumers are embracing subscription services for storage, photos, and mundane apps. Meanwhile, enterprise software continues its permanent transition to the public cloud. Widespread adoption of the recurring payment model is the future for both segments.

Recurring sales for Apple's Services segment total $75B, mainly from subscriptions for iCloud storage, Photos storage, and developer fees.



*Indicates forecast

Subscription software sales will likely top $175B in 2022, a sizable portion of the roughly $800B global enterprise software market.[1]



Consumer Cloud

Local devices are unequipped to deliver on the data processing and storage demands of the average consumer. Devices rely on the cloud for file storage and AI tools to improve user experiences. Apple's iOS ecosystem and diverse services base exemplify the shift. By including Ads, Fitness, Health, and Banking to its existing business lines, Apple's Services could represent close to 50% of its revenues by 2030.[2]

Enterprise Cloud

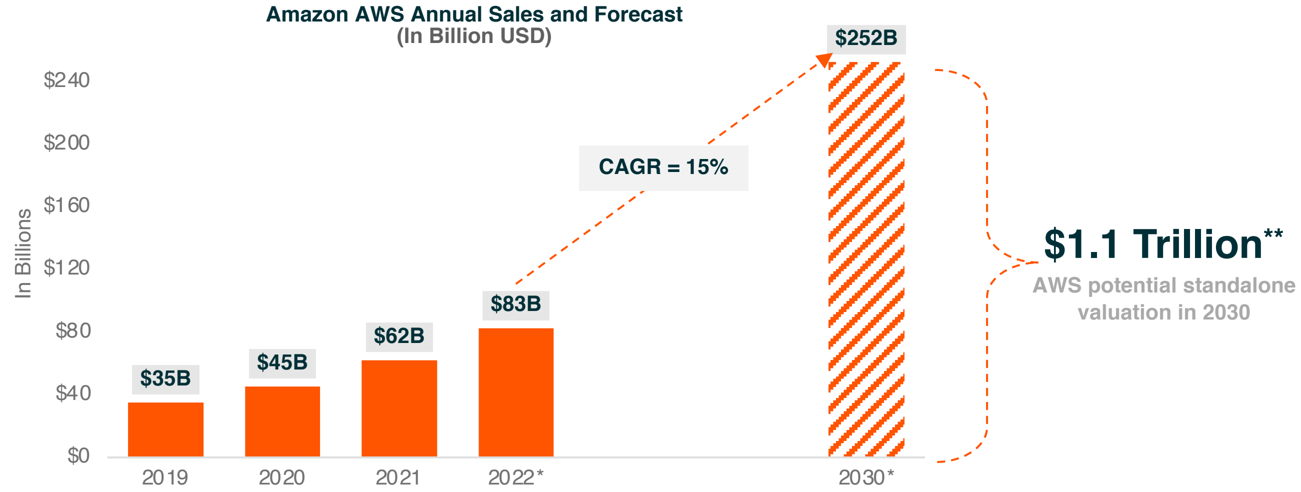
Consumption-based pricing is also taking over enterprise software and gradually displacing packaged software. New technologies built and talent trained are cloud native. The International Data Corporation (IDC) estimates nearly 90% of apps deployed by enterprises will be cloud native by 2025. [3]

Sources: Text: 1. Galloway, 2022; 2. Ibid.; 3. IDC, 2019; Visual (Top): Apple, Inc., 2022; Laricchia, 2022; Visual (Bottom): Gartner, 2022

Hyperscale Infrastructure Is a Lucrative Business

Big cloud franchises such as AWS, Azure, and Google Cloud could be worth trillions by the end of the decade. IaaS providers can multiply growth and boost margins by moving up the stack, adding more apps, integrations, platforms, and data tools that supplement bare-bone infrastructure.

Cloud infrastructure franchises could unlock trillions in value if ever spun out of their original companies.



*Indicates forecast

**Using a 4.4x PS multiple, same as the Indxx Global Cloud Computing Index on Sep 6, 2022, on forecasted 2030 revenues

Multiple Growth Levers

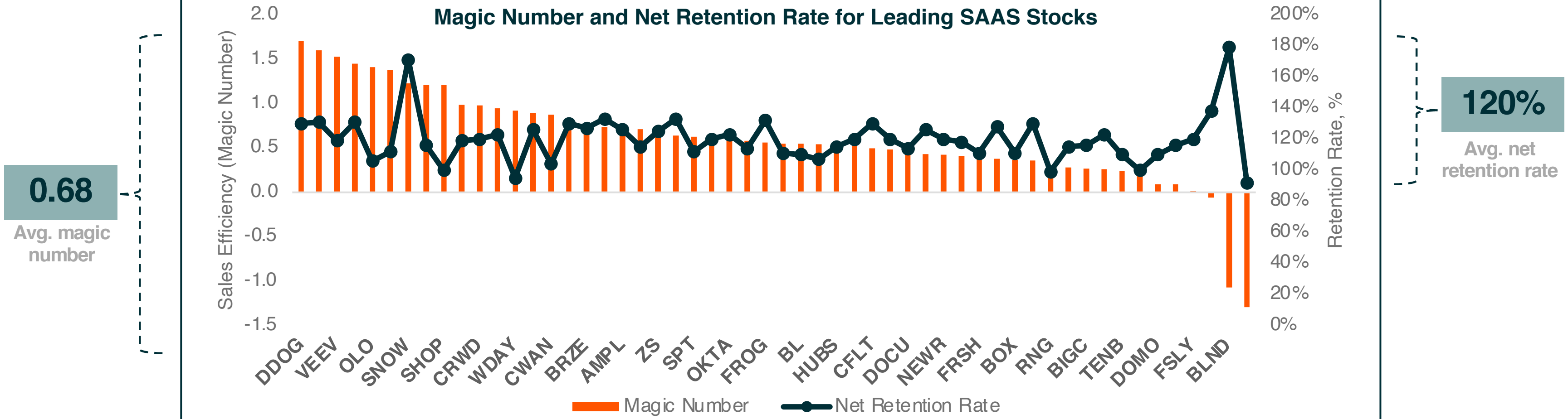
- **Steady sales growth:** Cloud adoption is still in the early phases. We estimate vendors could sustain 20%+ growth for 5 years given the strength of tailwinds.
- **Room for margin expansion:** AWS improved its operating margins by 365 basis points over the last 3 years to 29% in Q2 2022.[1] Margins could stabilize at 35–40% by 2030.
- **M&A optionality:** Infrastructure providers could diversify their portfolios via M&A. Google's takeout of Mandiant ($5.4 billion) and Microsoft's deal for GitHub ($7.5 billion) offer early glimpses.

Sources: Text: 1. Amazon, 2022; Visual: Amazon, 2022; Vailshery, 2022

Subscription Software Recurring Business Models Are Inherently Efficient and Resilient

Subscription software models increase cost predictability. Also, platforms can leverage their positioning to upsell and cross-sell end clients into more services, boosting top-line growth and margins.

Subscription-based models keep costs of servicing an existing customer low, directing a large portion of the revenue from existing customers to discover new customers.



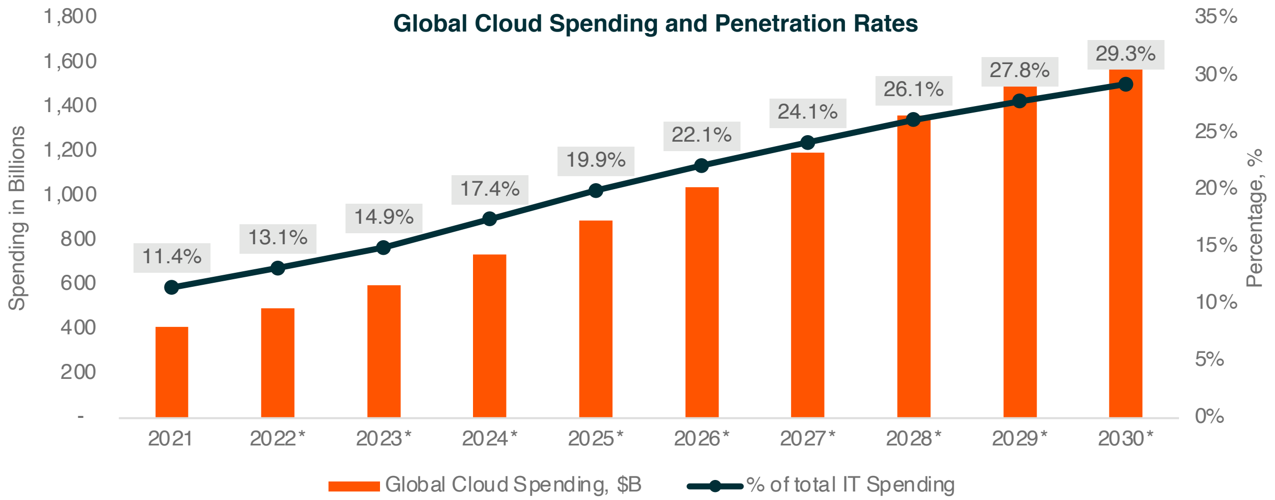
Magic number is a sales efficiency number defined as the output of a year's worth of revenue growth for every dollar spent on sales and marketing. Magic number can be defined as the percentage of incremental dollar earned in revenue for every dollar spent on sales and marketing for the previous quarter, which is an industrywide used metric for the efficiency of distribution power of the recurring business model. Net retention rate is defined as the percentage of recurring revenue that's retained from existing customers over a fixed period. SaaS businesses have a net retention rate of over 100%, which indicates that current customers almost always end up spending more on tools than they did before. Both ratios underline the efficiency and stickiness of the cloud software model.

Sources: FactSet Research Systems, n.d.

Adoption of the Public Cloud Is Still in Its Early Stages

Worldwide IT spending, excluding devices, was $3.6 trillion in 2021.[1] Cloud computing addresses the entire pocket, and current penetration leaves room for growth. In certain categories, such as enterprise software, 80%+ penetration is expected by 2030.

Despite its 15+ years in existence, the global cloud market accounts for less than 15% of global IT spending. Only 35% of the total IT workloads worldwide have moved to the cloud.[1]



*Indicates forecast. Projections derived assuming 23%, 21%, 17%, 15%, 14%, 12%, 11% growth rates for Public Cloud spending from 2024 through 2030, applied on top of Gartner Estimates for 2022 and 2023; Global expects IT spend to grow at a 5% CAGR through 2030.

Sources: Text: 1. Amazon, 2022; Visual: Amazon, 2022; Vailshery, 2022

Drivers of Cloud Adoption

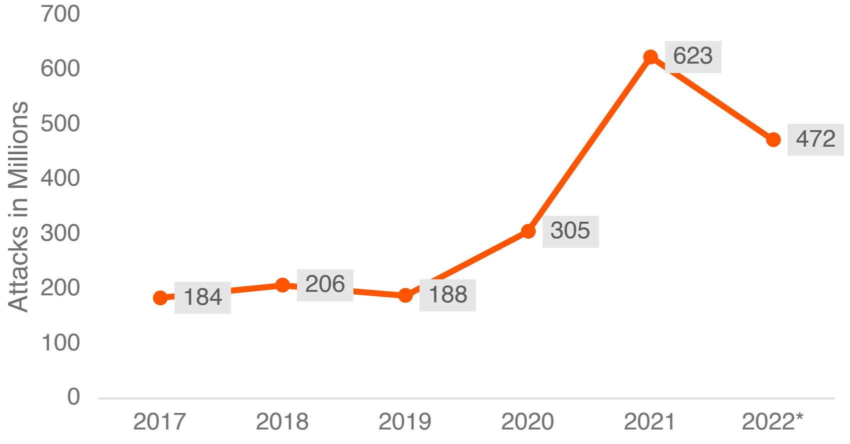
- **Spend consolidation:** Large enterprises could look at cloud migration as an opportunity to reset costs and reevaluate consumption.
- **Cost benefits:** The recurring payment model allows for low upfront costs, better visibility, and effective planning, resulting in low total cost of ownership.
- **Developer productivity:** Considerable developer time can be freed up by not having to manage back-end infrastructure. This factor is key to addressing talent shortages.
- **Security standardization:** Out-of-the-box and industry standard cloud solutions limit custom work for enterprises and reduce security risks.

Cybersecurity Challenges Will Grow in Sync With the Digital Economy

Remote work and the broad increase in digital activity expand the defensible surface area and create new entry points for cybercriminals. State-sponsored hacking also presents significant risks. As a result, cybersecurity spending will continue to accelerate, with governments particularly aggressive spenders.

Increased cyber engagement due to COVID-19 caused a massive increase in ransomware attacks. Attacks cooled off a bit in 2022 but remain elevated.

Ransomware Attacks on Global Corporations Worldwide (In Millions)



*Indicates forecast for 2022 based on data for 1H22.

Top Categories for Security Software

- **Network Security:** Firewall, Unified Threat Management (UTM), Network Detection and Response (NDR), SD-WAN, etc
- **Internet Security:** Secure Web Gateway (SWG), Web Application Firewall (WAF), and Remote Browser Isolation (RBI)
- **Endpoint Security:** Endpoint Protection Platform (EPP), Endpoint Detection and Remediation (EDR), and Data Loss Prevention (DLP)

Governments Drive Security Spending

- **IIJA:** Allocated $2 billion to cybersecurity defense at the federal level, including $1 billion for grants to improve the cybersecurity of state and local government entities.[3]
- **FY 2023 Budget:** The Biden Administration's fiscal 2023 budget allocated $11 billion towards civilian cybersecurity, up 11% year-over-year.[4]
- **Executive Order (EO) 14028:** On May 12, 2022, President Biden signed an EO to protect critical infrastructure and federal government networks.[5]

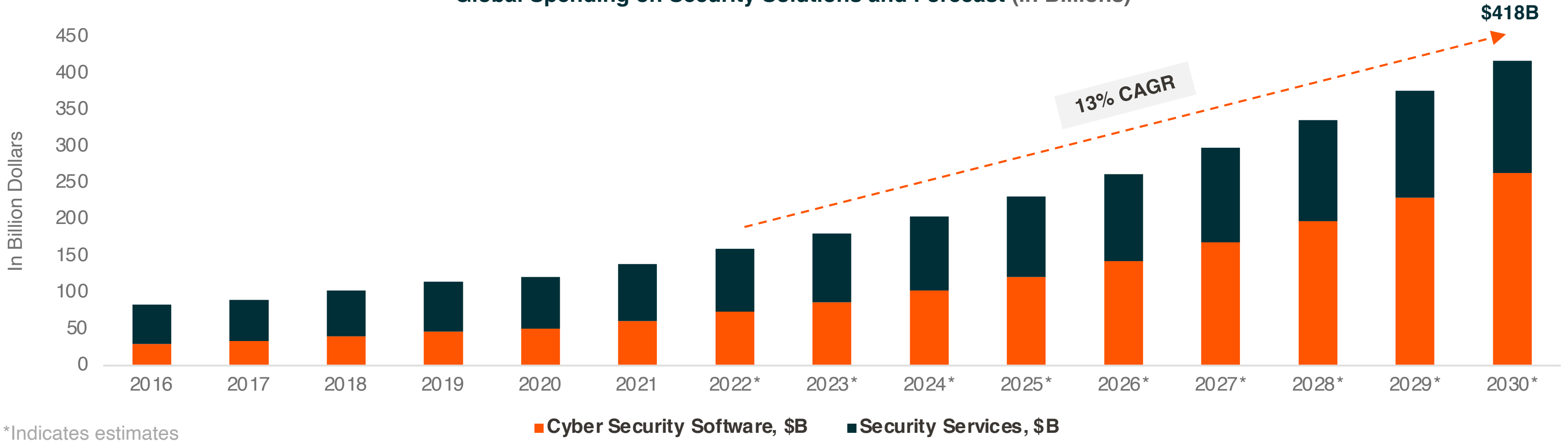
Sources: Text: 1. Verizon, n.d.; 2. Ibid.; 3. Ferber & Alexander, 2021; 4. Jones, 2022; 5. Cybersecurity & Infrastructure Security Agency, n.d.; Visual: Sonic Wall, Inc., 2022

More Severe Cyber Threats Are Accelerating Global Cyber Security Spending

The rapidly shifting threat landscape, remote work, and the risk of ransomware attacks and data losses are strong tailwinds for cybersecurity spending. Standardized software solutions have a long runway for growth.

Historically, most cybersecurity spending went to custom IT work. But state-of-the-art, cloud-deployed solutions are winning share. Security software is expected to grow at an 18% CAGR through 2030, much faster than custom services.

Global Spending on Security Solutions and Forecast (in Billions)



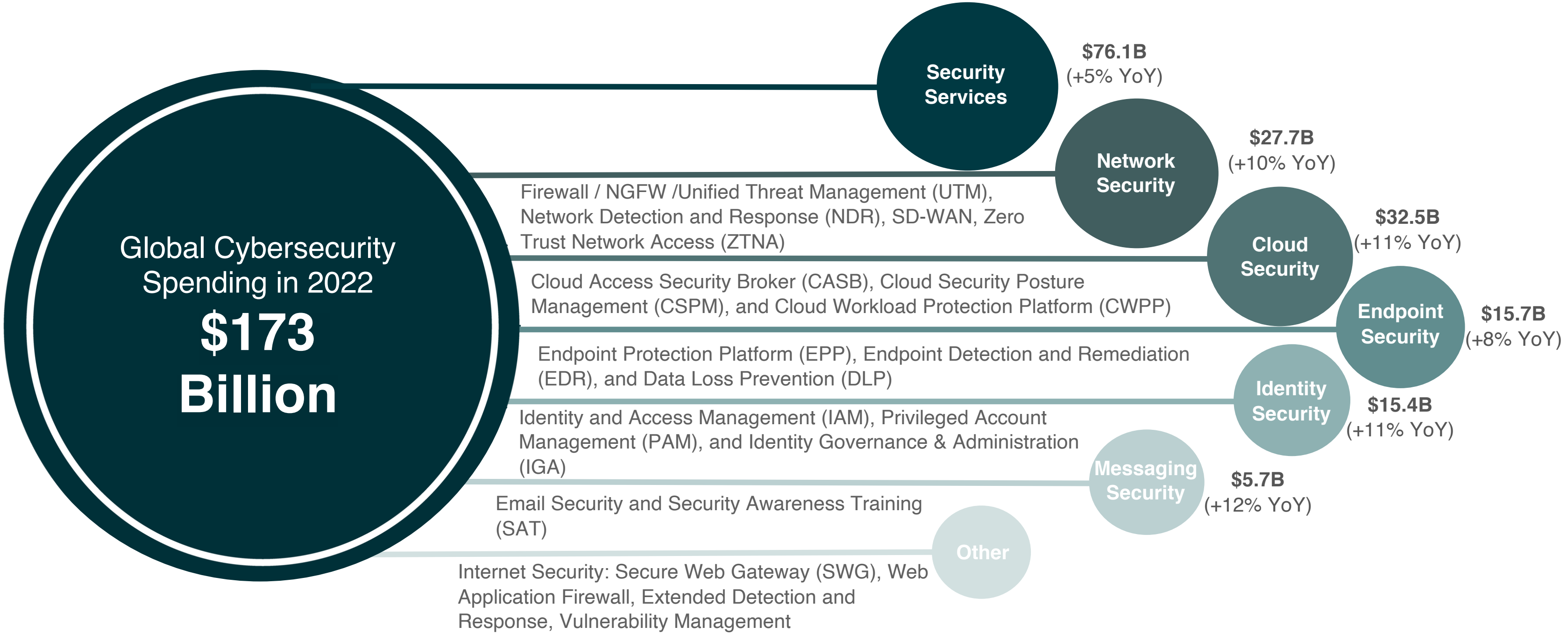
*Indicates estimates

Software includes software applications and platforms, while Security Services includes custom IT work performed by specialized security consultants that does not scale. Using Global X derived growth assumptions to project 2028, 2029, 2030 estimates.

Sources: Gartner, 2022a; Gartner, 2022b

Cybersecurity Market Is Fragmented With Several Emerging Categories

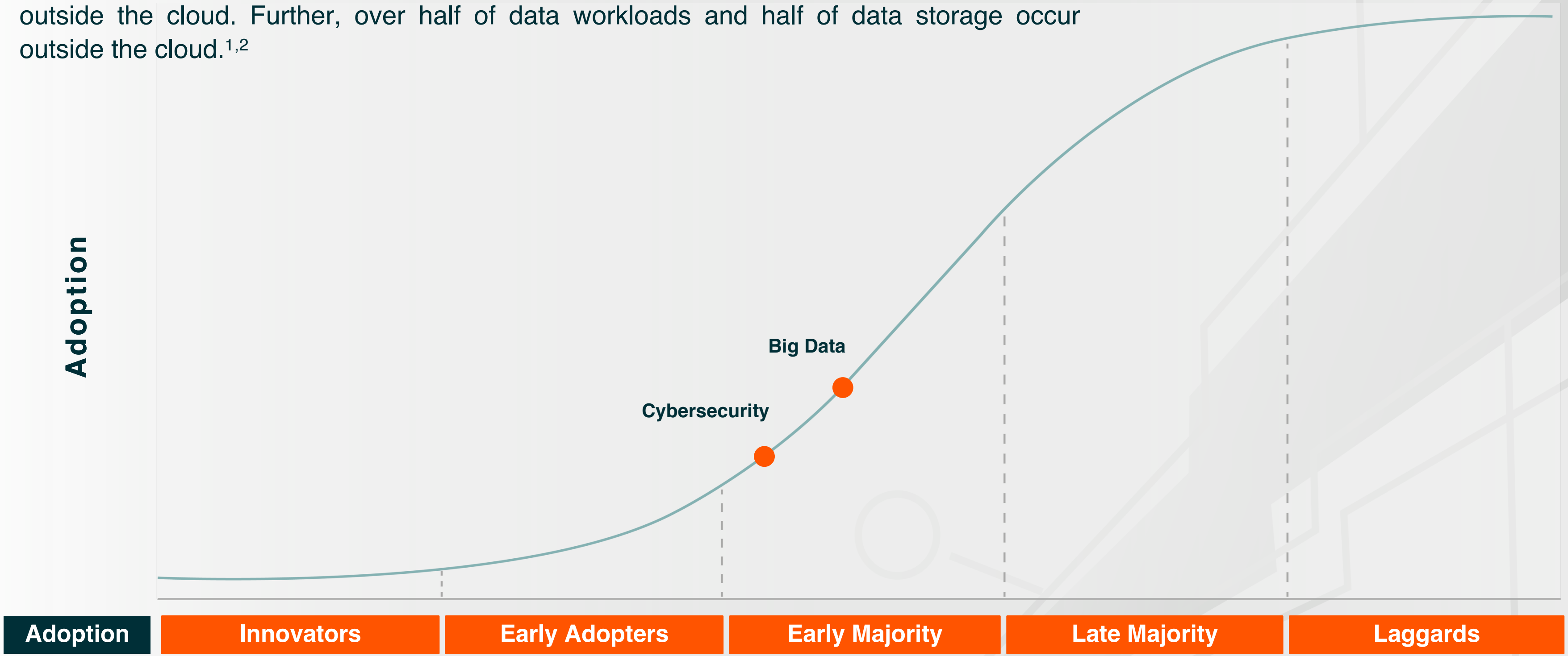
The cybersecurity ecosystem is complex with many verticals. Companies are now shifting from niche providers to one-stop solutions, driving industrywide M&A and deal activity through 2022.



Sources: Gartner, 2022a; Gartner, 2022b

S-Shaped Curve of Adoption – Big Data & SaaS

While most enterprises use public cloud solutions, 65% of the software market exists outside the cloud. Further, over half of data workloads and half of data storage occur outside the cloud.[1,2]



Sources: 1. Vailshery, 2022; 2. Thales Group, 2022

Displayed for illustrative purposes. Curve shape not indicative of mathematical transformation

Chapter 10

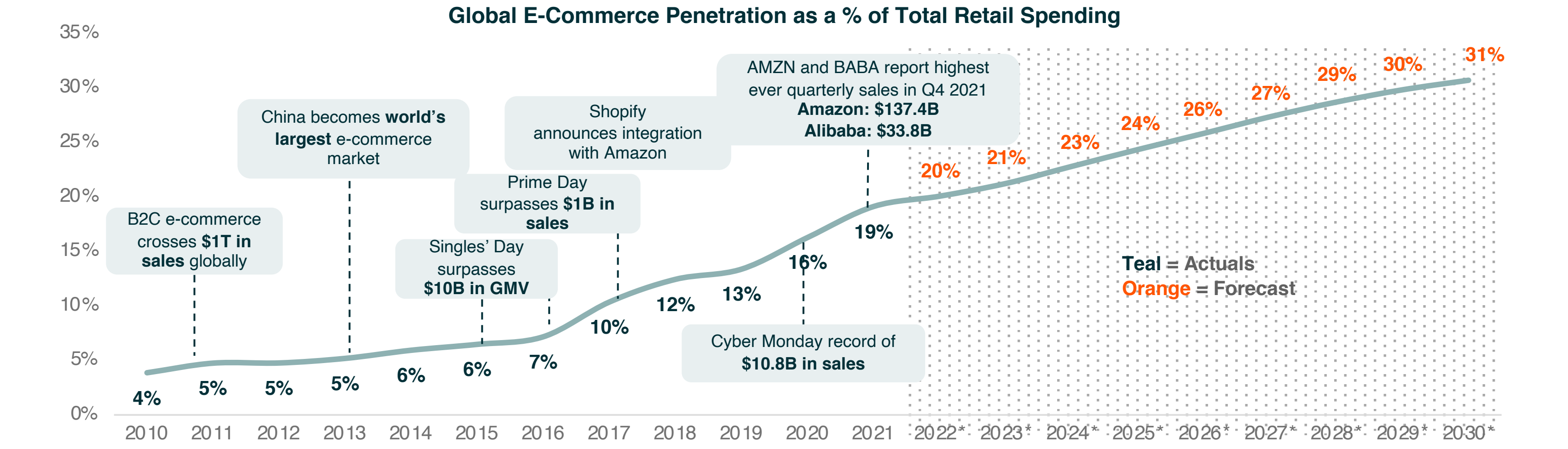
Future of Commerce

The pandemic shifted consumers online, but e-commerce spending still comprises only a tiny percentage of global retail spending. The runway for expansion is significant. E-commerce continues to grow rapidly, and the digitally-influenced post-pandemic consumer is likely to force a modernization of physical retail stores. Logistics-related capex spend from global retailers will continue. For smaller retailers, point of sale technology can help them level up, creating unique opportunities for tech-first players.

Global Digital Commerce Is Just Getting Started

The pandemic accelerated global e-commerce penetration and it continues to grow rapidly, but it remains in its early phases with plenty of runway for growth. The opportunity is significant, as digital commerce addresses all global retail spending.

Global e-commerce revenues are expected to top $10 trillion by the end of the decade



Sources: Flood, 2022; Insider Intelligence, 2022; U.S. Census Bureau, n.d.; U.S. Census Bureau News, 2022

Emerging User Behaviors Present New Opportunities for E-Commerce

Emerging technologies and consumer behaviors will facilitate deeper e-commerce penetration. Over 4.6 billion people around the world use social media platforms daily, as consumers look to friends, connections, and influencers to make purchasing decisions.

Social Behavior Influences Commerce

36%

U.S. digital users who made at least one social commerce purchase in 2021.[1]

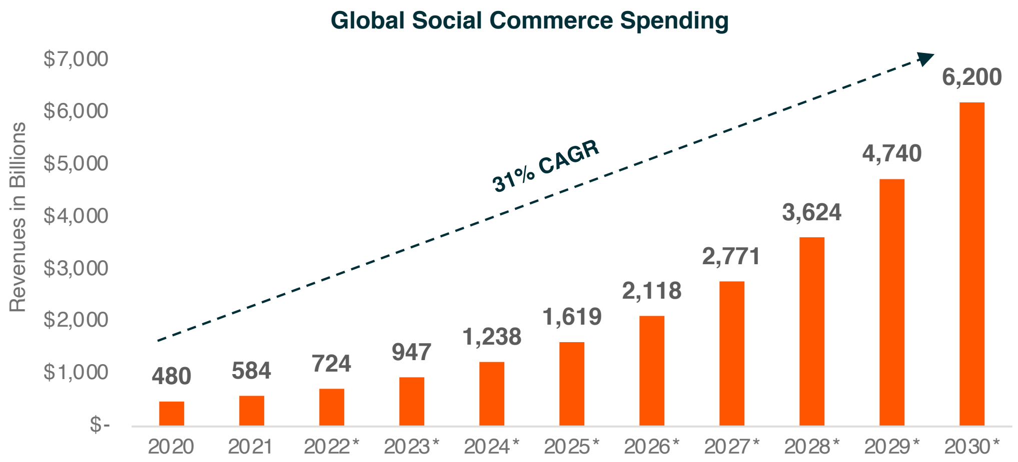
$500 Billion

Global live-commerce revenues in 2022.[2]

424 Million

Shoppers in China who made a social commerce transaction in 2021.[3]

Social media platforms initiate significant digital commerce activity as consumers look to their friends and connections for inspiration. Social commerce spending is expected to grow at a 31% CAGR through 2030.



Sources: Statista Market Intelligence, Grandview Research, April 2022. * Indicates forecast

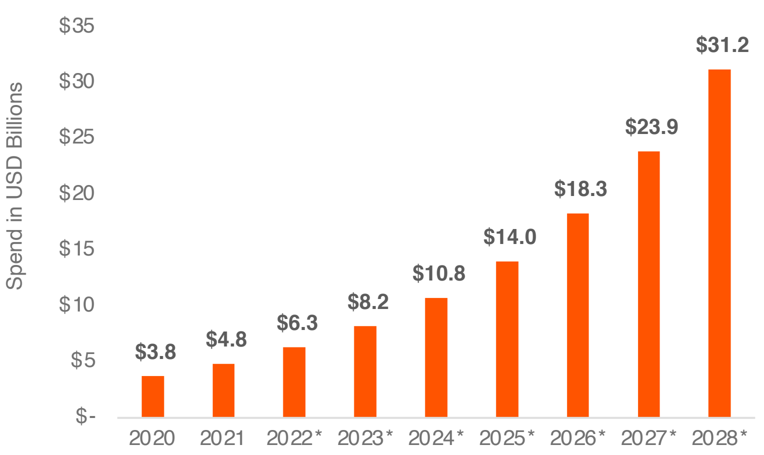
Sources: Text: 1. Kirsch, 2021; 2. Koetsier, 2022; 3. Kirsch, 2021; Visual: Chevalier, 2022

Retail Stores Are Getting a Technology Upgrade to Serve the Post-Pandemic Consumer

Omnichannel commerce is forcing retail locations to digitize as shoppers carry their digital habits into the store. Large retailers struggling with inventory issues and higher costs could look at technology use as a deflationary force.

The use of AI systems is growing within the retail industry. Applications run checkout systems, fraud detection, anomaly detection, and much more.

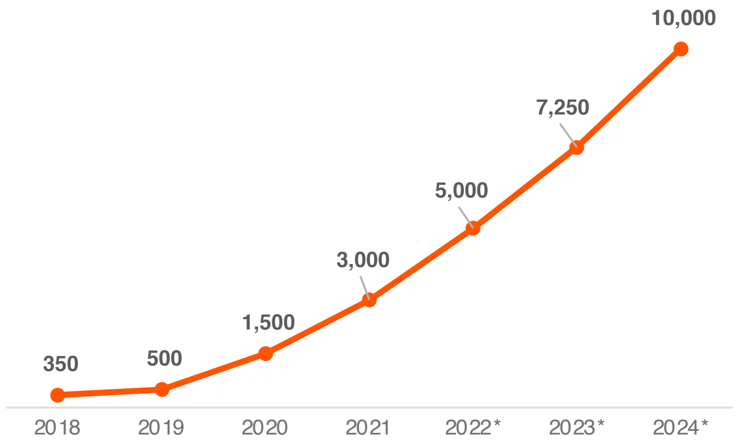
Retail Industry Spend on AI-powered Technology



* Indicates forecast

10,000+ stores worldwide are expected to embrace autonomous checkout technology by 2024. Amazon, one of the pioneers in this space, has 27 Go Stores in 2022.

Number of Global Stores With Autonomous Checkout Technology



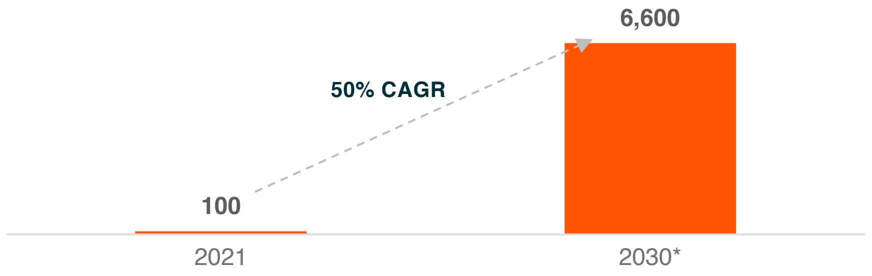
* Indicates forecast

Sources: Visual (LHS): Fortune Business Insights, 2021; Visual (RHS): Sabanoglu, 2022

Micro Fulfillment Centers Represent a Sea Change in Logistics

E-commerce vendors are pivoting to increase regional density by building micro fulfillment centers close to urban centers.

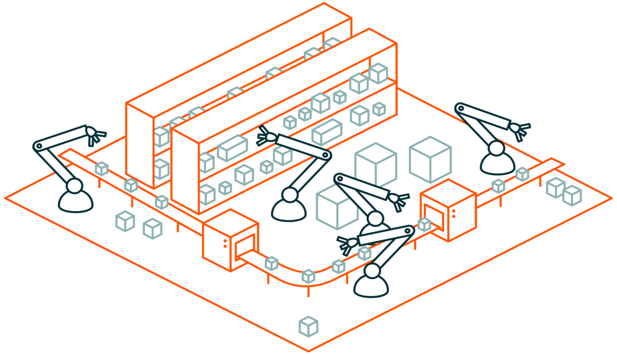
The global micro fulfillment center installed base is expected to grow at a 50% CAGR through 2030. Of the facilities built, 80% will be in North America.



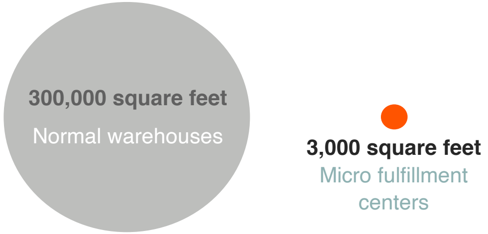
What Are Micro Fulfillment Centers (MFC)?

Micro fulfillment centers are smaller, highly automated fulfillment centers designed to service e-commerce orders and pickup orders in dense urban and residential areas. Due to their compact size, ease of installation, and heavy use of automation, MFCs can be part of an existing store, such as a repurposed basement or other non-visible storage areas.

MFCs are critical to the last-mile strategy of top retailers such as Walmart, which is repurposing 4,700 of its stores as MFCs. In the last 12 months, store processed digital orders for Walmart grew 170% year-over-year, with a 20% increase in pickup and delivery capacity.[1]



Normal Warehouses vs. Micro Fulfillment Centers

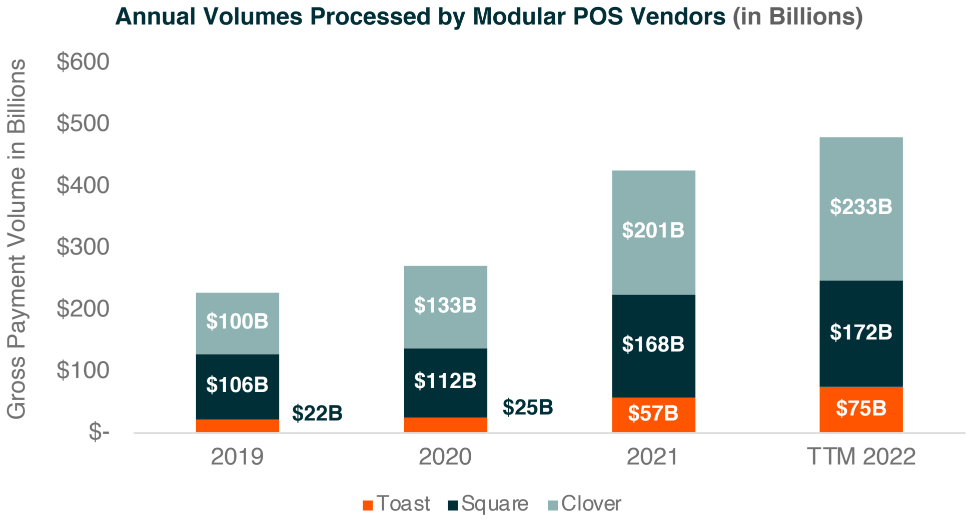


Sources: Text: Stallbaumer, 2022; 2. Devanesan, 2021; Visual (LHS): Stretar, 2022; Visual (RHS): CB Insights, 2020

Modern and Digital Native Point of Sale Systems Help Small Business Commerce Scale

Smaller retailers will increasingly look to modular point of sale (POS) solutions providers to level up and match the technological sophistication of big-box retailers.

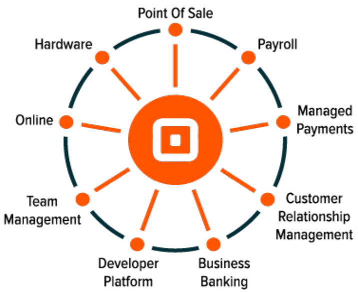
Adoption of modular POS solutions by smaller businesses in recent years is significant, evidenced by the dramatic rise in volumes processed.



TTM 2022 indicates annualized volumes over the last 12 months, up until 2Q22.

Block Inc.'s Ecosystem of Services

Block Inc. offers a range of services that use POS hardware and consumer apps to help smaller businesses realize efficiencies and meet the needs of digitally savvy consumers. Businesses can access some services for free, while others carry a fee.



Sources: Visual (LHS): Toast, 2022; Block, 2022; Fiserv, 2022; Visual (RHS): Cash App, 2022

Automation and Robotics Will Accelerate the Modularization of Last-Mile Delivery Services

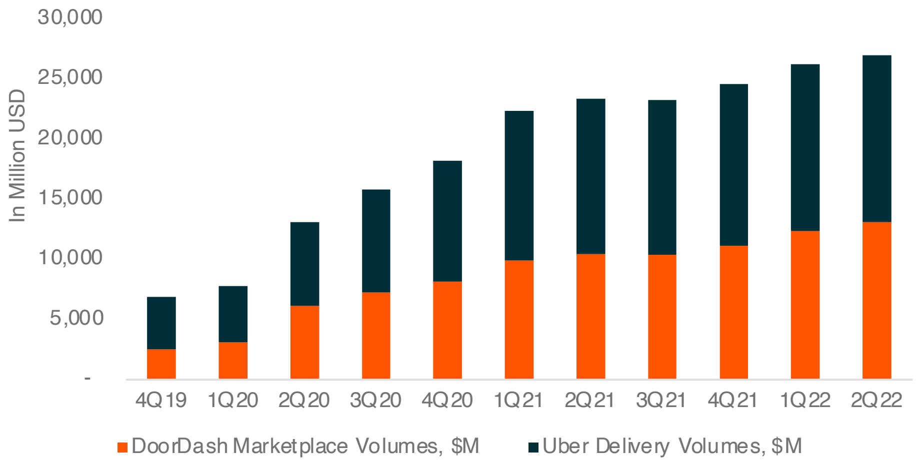
Automation will help lower costs with last-mile commerce as volumes increase in the grocery, food delivery, and local commerce categories. Robotic delivery agents will be served on an API-first basis.

Delivery Infrastructure Delivered as a Service

Pool of Agents	Over time, we expect a mix of human and robotic agents to form the bulk of delivery pools, causing cost per mile to decline significantly and use of manpower to increase.
API Callable	Today, delivery services are available through third-party partnerships. Automation will allow for modularization, where local delivery services are served as an infrastructure enabling commerce.
Favorable Economics	Automation and modularization will help platforms decentralize economics by facilitating instant payouts and cutting out middleman commissions. Total cost of delivery will decline.

The pandemic helped local delivery volumes increase rapidly and shift consumer behaviors. The diversifying category mix is another growth driver.

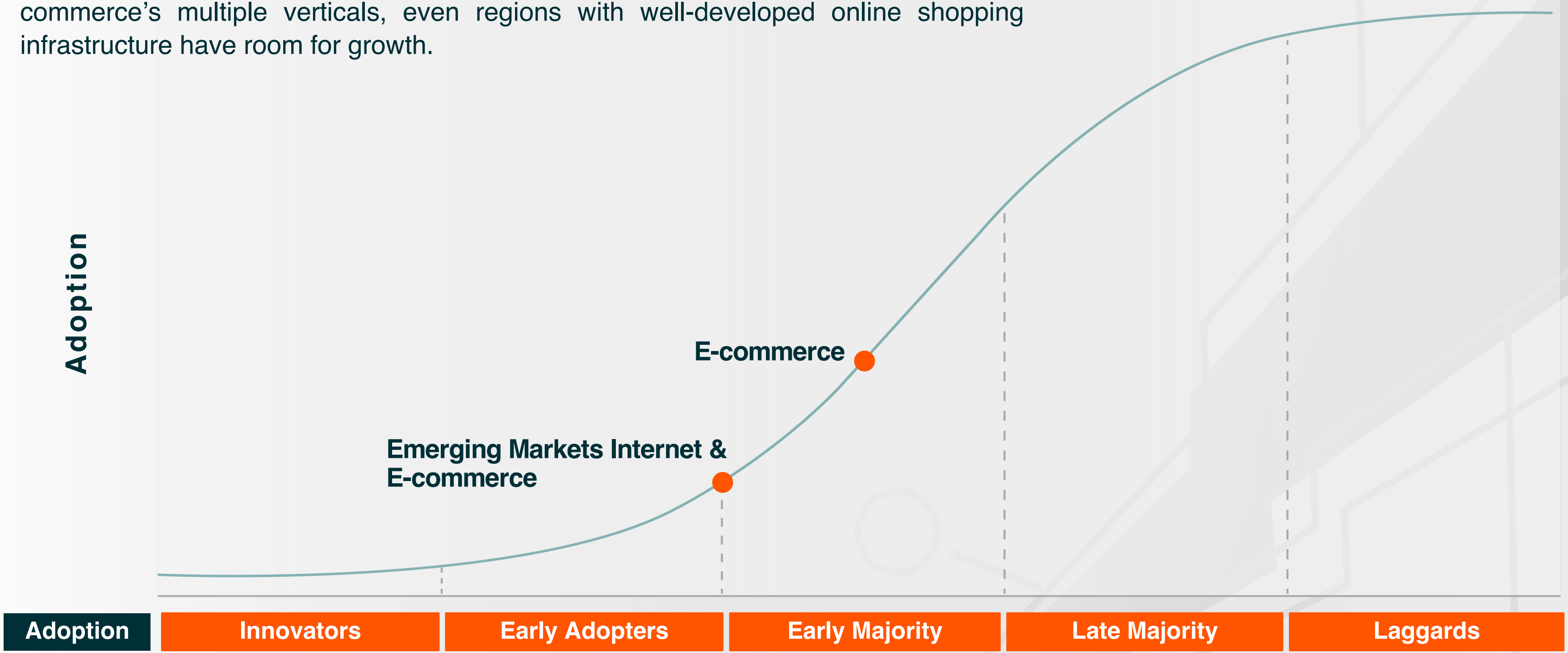
Order Volumes for Top Local Delivery Services in the U.S.



Sources: Visual: Uber Investor, 2022; DoorDash, 2022

S-Shaped Curve of Adoption – Future of Commerce

Key technological advances are shaping e-commerce penetration. Due to e-commerce's multiple verticals, even regions with well-developed online shopping infrastructure have room for growth.



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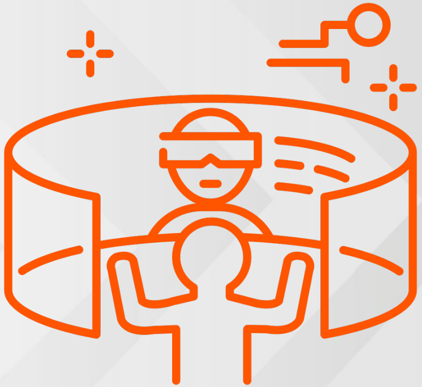
Chapter 11

Metaverse & Digital Experiences

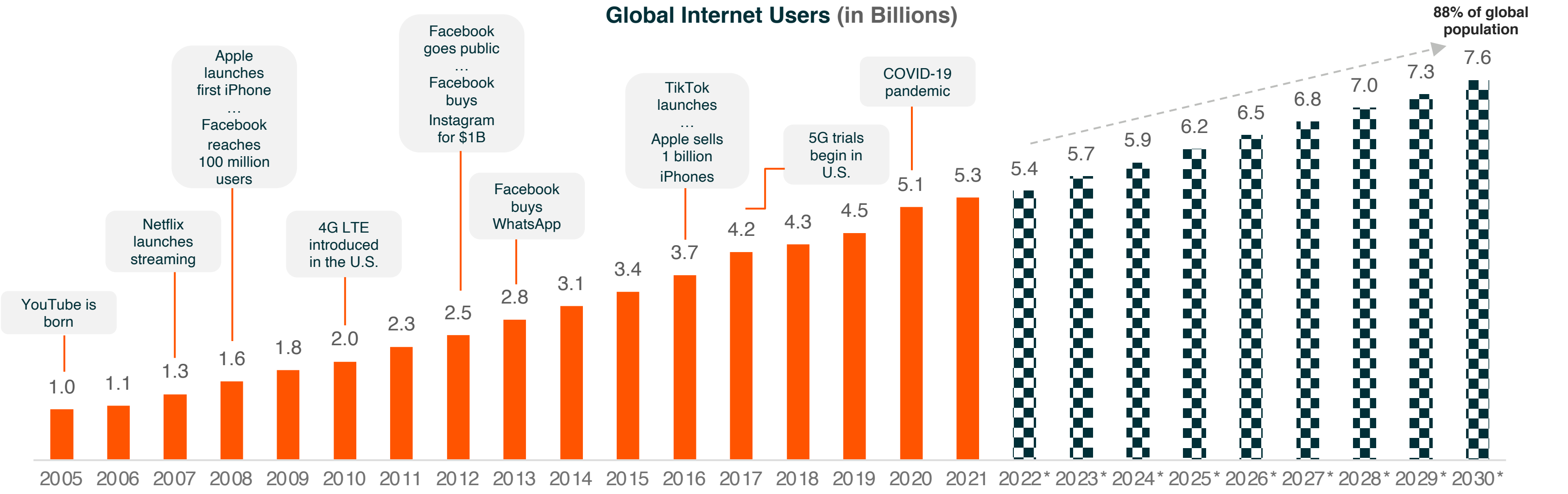


Technology-enabled disruption is in full force across the global economy. COVID-19 accelerated the pace of adoption of digital products and services, forever changing entertainment, commerce, payments, and other key consumer activities. With active participation growing, society's demand for and expectations of platforms and hardware are shifting. As consumer needs evolve, shaped by new generations, these demands will have lasting implications for subsectors and categories.

More Than 5 Billion People Access the Internet Everyday Worldwide

Over the past decade, early challenges to improving connectivity and access to devices were resolved. By 2030, the internet will have 88% global penetration. Network upgrades to 5G will supercharge usage and facilitate deeper participation.

By 2030, 88% of the global population (over 6 years of age) is expected to be digitally connected. By 2027, nearly 4.4 billion people worldwide are expected to have 5G connectivity.

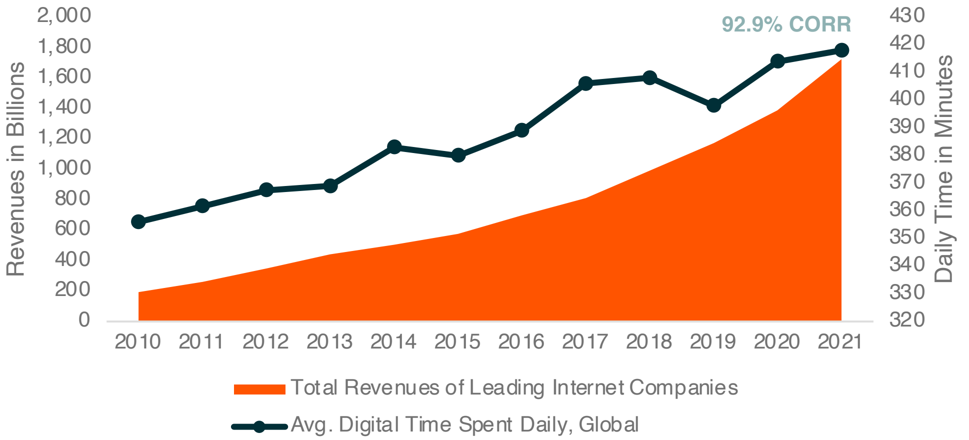


Sources: Internet World Stats, 2022; Statista Research Department, 2022

Digital Services Are Winning Incremental Time Share and Dollars

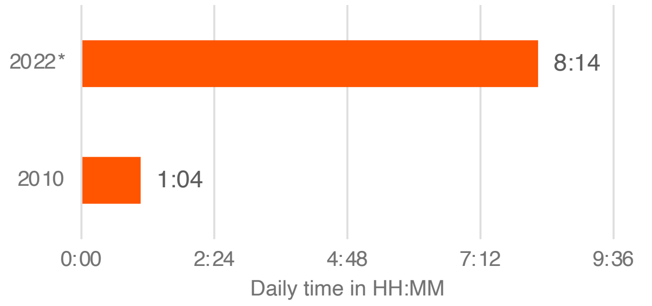
Digital participation creates strong network effects, which fuels more engagement. The average global user spends 45% of their daily awake time connected to digital services. Rising participation has translated into growing fortunes for top internet companies.

Time spent digitally has directly accrued value to leading platforms.



* includes GOOGL, AMZN, AAPL, MSFT, BIDU, TCEHY, BABA, META, NFLX, PYPL, EBAY, JD, BKNG, TWTR.

The average U.S. adult spends nearly 8 hours and 14 minutes connected to the internet every day.



* indicates forecast

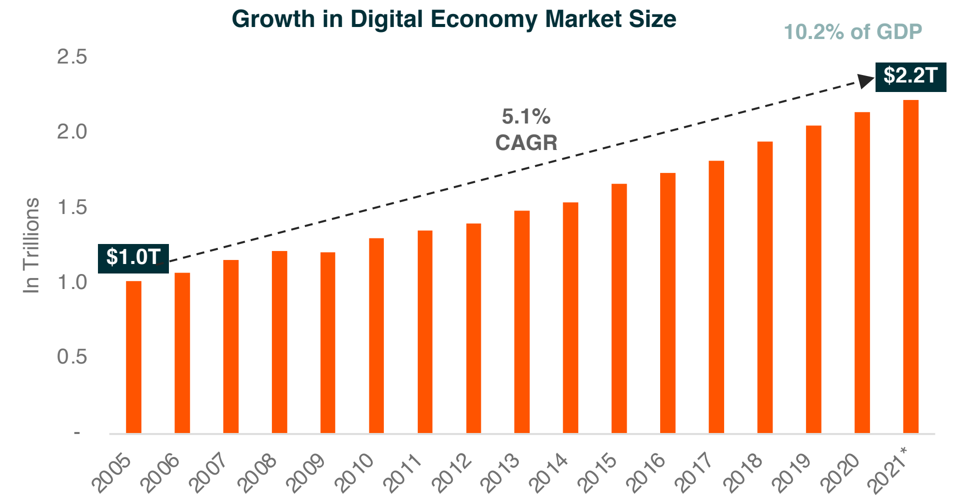
Digital participation went from an option for entertainment and basic needs to a necessity over the past two decades. Early on, leisure activities, such as shopping, entertainment, and gaming, migrated online. More recently, digitization has disrupted everything from banking and payments to how society works, lives, and receives healthcare and other critical services. For future generations of consumers, digital will be native.

Sources: Visual (LHS): Factset, n.d.; Comscore, 2011, U.S. Bureau of Labor Statistics, 2021; Kemp, 2022; Visual (RHS): Lebow, 2022

Digital Participation Drives Significant Economic Value

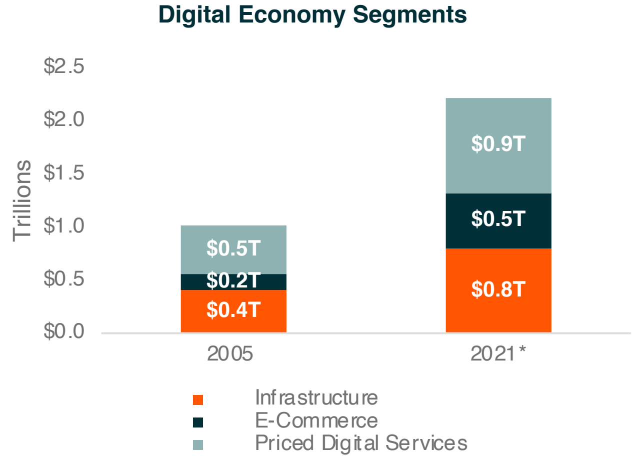
By traditional metrics, the digital economy is growing faster than other areas and could eventually rise to be the top contributor to GDP in the United States. The momentum is particularly strong post-COVID.

The global information revolution is roughly 30 years old. In that time, the digital economy became a sizable base of the U.S. economy at 10.2% of total GDP.



* Indicates forecast

Digital disruption is evident in all corners of the digital economy, with breakouts in key segments.



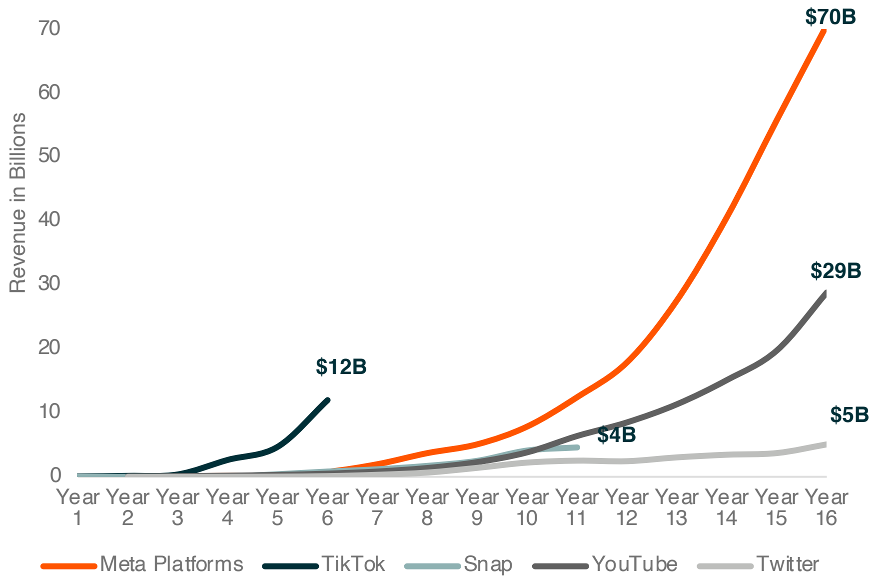
Infrastructure includes software and hardware; E-commerce includes retail and B2B digital commerce; Priced digital services includes cloud services, telecom services, internet and data services, and other digital services.

Sources: Bureau of Economic Analysis, 2022a; Bureau of Economic Analysis, 2022b

Next-Generation Services Achieve Scale Much Faster

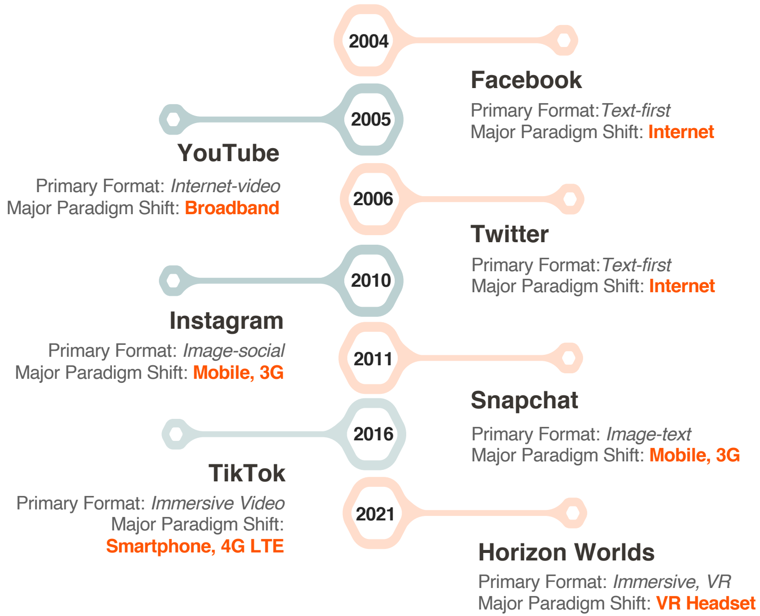
Consumers want more from their platforms. Platforms that attract and engage users for longer periods are growing at a much faster rate than previous generations of services.

Revenue Scaled by Year Since Launch



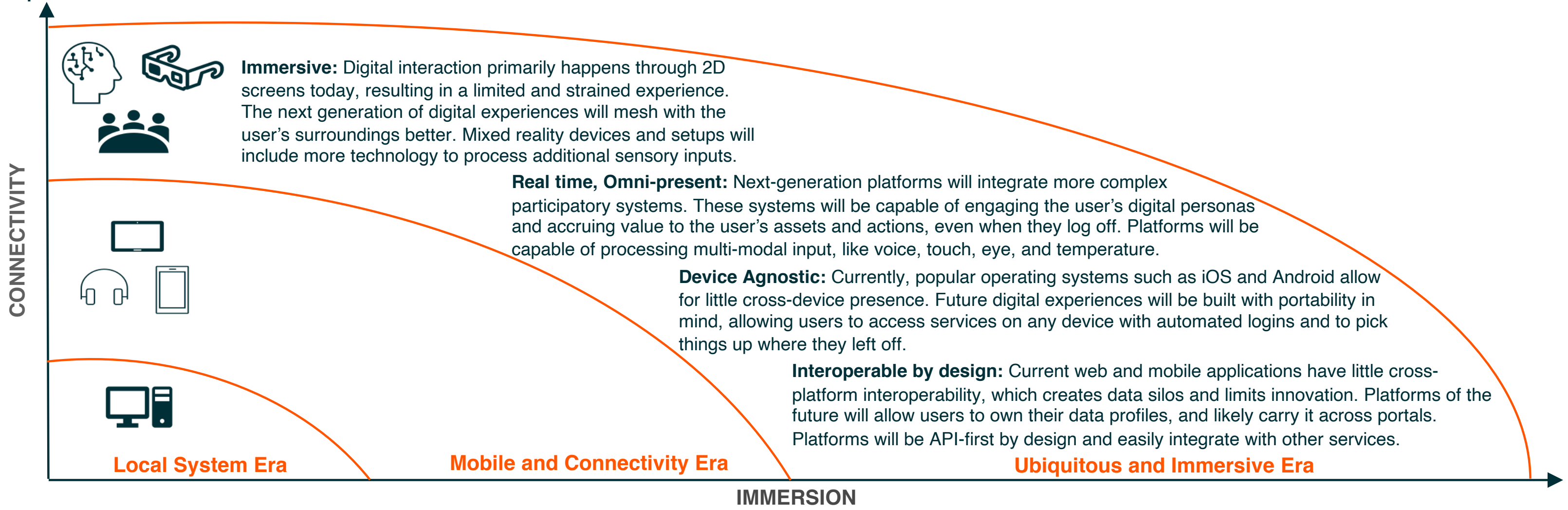
Sources: Chartr, n.d.; Iqbal, 2022; Vranica & Lin, 2022

Technological Innovation Unlocks Digital Participation



The Next Generation of Digital Experiences Will Be Increasingly Immersive

After solving early challenges related to connectivity, access to devices, and applications, we expect digital experiences will evolve to increase participation, engage additional human senses, and drive more utility out of digital participation. To support this evolution, platforms and hardware interfaces will evolve.



Networks:	2G Networks	3G + 4G LTE	5G and Next-Gen Networks
Processing:	Local	Local + Cloud	Hyperscale and Edge
Sensing/IO:	Keyboard + Mouse	Touch, Voice	Immersive and Predictive

Immersion Needs Key Independent Technologies to Converge

The Metaverse requires the convergence of hardware technologies, platforms and users, graphic software, and new economic models.

1 Hardware Technology

- **Current:** The average user experiences the digital world through desktop and handheld devices.
- **Future:** The next generation of immersive experiences will feature seamless presentations of projections onto a user's surroundings through headsets worn by users or holographic imagery.
  - **Key companies:** Apple, Meta Platforms, Snap, Google, Vuzix, Microsoft, Magic Leap

2 Graphic Technology

- **Current:** Developers working on immersive apps foresee a decade-long buildout cycle.
- **Future:** Companies selling graphic engines, APIs, easy-to-use graphic studios, ready-made components, and blocks will play a large role in enabling a more immersive app experience/ecosystem.
  - **Key companies:** Unity, Unreal Engine, Roblox, Snap, Apple, Google, Activision Blizzard, Microsoft, Matterport

3 Platforms and Users

- **Current:** Large platforms exist in terms of reach and ecosystem of services.
- **Future:** New functionalities and features added to capture immersive needs of users will be integral to pushing adoption in early killer apps around gaming and entertainment.
  - **Key companies:** Meta Platforms, Roblox, Snap, Twitter, Tencent, Google, Apple IOS, Microsoft, Amazon

4 Economic Models

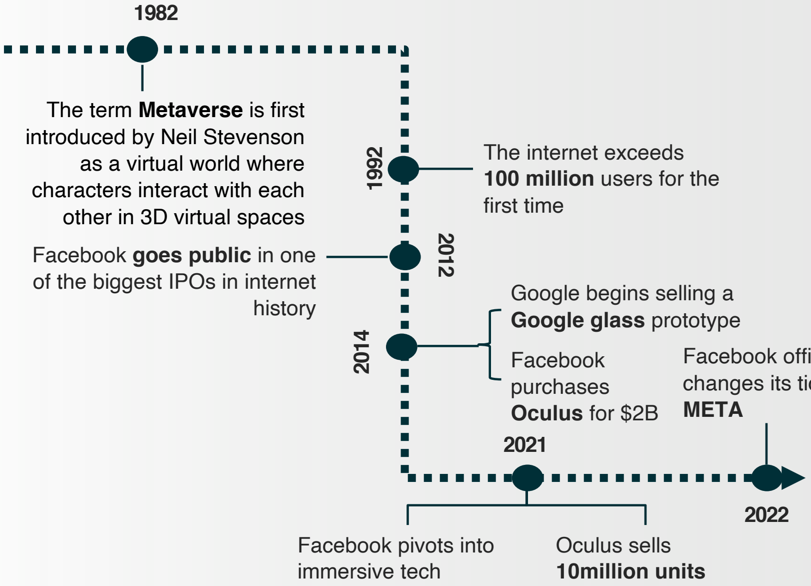
- **Current:** Legacy financial infrastructures enable payments and transactions.
- **Future:** Emerging technologies like NFTs will be critical to controlling ownership and distribution royalties. Earnings and payouts will be instant, low-fee, and settled on verifiable public blockchains.
  - **Key companies:** Block, PayPal, Meta Platforms, Apple, Google, Coinbase, Roblox

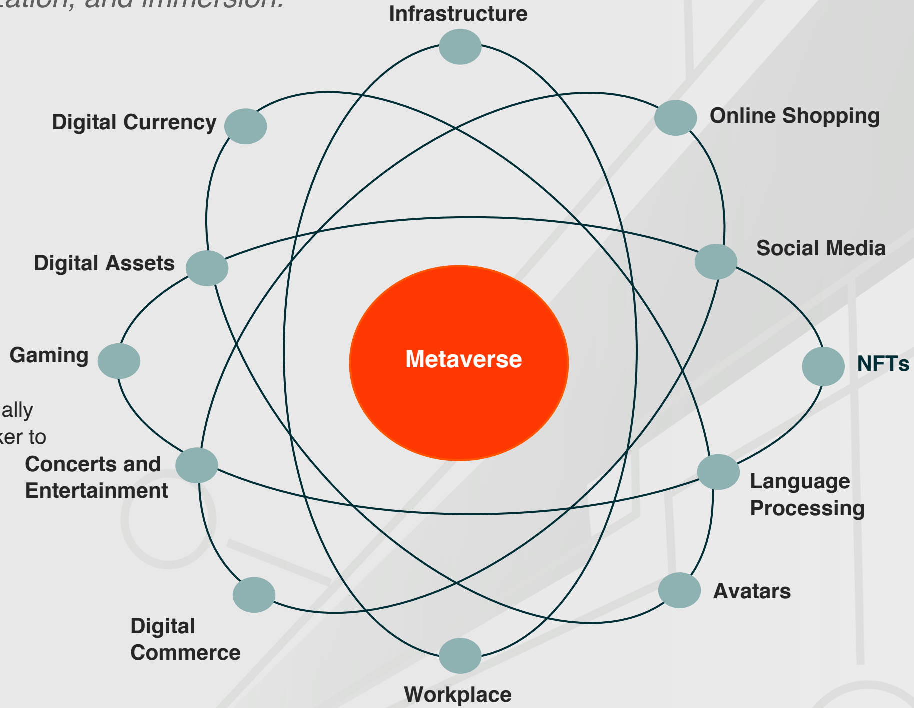
What Is the Metaverse?

Cathy Hackl

The Metaverse is the inevitable convergence of the physical and digital worlds as consumers demand more from technology as part of their everyday lives. The Metaverse will build on critical enabling technologies such as the blockchain, 5G, edge computing, and NFTs to deliver new models of content ownership, monetization, and immersion.

Metaverse Coming Under Focus





Sources: GlobalData, 2022; Marr, 2022; Radoff, 2021; Wiles, 2022

Augmented Reality (AR) / Virtual Reality (VR): Timeline and Beyond

A quick look at virtual reality through the years shows the progress already made through AR/VR technology.

1838

Charles Wheatstone's Stereoscrope

First ever VR device, distinguished between right and left eye perception to make images seem 3D

1957

The Sensorama

First virtual simulator that included a stereoscopic 3D display imitating wind, motional chair, and odors

1968

Sword of Damocles

First AR/VR helmet, device attached to ceiling showing the "Ultimate Display" concept

1980-87

EyeTap, EyePhone Glasses, DataGlove

EyeTap (1980) was the first portable AR device that superimposed graphics

1993-95

Gaming Consoles

Sega Genesis headset (1993) remained in prototype, Virtual Boy Nintendo (1995)

2012-15

Oculus, Google Glass/Cardboard, Gear VR, Microsoft Hololens

Oculus Rift CV1 VR helmet (2015) sold its first batch in 14 minutes, Facebook acquired Oculus, VR emerged on mobile devices

2016

VR Headsets

HTC Vive, Playstation VR, and Google Daydream

2017

Apple, Google Phone AR

Apple joined the VR scene with ARKit, Google progressed VR with ARCore, spatial awareness emerged

2018-19

Magic Leap, AR/VR Expands

Magic Leap retinal display, Vive Pro Eye, Oculus Quest, AR/VR technology in everyday items like NordicTrack VR Bike, Cybershoes

2020-21

AR/VR of the Future

Oculus Quest 2 headset, merging PC and standalone headsets, gaming immersion

Present and Beyond

PSVR 2 from Sony, haptic technologies, Qualcomm/Microsoft AR Glasses, Nvidia/AMD graphics cards, rumored 2023 Apple Headset

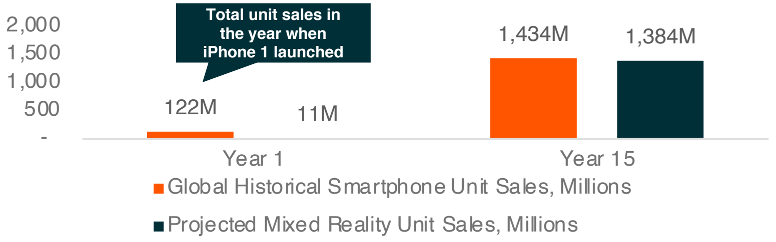
Sources: Ritterbusch, n.d.; Virtual Reality Society, n.d.

User Adoption of Immersive Hardware Picking Up Pace

Much like the smartphone revolution, the Metaverse and the next generation of the internet require supporting hardware. Much nimbler headgear will evolve as key challenges in computing resources, power electronics, and optics are resolved. The growth of VR hardware indicates consumer enthusiasm.

Smartphone unit sales grew at a CAGR of 20% in the first 15 years after the iPhone 3G launched. We expect mixed reality headset adoption to follow a similar trajectory.

Smartphone Unit Sales vs. Mixed Reality Estimate (Millions)

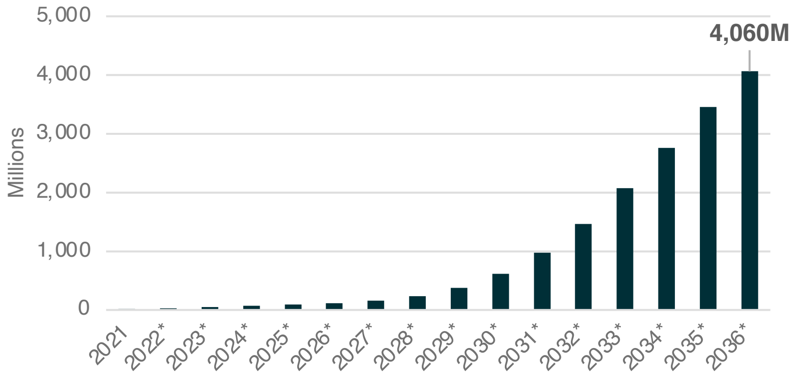


Product Paradigm	Year 1	Year 15
Smartphone Era	In 2008, the 3G enabled iPhone 2 kicked off the global smartphone revolution.	Key upgrades in network, processing, camera tech and subsequent commoditization propelled the smartphone to become a staple worldwide.
Mixed Reality Era	We view the launch of Oculus Quest 2 in 2021 as the base year for mixed reality projection.	Similar to smartphones, technological innovation unlocking over the next decade will drive the adoption of post-smartphone hardware.

Sources: Boland, 2021; Hector, 2022; Scarsella, 2022; Welch, 2007

Mixed reality headsets will need to overcome technological barriers to deliver on the projected addressable base that follows a smartphone-like adoption curve.

Estimated Installed Base of Mixed Reality Headsets (Millions)



* indicates forecast. Sources for baseline data: IDC Smartphone Tracker, Canalys, Statista, TechRadar, AR Insider; Forecast derived using growth rates for smartphone unit sales after the year the iPhone launched; Assuming 3-year average life of a mixed reality headset, similar to smartphones in 2020.

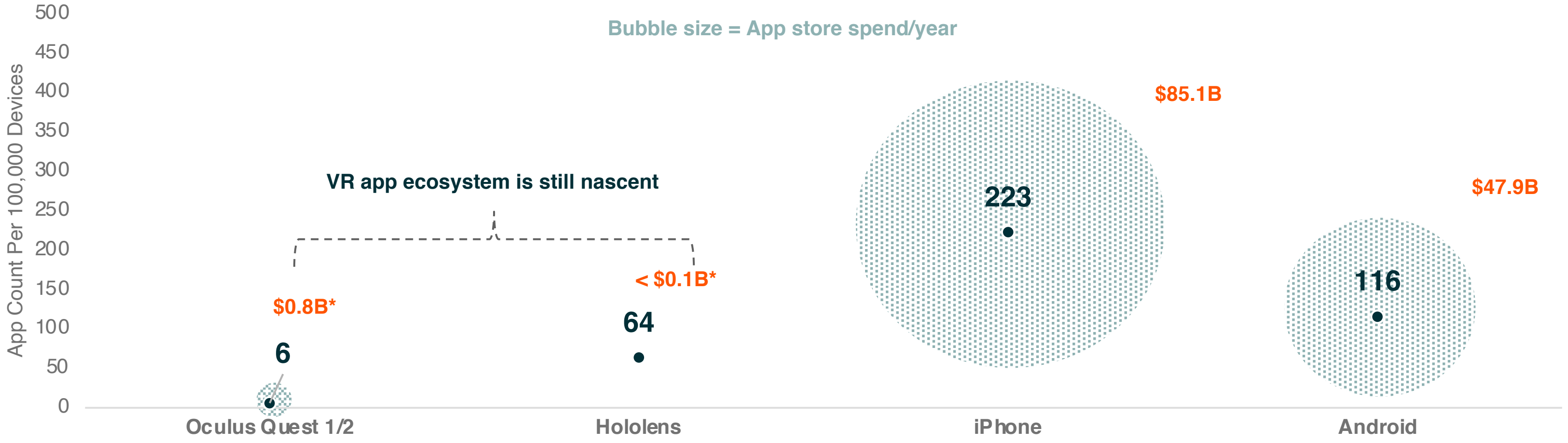
Parallel Boom in Application Development Will Be Necessary to Spur Growth

The smartphone application ecosystem offers clues about the transformational impact an immersive application ecosystem could deliver. However, the market is still in its early stages.

App development in the VR ecosystem is well behind smartphones, resulting in a lack of quality content. As the number of VR users grows, developers will become more incentivized to support the space.

Apps per 100,000 Devices and Annual App Spend

Bubble size = App store spend/year



Bubble size = Annual In App User Spending;* indicates estimates

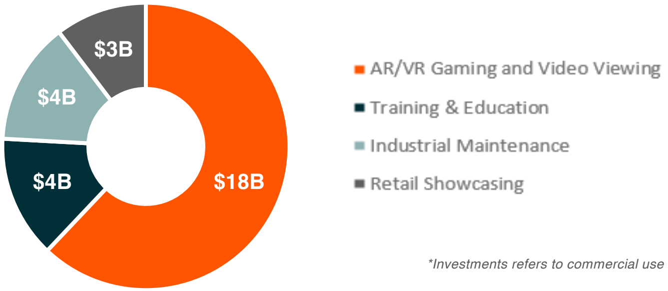
Source: Apple, 2020; Ceci, 2022; Curry, 2022; Espósito, 2021; Heaney, 2022; Lang, 2022; Potuck, 2022

Adoption of Immersive Technology Within Gaming Is Increasing Steadily

We believe gamers will be key to driving engagement and adoption of the Metaverse early on, before hardware and platforms are ready for mass market use cases. Unit sales of XR equipment within the gaming space show promise.

Among industries at the forefront of AR/VR adoption, gaming takes the lead with a forecast for $18 billion in investments by 2024.

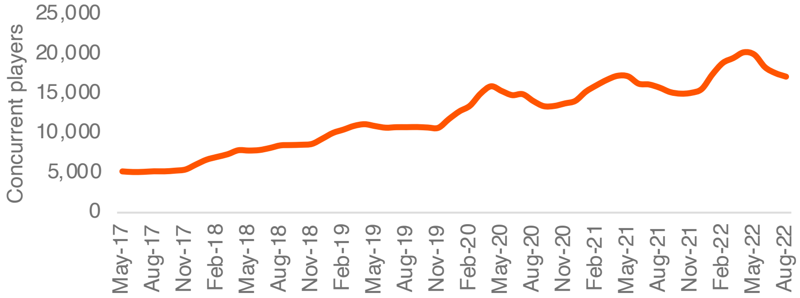
Forecasted AR/VR Investments* in Industries Through 2024
(Billions of US$)



**Investments refers to commercial use cases*

Individual use of VR tech has focused on early gaming experiences. Distribution platforms like SteamVR show signs of adoption rising.

Average Daily Concurrent VR Players on Steam



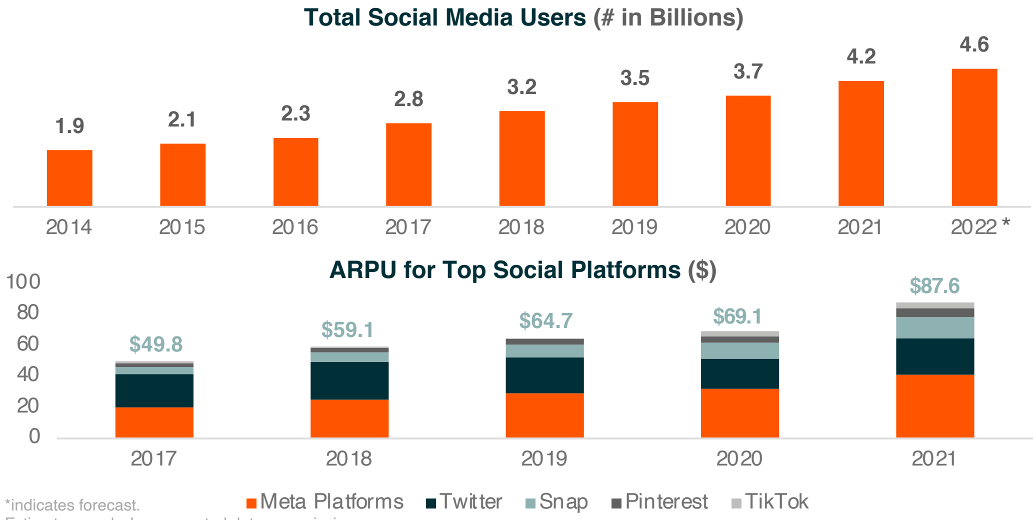
- As of 2022, **27%** of global game developers announced plans to develop projects compatible with the Oculus Quest and **13%** with the Oculus Rift.[1]
- Meta's Oculus Quest 2 shipped nearly **15 million** units worldwide as of Q2 2022.[2]
- Oculus **owns 80%** of the XR shipment market share.[3]

Sources: Text: 1. Game Developers Conference, 2022; 2., Ochanji, 2022; 3. Team Counterpoint, 2022; Visual (LHS): Alsop, 2022; Torchia, Dimitrov, Elshewy, Muranishi, Sarkar, & Zhang, 2022; Visual (RHS): Bezmalinovic, 2022

Social Networks Critical to Driving Early Adoption

Social platforms are dense with engagement. A gradual text to image to video shift has been playing out. Over time, immersive content will pick up, too. Social platforms will drive early adoption of avatars and more, securing user buy-in while playing a key role in disseminating DIY 3D graphic tools to the developer community.

Social platforms dominate user attention, which they continue to monetize. This share could also turn into an advantage when onboarding users onto immersive experiences.



*indicates forecast.
Estimates used where reported date was missing.

Sources: Visual (Top): Kepios, n.d.; Visual (Bottom): Iqbal, 2022

Social Networks Critical to Drive Early Adoption

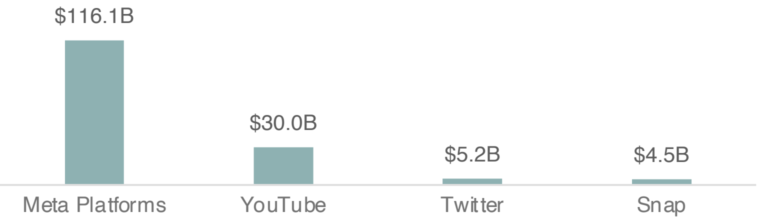
- **Casual games:** Immersive casual games could be tested for virality. Social played a key role in driving the popularity for mobile games in the past.
- **Avatars:** Platforms are integrating avatars and skins, which are steppingstones to a virtual persona.
- **Virtual events:** Virtual worlds like Horizon World and even Roblox are major promoters of virtual events led by major celebrities.
- **Filters and Screens:** Casual image filters and interactive screens can be used to release more tooling to create interactive content.

Creator Economy Needs Better Technology

Social platforms foster economic innovation, such as the creator economy. Creators are expected to drive $120 billion in value for brands in 2022, yet they will be paid only a small fraction of the value that they create. New technology will disrupt attribution and distribution and simplify immersive creation, further boosting creator mobilization.

Today, leading platforms accrue most of the value as they monetize users' content creation via ads.

Last 12-month Ad Revenues for Top Social Networks in the US (in Billions $)



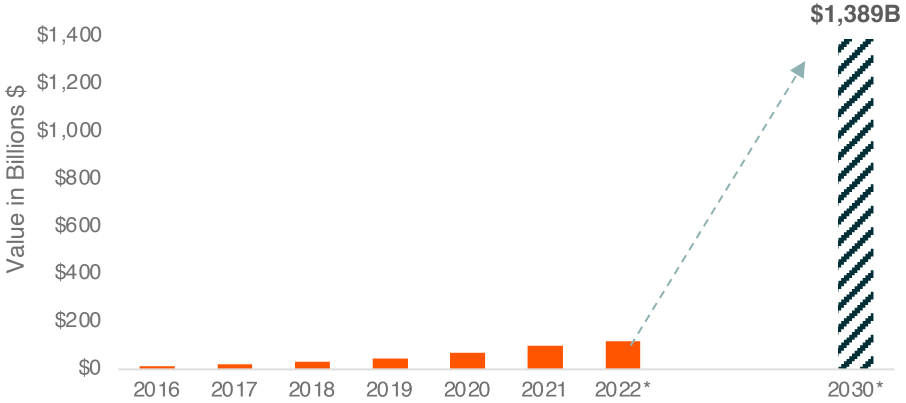
Problems With the Creator Economy

Inefficient tooling: Creators use a mix of third-party tools to operate online, which causes scaling issues.

Platforms dictate terms: Platform policies may seem arbitrary, with creators having little ownership of their audience.

Misplaced Incentives: Creators have no way to track and follow the value that they drive for third-party brands, products, and services.

Economic Value Driven by Creators & Influencers (in billions $)



*Indicates forecast.

Creators drive significantly more economic value, in terms of ad impressions generated, commerce influenced, and content subscribed to by users, than what is paid out to them by platforms. For example, YouTube paid out only 13% of the total ad dollars it generated to top creators in 2021. Using YouTube, the largest creator platform, as a benchmark, we assume creators globally net an average of 13% of the platform monetization they drive. Using Statista's forecast for the creator economy market, we extrapolated until 2030 using an average of a linear and an exponential fit to arrive at the income earned by creators by 2030 ($243 billion) and the economic value influenced by creators ($1,389 billion).

Sources: Visual (LHS): FactSet Research Systems, n.d.; Alphabet, 2022; Visual (RHS): Statista Research Department, 2022; Spangler, 2022; Andonov, 2022

Non-Fungible Tokens (NFTs) and Blockchain Could Revolutionize Ownership and Payouts

Virtual assets within the Metaverse will rely on Web3 and NFT technology to embed ownership, verify authenticity, and allow for economic activity.

NFTs Can Super-Charge Digital Ownership

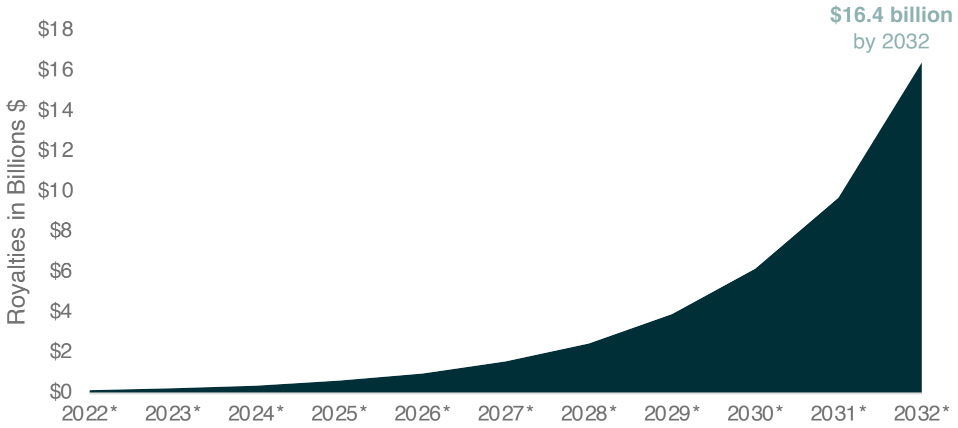
- **Artist royalties:** NFTs allow artists to receive royalties on transactions pertaining to their artwork in perpetuity, boosting artist incentives and willingness to invest.
- **Graphic content:** Content creators can use embedded tools to raise money for projects, fund content, distribute ownership, and drive community participation.
- **Creator payout:** Native wallets can streamline the attribution process, enabling instant payouts.

Social Platforms Are Running to Integrate Digital Ownership

Platform	Gameplan	Timeline
Instagram	NFT wallets will be added to Instagram profiles. Users will also be allowed to display NFT assets.	May 2023
Snapchat	Creators can turn their NFTs into AR lenses and incorporate them into Snapchat.	August 2022
YouTube	Creators can use a content ID tool to verify their assets, and they can sell video NFTs through the platform	2022

NFT technologies could allow creators to design and commercialize services in the Metaverse, driving $44 billion+ in cumulative NFT-based royalty earnings on top platforms by 2032.

Estimated Royalties Earned on Virtual Commerce



NFTs allow creators to license their digital work, earning commissions as the work is transmitted, consumed, and shared by consumers downstream. We assume an average of 2.5% commission rate that creators can keep in perpetuity. The chart shows total cumulative royalties earned by creators over the years.

Sources: Chakravarty, 2021; Chan, 2021; Market Decipher, n.d.; PWC, n.d.; Sava, 2022; Zander, 2021

Web3 vs. Metaverse

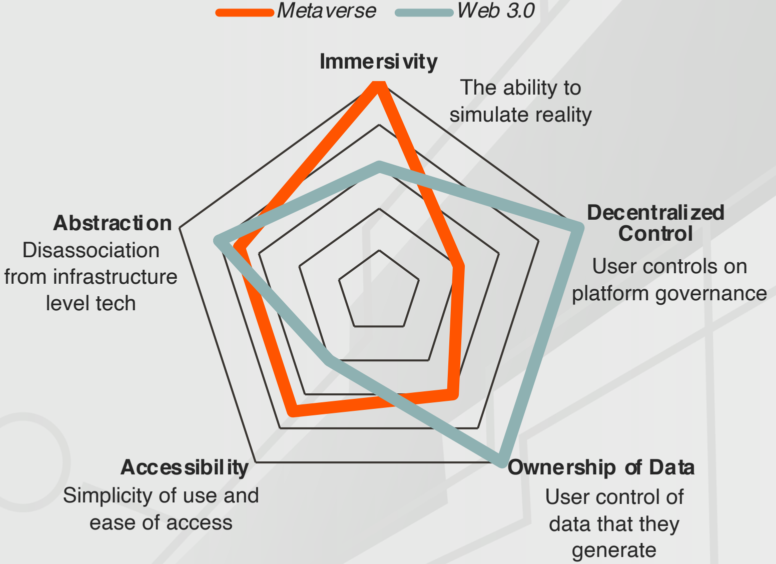
Cathy Hackl

Web3 and the Metaverse are intrinsically connected but not interchangeable. Web3 is how people, spaces, and assets will be connected in the future internet, whereas the Metaverse is how end users experience the future internet.

Criteria	Web3	Metaverse
Definition	Protocol level technology that pools decentralized nodes to deliver compute, storage, and with verifiable features leveraging a public ledger	Immersive digital spaces that expand on Web2 platforms, allowing seamless device agnostic participation
Enabling Technology	• Blockchain and cryptocurrencies • DAOs, NFTs, DeFi	• Multi-modal input • Sophistication 3D graphics • Next generation wireless • Specialized devices
Abstraction Level	Infrastructure and protocol level technology	End-user experience level technology
Target	Blockchain-controlled, P2P network facility, securing record keeping, governance, compute, and access	Platforms capable of delivering XR experiences for the post-smartphone era

Sources: Abrol, 2022; Marketers That Matter, 2022; Weston, 2022

Metaverse vs. Web3 on Critical Factors



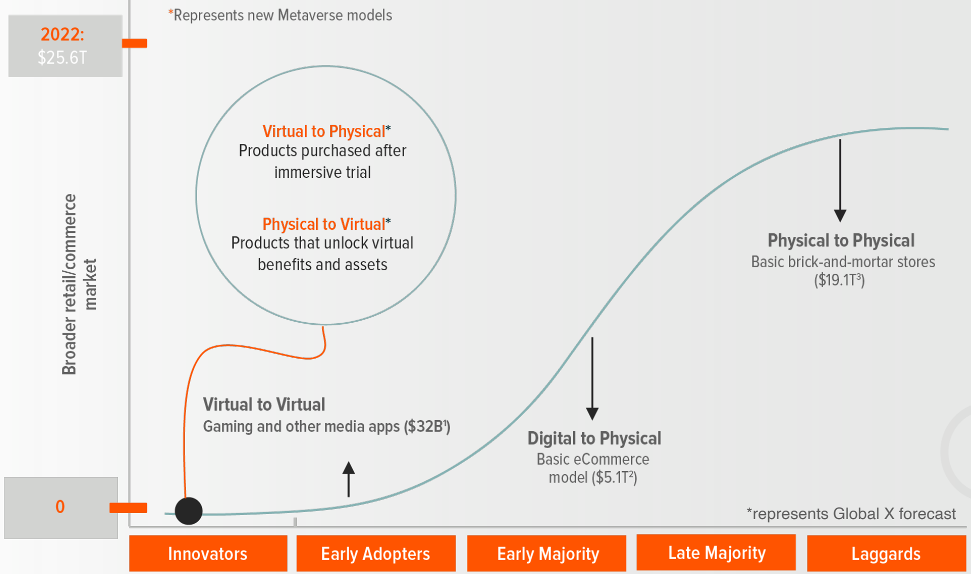
* Scale 0-5; 5 being most relevant

Commerce in the Metaverse Is Inevitable

Cathy Hackl

Brands are eager to capitalize on the emerging virtual items market, launching products and services for digital avatars. The Direct-to-Avatar (D2A) model signals a new frontier that builds on B2B and B2C paradigms. D2A is in the Innovators adoption phase, but enabling tech could spur growth.

Metaverse Commerce Adoption Cycle



Sources: Bonnin, 2022; Chevalier, 2022; Coldewey, 2019; Google, n.d.; Hackl, 2022; Priyadharshini, 2021; Sabanoglu, 2022

Brands Are Embracing Virtual Commerce

Nike cemented its position in the Metaverse in 2021 when it launched Nikeland, a branded, interactive space. Also, Nike acquired RTFKT, an NFT studio focused on virtual footwear.

In May 2021, Gucci debuted the Gucci Garden in Roblox. The two-week art installation was aimed at raising brand awareness among young customers.

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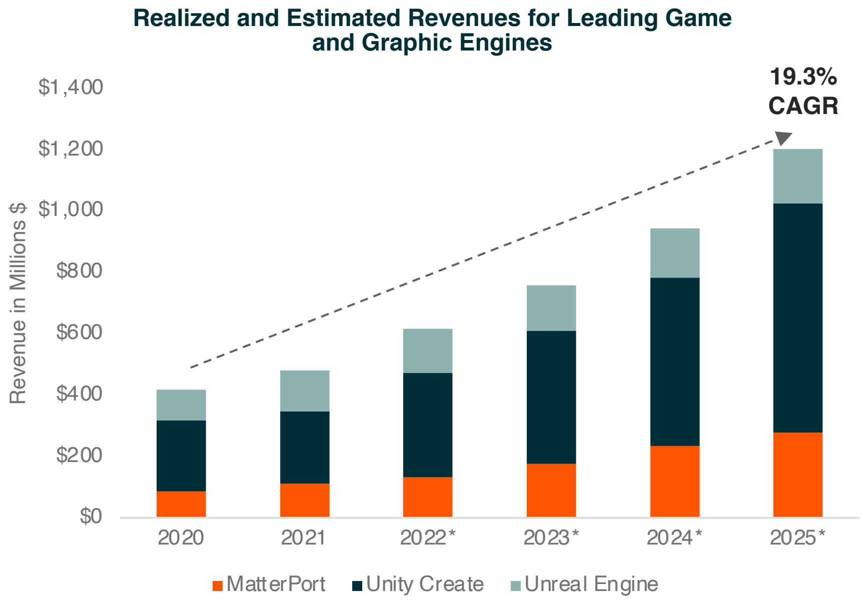
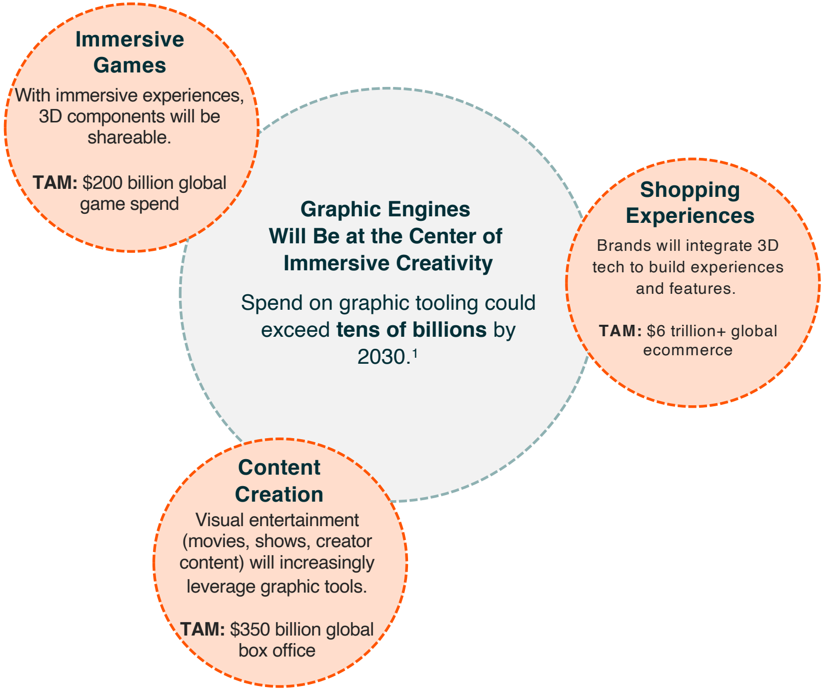
DIY Graphic Tooling Will Be Key to Spurring Creativity Beyond Gaming

Parallel improvements in DIY graphics tools and graphic engines will be central to a vibrant application development ecosystem.



* Indicates forecast



Sources: (LHS) FactSet Research Systems, n.d.; (RHS) 1. Clement, 2022

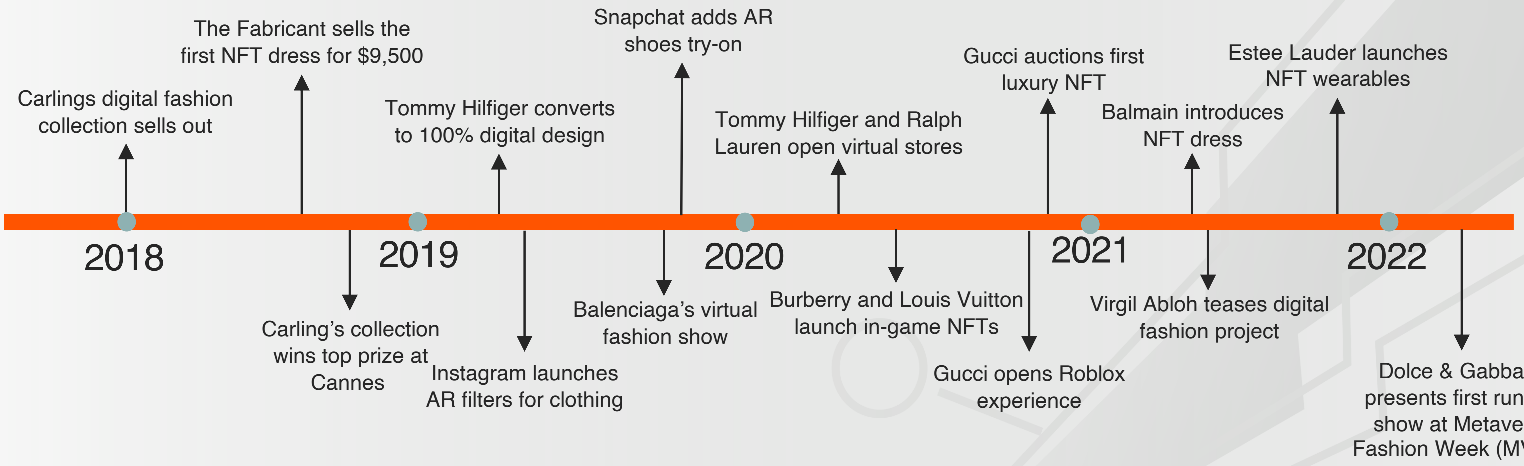
The Metaverse Blends Virtual & Physical Worlds

Cathy Hackl

Digital sizing technologies that capture the physical dimensions of the human body will enable brands to create personalized digital items that simulate those in the physical world.

Over time, virtual store assistants will likely better understand users' shopping habits based on purchase history. This data will help create custom virtual shopping experiences and tangible value creation.

Milestone Moments That Advanced 3D, Digital Clothing, and Virtual Wardrobes in the Metaverse



Sources: McDowell, 2021

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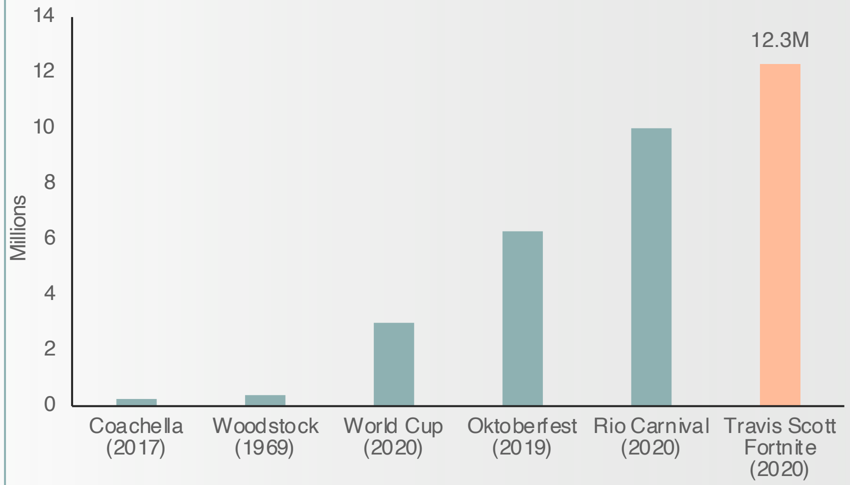
Metaverse Could Find Its Killer App in Gaming

Cathy Hackl

In April 2020, rapper Travis Scott held a live concert inside online video game Fortnite—and more than 27.7 million gamers attended. The event made it clear that gaming is at the center of popular culture.

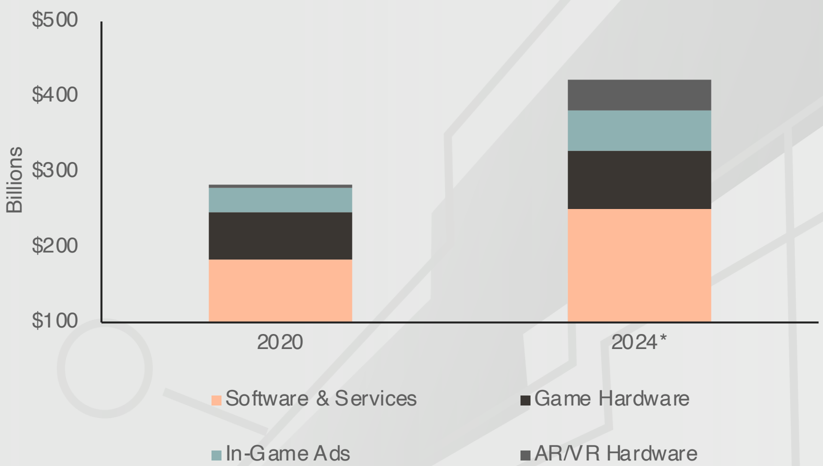
In the Metaverse, humans are no longer bound by physical limitations.

Attendance at Major Entertainment Events (in Millions)



Gaming, AR, and VR create a $413 billion primary market.

Revenue Opportunity for Video Game Makers (in Billions)



*Indicates forecast

Sources: Alroumi, 2021; Iqbal, 2022; Kane, 2022

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Gaming Is a New Hotbed for Economic Disruption

Cathy Hackl

Models such as play-to-earn and play-to-own supplement in-game currencies, giving users ownership of virtual assets that they create through gametime. We believe that classic game play merging with digital economic systems like the blockchain has vast implications for social media, commerce, influencer marketing, content creation, and more.

1990s — Pay-to-Play

Currency is exchanged for the privilege to play the game. Users get the whole game, with all its content, in one payment.

Legacy games

Ex: Madden, Call of Duty

DAU: 3B+

2010s — Free-to-Play

Players are given access to the game at no cost; however, payments are typically required for in-game purchases.

Current generation games

Ex: Fortnite

DAU: 25M+*

2020+ — Play-to-Earn

Players are rewarded for participating in in-game activities via tradeable online currencies.

Immersive (next gen) games

Ex: Axie Infinity, Sandbox

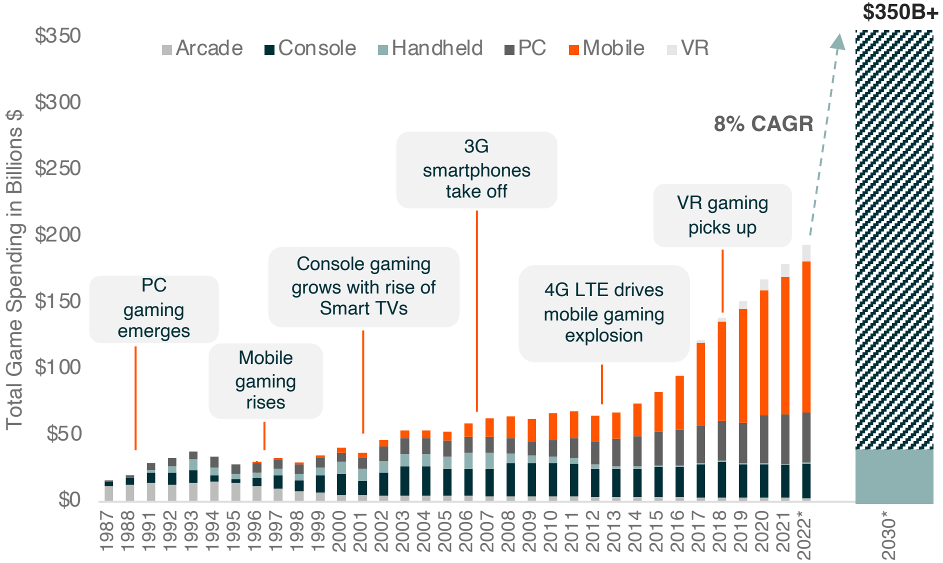
DAU: 1M+

Sources: Lightbox (NFTs and Gaming Blog on Medium), Business of Apps, Dappradar, Free-to-Play DAU only considers Fortnite

Technological Innovation Unlocks Growth in Gaming

Immersive hardware technology coupled with cloud gaming could end up displacing the console market, diversifying gameplay, bringing millions of new gamers into the market, and compounding the total addressable market.

Gaming Growth Unlocked by Key Technological Innovation



* Indicates estimates

Sources: Business Wire, 2022; Nakamura, 2019

Moving Beyond Consoles

Enter Cloud Gaming

Console-enabled local processing makes it easy to play premium, media-rich games. But the entry cost of buying a console restricts the number of users who can enjoy high-quality gameplay.

Worldwide, there are only 800 million console game players. But the growing number of smartphone gamers indicate that the addressable base for games is much bigger.

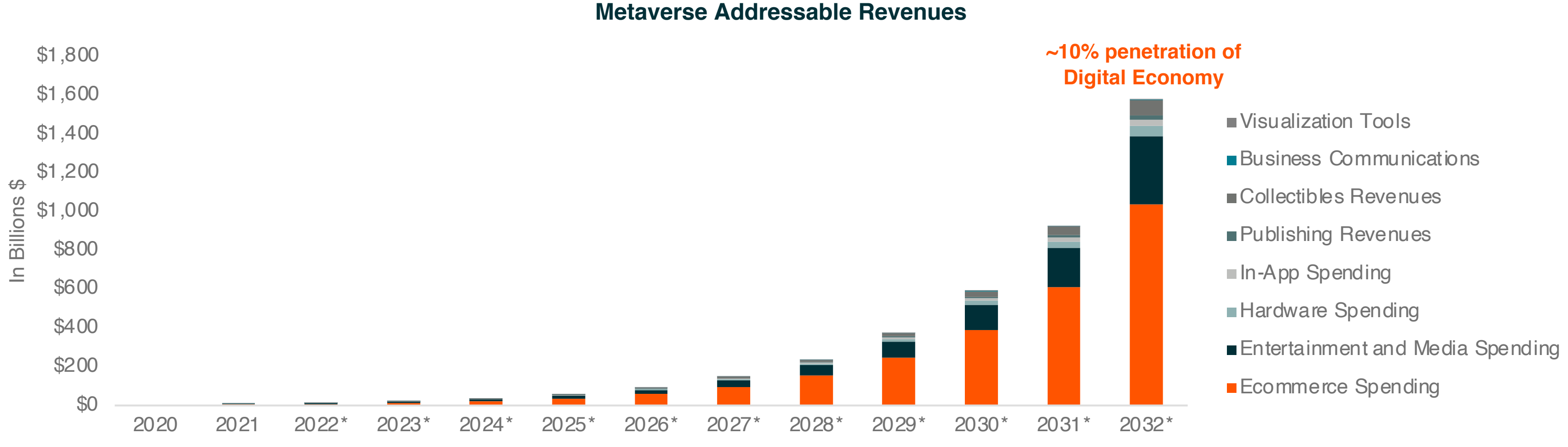
Cloud gaming, or game streaming, will enable billions of users around the world to enjoy gaming experiences more freely for a simple monthly fee. Gaming and the convergence of key technologies in mixed reality, social media, content creation will redefine the consumer internet landscape in the future.

$21 billion* in revenues by 2030, from Cloud Gaming

The Metaverse Addresses Trillions in Economic Value

The Metaverse is a pursuit to redesign digital experiences with ubiquity, immersion, and embedded incentives in mind. In time, the Metaverse will address the entire digital economy and allow digital services to capture incremental share of the offline economy.

Early Metaverse value capture will be focused on areas with deep digital penetration, such as payments, commerce, and entertainment.



*Indicates forecast; Entertainment & Media Spending includes spending on Gaming, Movies, TV, Streaming, VoD, Audio.
Forecasts derived by accounting segments of digital economy that are addressable by immersive platforms and modeling an exponential adoption rate with three diverse adoption scenarios.

Sources: Bernhardt, 2022; Ceci, 2022; Chan, 2021; Flood, 2022; Laricchia, 2022; Market Decipher, n.d.; Navarro, 2022; PWC, n.d.; Read, 2022; Sava, 2022; Statista Research Department, 2022; Tartaglione, 2021; Wilman, 2021; Young, 2021

Metaverse Utility Extends Beyond Consumer Media

Cathy Hackl

The evolution of enabling technologies will take the Metaverse beyond the Early Adoption phases and help it disrupt historically laggard markets and industries.

The Metaverse's Enabling Technologies

Technology	What it enables and/or simulates?
Advanced Graphics	3D visualization
Specialized Immersive Hardware	Simulates real-world sensory experiences; over time, the Metaverse is likely to employ a combination of AR and VR, otherwise known as **mixed reality (MR)**
5g, 6g, and WiFi	Enables lag-free streaming and low latency experiences
Blockchain	Validates value transfer, credibility, and data storage
Artificial Intelligence	Ensures the infrastructure's stability while also delivering actioning insights for the upper layers
Cloud and Edge Computing	Enables faster data transmission without having to set up an entire hardware infrastructure

Sources: Prabhu, 2017; Reese, 2021

Mixed Reality Use Cases Across Industries

Engineering
- 3D visualization and CAD
- Teamwork and collaboration

Industrial & Manufacturing
- Guided training and remote support
- Real-time factory diagnostics

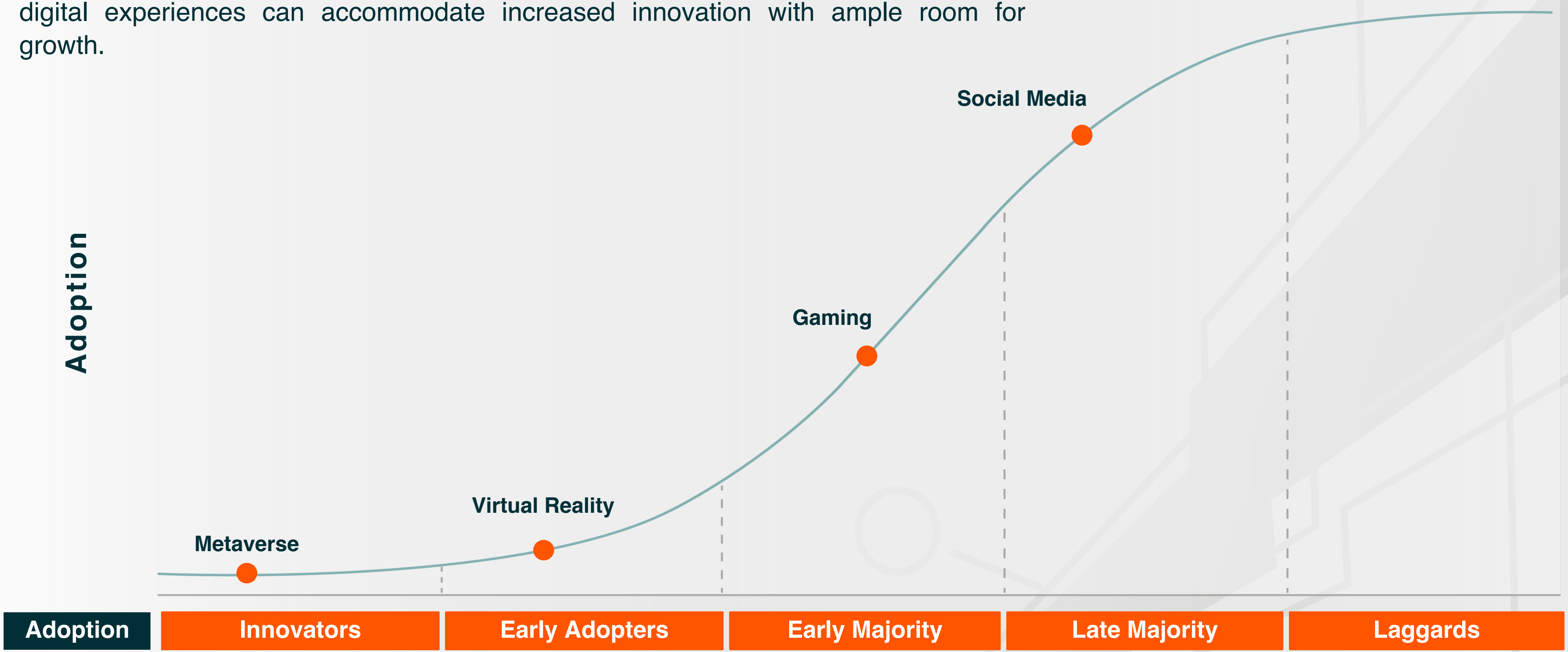
Education
- Immersive, interactive learning
- Any subject, anywhere

Healthcare
- More efficient patient care
- Surgical training and visualization

Retail
- Try before you buy: clothes, furniture
- Personalized products and coupons

S-Shaped Curve of Adoption – Metaverse & Digital Experiences

With a new era of devices and software adapting to shifting consumer preferences, digital experiences can accommodate increased innovation with ample room for growth.



Source: Sekulic, 2022

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Chapter 12

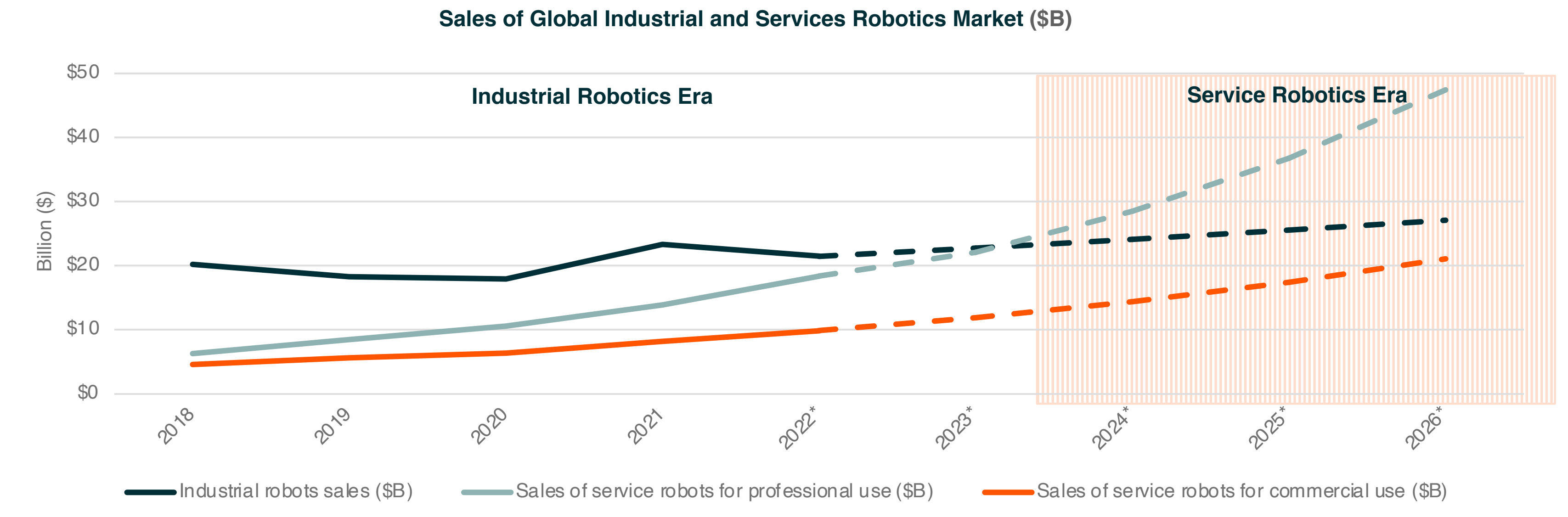
Robotics

Industrial robotic installations are at record highs, and we expect demand to remain strong. At the same time, we believe the robotics industry is about to enter a services era as sales of professional service robots, such as those used for delivery or healthcare applications, overtake industrial robot sales in 2023. Robotics as a Service (RaaS) is another emerging trend, which along with the declining cost of robotics makes robots ever more affordable.

The Services Robotics Era Is Beginning to Emerge

Automotive and consumer electronic companies were the frontrunners in deploying robotics and automation. However, in recent years services industries such as food, consumer goods, and life sciences account for most of the growth in robotics.

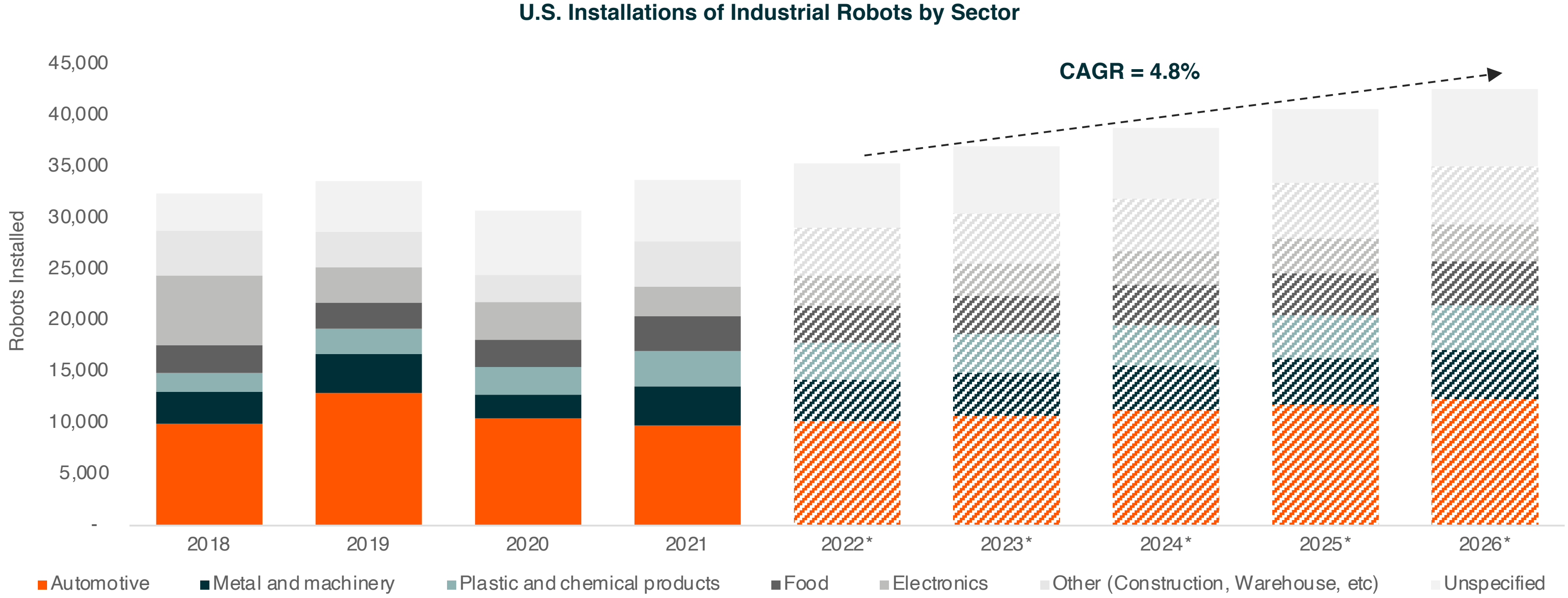
We expect a paradigm shift in 2023 when sales of professional service robots become larger than industrial robotics.



Sources: Guerry, Müeller, Kraus, & Bieller, 2021

Adoption of Robotic Systems Across Industry Types Is Growing

Technological advancements in robotics and artificial intelligence (AI) are driving record sales across industries.

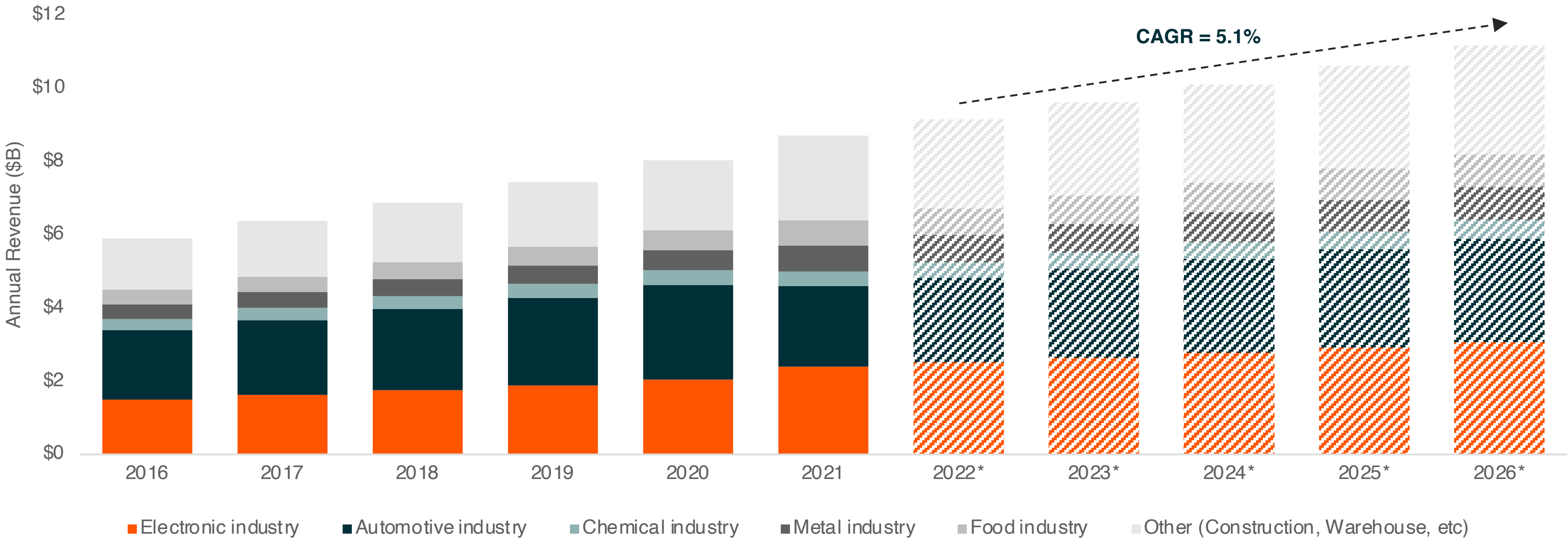


*Indicates forecast
Sources: Global X analysis based on data derived from: American Machinist, 2022; Tobe, 2019

Revenue Growth Takes Off as Industries Embrace Robotics

Across industries, automation and robots are increasingly common due to their efficiency and precision, especially in manufacturing facilities. The upward trajectory in revenue growth reflects the increase in prevalence.

Robotic System Revenues (in $ Billion)



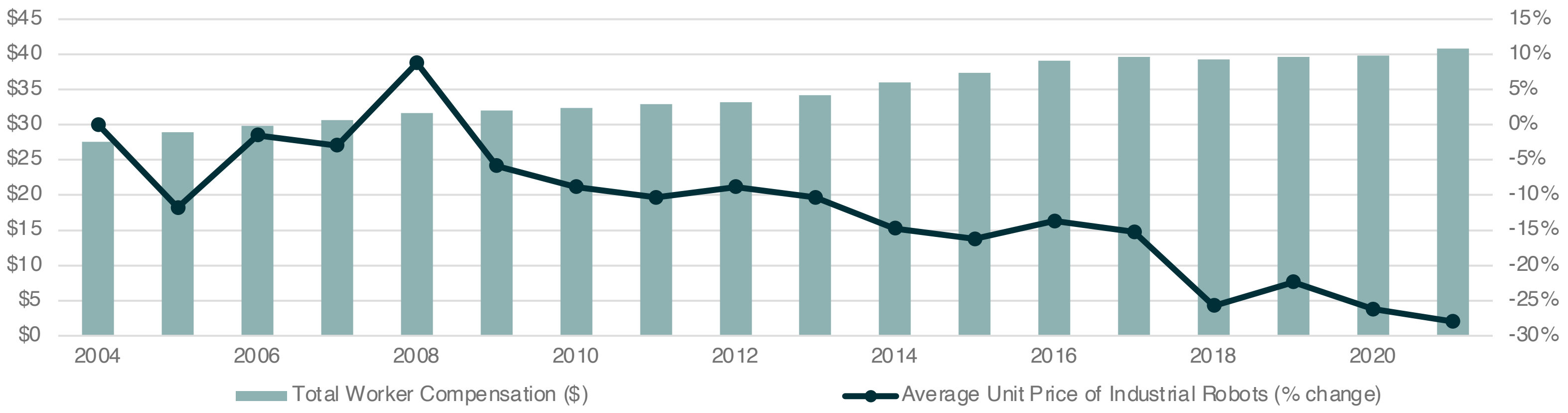
*Indicates forecast
Sources: Drives & Controls, 2022; Garlard, 2022; McCain, 2022; Zandt, 2022

Robotics Demand to Remain Strong as Global Economic Factors Prove Persistent

Manufacturers trying to maintain productivity and efficiency levels amid pandemic-induced supply chain disruptions and labor shortages increasingly see robotics and automation as the way forward.

Historically low U.S. unemployment rates are pushing labor costs even higher, causing manufacturers to turn to automation.

Total Worker Compensation for the Manufacturing Industry in the United States ($) vs. Average Unit Price of Industrial Robots in the United States (% Change vs. Base Year = 2004)



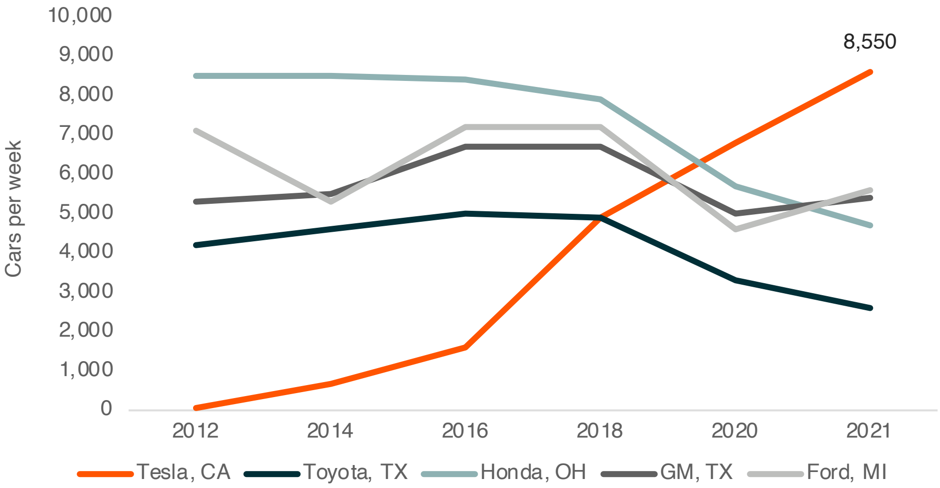
Sources: Jurkat, Klump, & Schneider, 2021; U.S. Bureau of Labor Statistics, 2022a; U.S. Bureau of Labor Statistics, 2022b; Wessling, 2022

Robotic-Heavy Auto Manufacturers Are More Efficient Than Traditional OEMs

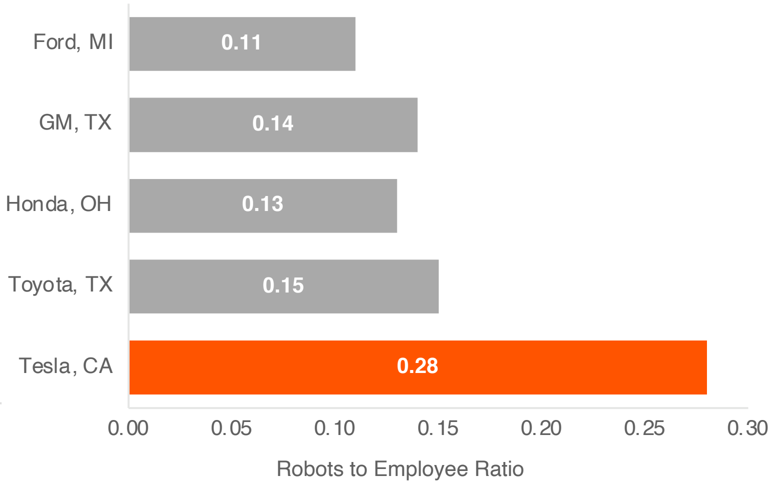
By allocating less spending on human capital and more on robotics and AI, manufacturers can see meaningful productivity gains. Tesla's use of robotics and AI helped the company produce more vehicles in 2021 than any other U.S. automaker.

Tesla's factory in Fremont, California, produced an average of 8,550 cars per week in 2021, outpacing Ford's truck plant in Dearborn, Michigan (5,564/week) and General Motor's Arlington, Texas facility (5,400/week). [1]

Average Weekly Output by Year and Factory



Number of Robots per Employee for Top U.S. Automakers

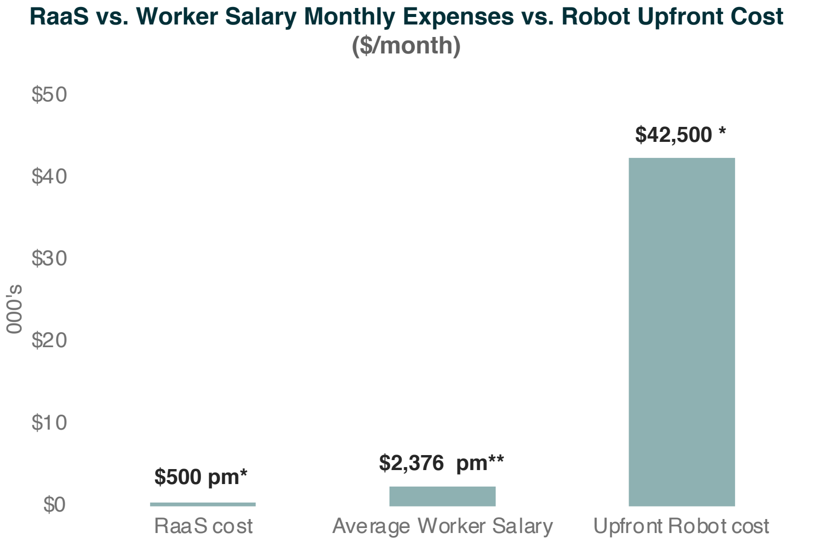


Sources: 1. Global X analysis of information derived from: Bogage, 2016; Randall & Pogkas, 2022; Toyota, n.d.; Toyota, 2020; Wikipedia, 2022a; Wikipedia, 2022b; Wikipedia, 2022c; Wikipedia, 2022d; Wilson, 2020; Wired, 2013

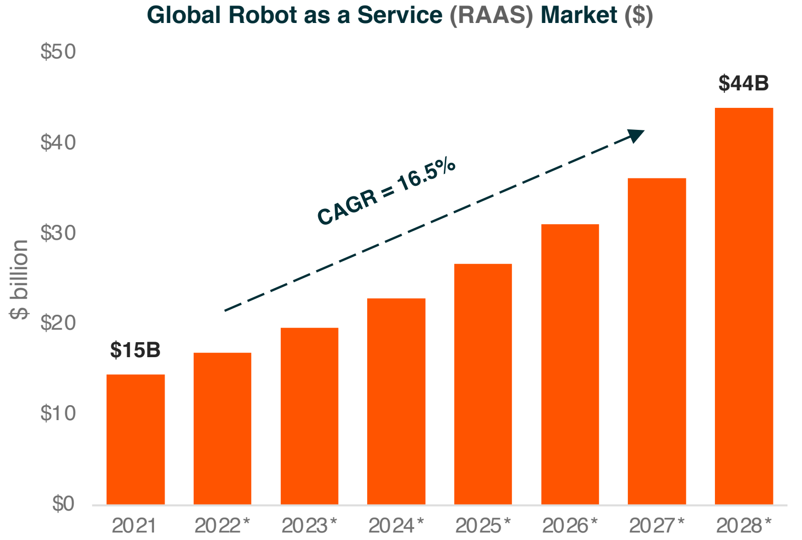
Robots as a Service (RaaS) Is Increasing Robotics Adoption

Companies can now use RaaS subscriptions to scale robotics into their manufacturing processes. They can lease units to reduce upfront costs and entry barriers to technological acquisition.

Demand for RaaS is rising among small and medium enterprises that cannot afford to buy a robot upfront.



The total addressable market for RaaS is expected to grow nearly threefold by 2028 as entry barriers to technology acquisition decline.



*Based on the average costs of Floor Cleaning Robots; **Based on average U.S. cleaner salary
Sources: Global X analysis of data derived from: Facts & Factors, 2022; Indeed, n.d.; U.S. Bureau of Labor Statistics, n.d.; Yates, 2021

GLOBAL X by Mirae Asset

Drone Delivery Market Gaining Momentum Due to E-Commerce Growth

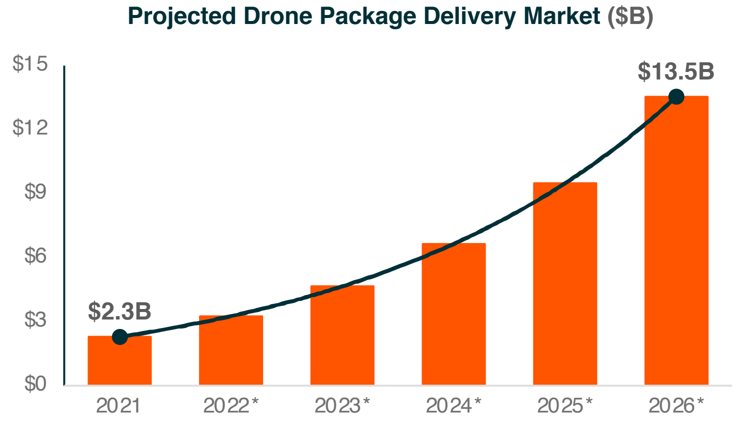
Mega-cap tech companies like Alphabet and Amazon are set to gain a considerable share of the drone delivery market along with major parcel delivery companies such as UPS and FedEx.

KEY DRIVERS

- **Technological advancements** in drones that make them go farther and carry heavier packages.
- **Demand for faster delivery** that is not dependent on traffic congestion.
- **Investments in drones nearly tripled** in 2021 to $7 billion from 2020.[1]
- **Growing need to reduce** carbon emissions.

Company	Summary of Drone Delivery-Related Activities
Alphabet	• Alphabet's self-delivery service Wing launched in Dallas in April 2022.[2] • Wing's drones can complete a round trip distance of 12 miles, carry roughly 2.6 pounds of goods, and travel 65 miles per hour.[3] • Wing has made over 200,000 deliveries as of earlier this year, and testing began in Virginia, Finland, and Australia.[4]
Amazon	• Amazon's Prime Air drone delivery company plans to deliver 5–30 pound packages with small drones.[5] • Amazon recently launched commercial tests of its drone delivery service in California. The company plans to operate 145 drone launch stations and deliver 500 million packages by drone a year.[6,7]
UPS	• UPS launched its subsidiary UPS Flight Forward in 2019. • The company received a Part 135 certification from the U.S. Department of Transportation giving it permission to operate a drone airline. • UPS Flight Forward currently only provides drone delivery services to the healthcare industry but plans to expand its offerings to other industries.

The drone package delivery market is projected to grow at a constant annual growth rate (CAGR) of 42.7% from 2021–2026.

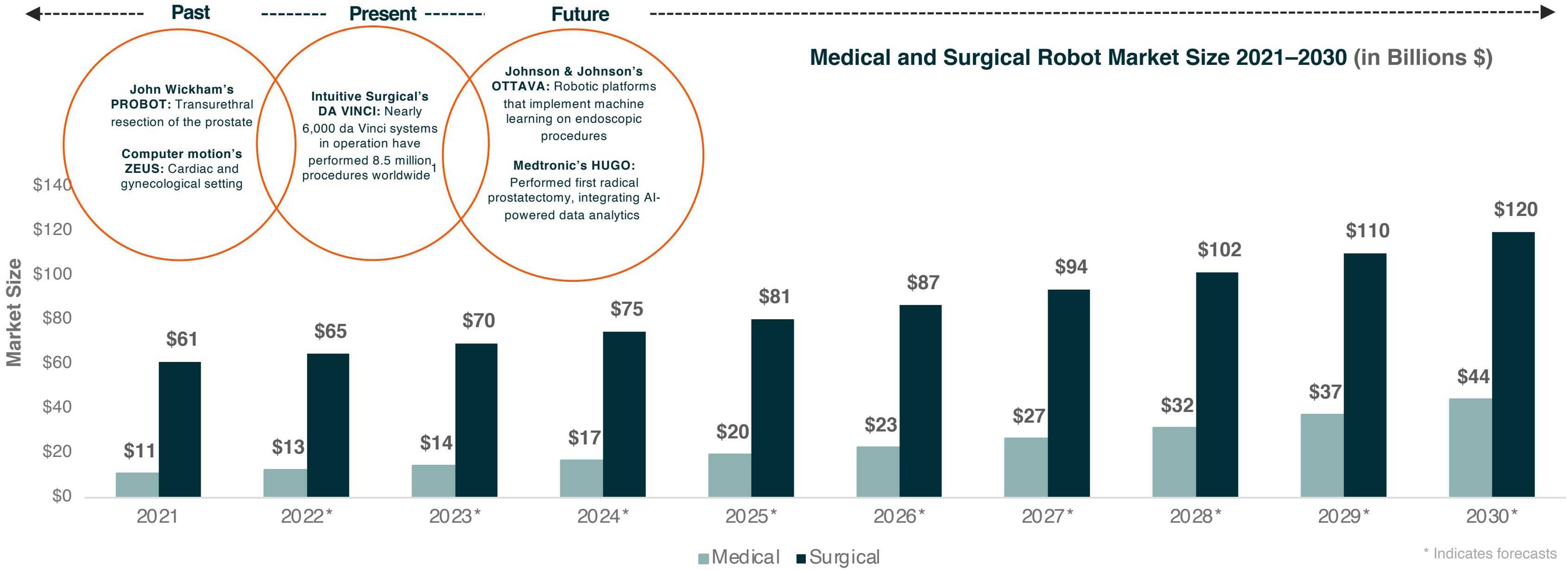


Sources: 1. Alvarado, 2022; 2. Wilmer & Snell, 2022; 3. Kenwell, 2022; 4. Ibid.; 5. Emergen Research, 2022; Amazon Staff, 2022; Ueland, 2022; Visual: Global X analysis of data derived from Technavio, 2022

Robots Assist in the Operating Room

Medical and surgical robots are on track to garner significant market value by 2030, growing by 4x and 2x, respectively.

The medical and surgical robotics market seeks to become integral to healthcare. The surgical robot market is valued at $120 billion by 2030. [1]

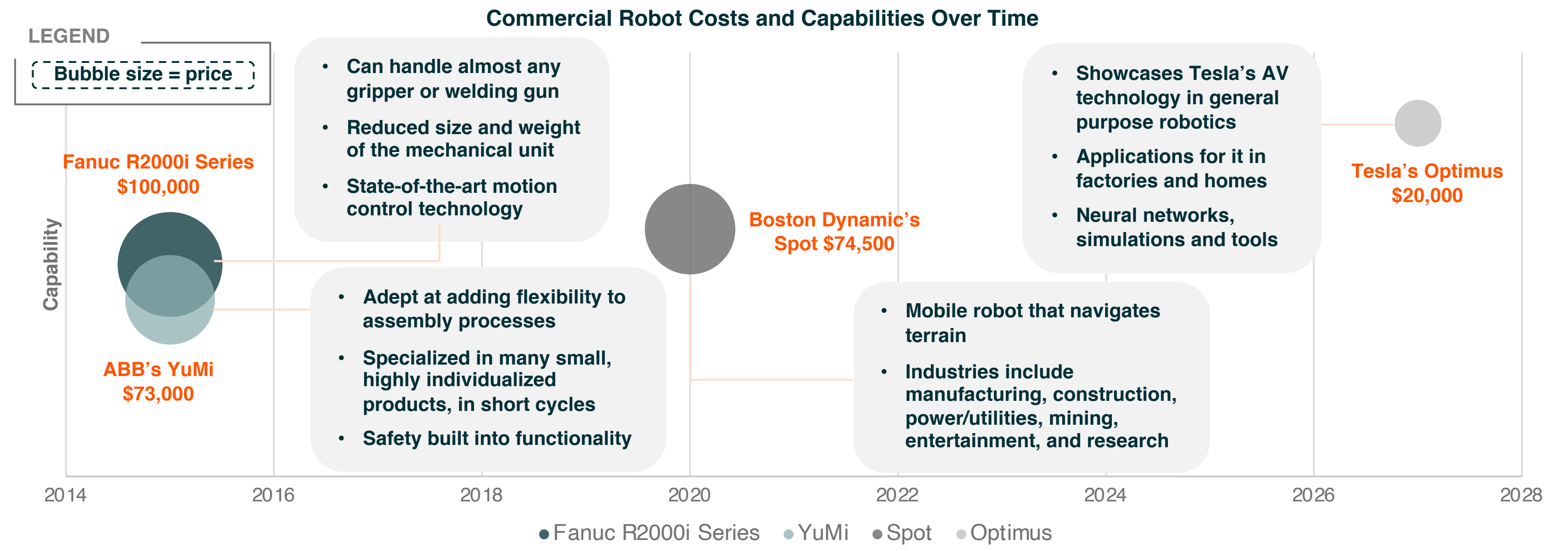


Sources: 1. Mayor, Coppola, & Challacombe, 2022; Next Move Strategy, 2022

Robotics & AI: Cheaper and More Capable

Robot features and functionality continue to increase while prices decrease, making robotics more attainable for consumers.

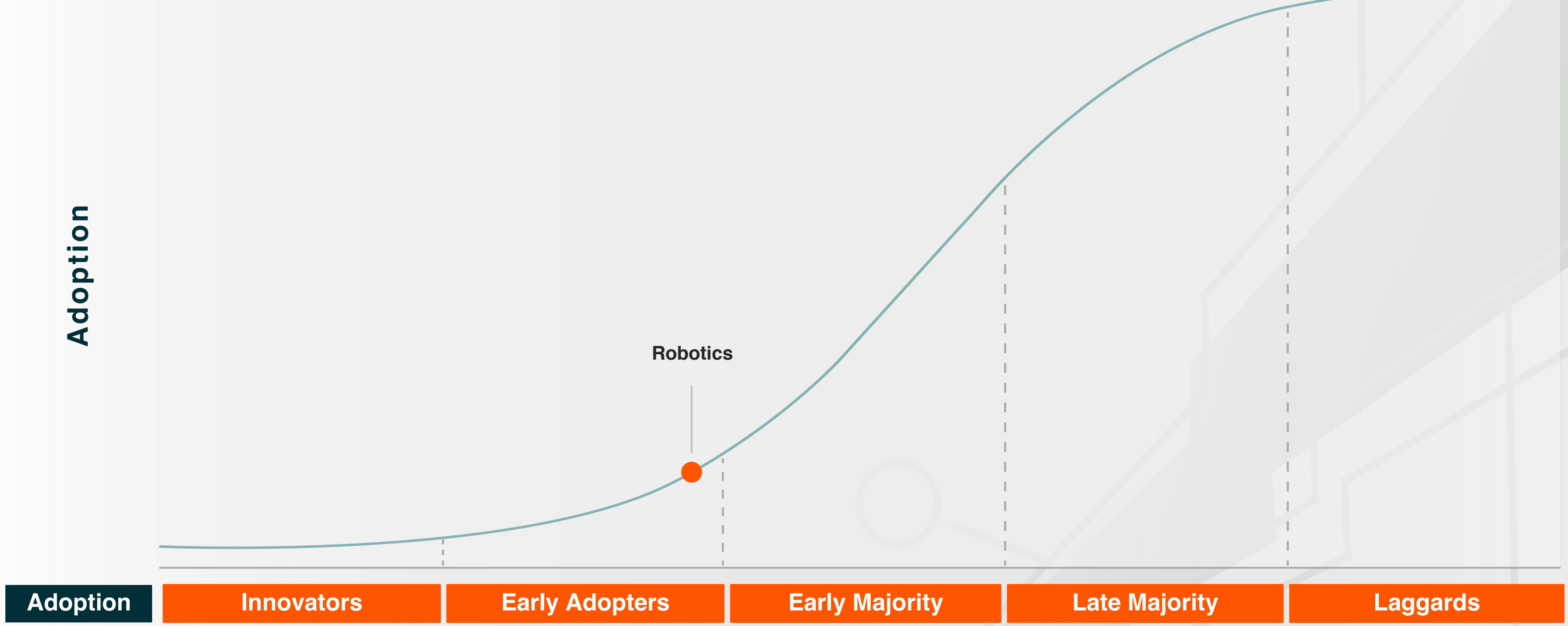
AI tech has evolved to make robotics more useful, yet costs continue to decrease. By 2027, we expect Tesla's Optimus to cost less than many EVs.



Sources: ABB, n.d.; Ackerman, 2020; Motion Controls Robotics, n.d.; Ortiz, 2022

S-Shaped Curve of Adoption – Robotics

We expect the global robotics market to grow to about $92 billion by 2026 from $56 billion in 2021, a compound annual growth rate (CAGR) of 10.5%.[1]



Sources: 1. BCC Research, 2022

Displayed for illustrative purposes. Curve shape not indicative of mathematical transformation

Chapter 13

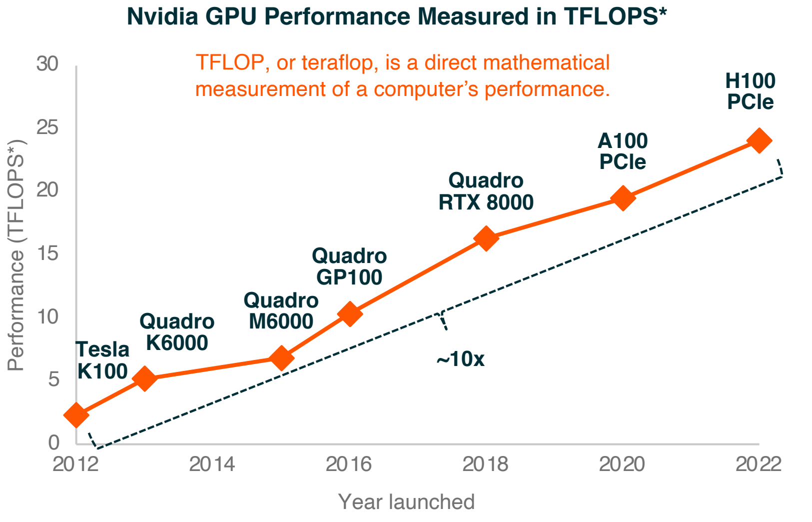
Artificial Intelligence

AI technology on the hardware and software sides continues to advance by leaps and bounds. Graphic Processing Unit (GPU) performance is 10 times better than it was 10 years ago, and technologies like real-time ray tracing are creating ever more realistic environments. Meanwhile, the commercialization of autonomous vehicles and quantum computing are fast approaching, spurred by public and private sector investment.

Major Advancements in AI-Related Hardware Expected to Continue and Potentially Accelerate

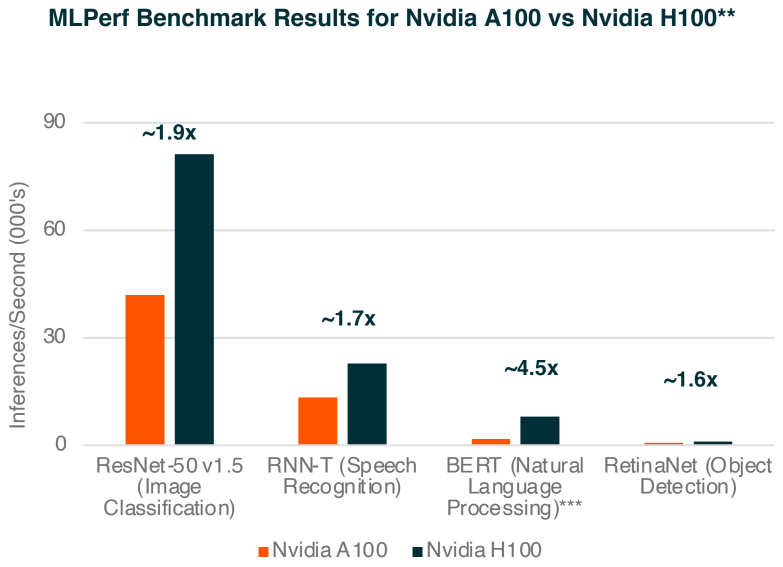
Hardware capabilities have improved rapidly over the last 20 years. Upcoming GPU launches are expected to make a major leap in performance, and AI accelerators are expected to become even faster.

Nvidia's GPU theoretical performance as measured in TFLOPS has been improving at an average rate of about 50% over each generation.



*Theoretical performance measured in FP32 (float) or TFLOPS **Based on MLPerf 2.1 Inference *** BERT 99.9% accuracy target used for H100 and A100

Nvidia's H100 Tensor Core GPU significantly outperformed its predecessor, the Nvidia A100, in major machine learning tests.



Sources: Global X ETFs with information derived from: TechPowerUp, 2022; Nvidia, n.d.

Advancements in Software Like Real-Time Ray Tracing Create More Realistic Virtual Environments

Ray tracing can simulate a scene's lighting and its objects by rendering physically accurate reflections, refractions, shadows, and indirect lighting.[1] Applications include movie production, gaming, and augmented reality (AR), virtual reality (VR), and the multiverse.

It took the Quadro K6000 29 hours to render a single frame

Architecture Kepler

The GPUs used in Pixar's "Monster University" were the first capable rendering of real-time ray tracing.

2013
Nvidia Quadro K600

*The RTX 2080 renders 58 frames per second (fps) on average**

Architecture Turing

Due to AI upscaling technology and powerful RT cores, the GPUs render at a stable 30–60 fps.

2018
Nvidia GeForce RTX 2080

*The RTX 3080 renders 79 frames per second on average**

Architecture Ampere

With 10GB of video memory, this GPU is double the performance of the RTX 2080 in ray tracing tasks.

2020
Nvidia GeForce RTX 3080

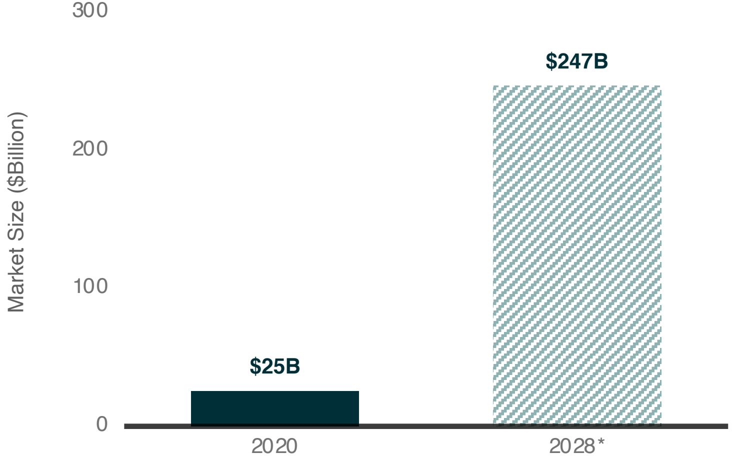
*Based on the Blender 2.90 benchmark
Sources: Text: 1. Nvidia Developer, n.d.; Nvidia, 2022

The AI Chipsets Market Is Poised for Fast Growth but May Become More Segmented

The global GPU market is set to grow tenfold from $25 billion in 2020 to $247 billion by 2028.[1] In the process, the GPU market share split may reshuffle.

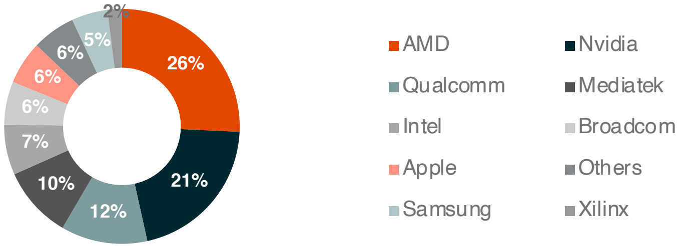
Nvidia, AMD, and Qualcomm may continue to dominate the market, but new entrants will likely grow to occupy significant shares.

Global GPU Market Size in 2020 vs. 2028*

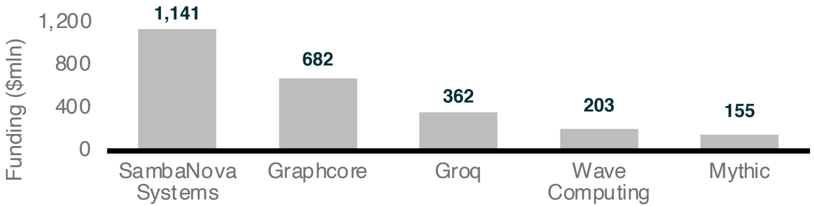


* Indicates forecast

Global Share of 7-Nanometer Shipments in 2021, by Customer



Top Funded AI Chip Startup Companies in 2021



Sources: 1. Global X ETFs with information derived from: Verified Market Research, 2022; Gai, 2021; Crunchbase, n.d.

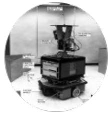
Innovation in Artificial Intelligence Has Been More Than Half a Century in the Making

1950
TURING TEST
Alan Turing publishes "Computing Machinery and Intelligence," a paper arguing machines can have human-like intelligence.[1]

1955
ARTIFICIAL INTELLIGENCE
John McCarthy coins the term artificial intelligence, describing the science and engineering behind making smart machinery.

1961
UNIMATE
GM unveils Unimate, the first industrial robot put to work on the assembly line.

1964
ELIZA
Joseph Weizenbaum builds a chatbot called Eliza that can hold conversations with humans at MIT.



1966
SHAKEY
Stanford designs Shakey, the first general purpose mobile robot capable of reasoning and explanation of its own actions.

AI WINTER
Lack of credible applications and stunted hardware/computing innovation cool down AI progression.

1997
DEEP BLUE
IBM creates a chess-playing computer system known as Deep Blue that is able to defeat the world chess champion and grand master.[2]

1998
KISMET
MIT introduces Kismet, an emotionally intelligent robot that can detect and respond to people's feelings.

1999
AIBO
Sony creates Aibo, a four-legged entertainment robot equipped with motion editing so users can create moments for the robot.

2002
ROOMBA
Roomba becomes the first mass-produced autonomous robot vacuum cleaner.

2011
SIRI
Apple acquires Siri from SRI International for over $200 million and integrates it as a smart assistant in the iPhone 4S.[3]

2011
WATSON
IBM's smart computer Watson wins a million-dollar prize on the television quiz show Jeopardy.[4]

2015
OPEN AI
Open AI launches, a non-profit artificial intelligence research agency founded by notable technologists and companies.

2017
ALPHAGO
Google AI designs AlphaGo, a board game-playing robot that defeats Go world champion Ke Jie.[5]

2019
GPT2
Open AI launches its second iteration of GPT, an advanced general purpose NLP model trained on 774 million parameters.[6]

2021
DALL E
Open AI reveals Dall E, a GPT-3 AI system capable of generating descriptive images based on textual prompts– trained on over 12 billion parameters.[7]

Sources: 1. Turing, 1950; 2. IBM, n.d.-b; 3. Perlroth, 2011; 4. IBM, n.d.-a; 5. Byford, 2017; 6. Roadord, Wu, Amodei, Amodei, Clark, Brundage, Sutskever, Askell, Lansky, Hernandez, & Luan, 2019; 7. Ramesh, Pavolv, Goh, & Gray, 2021

Open AI's DALL-E Charts a New Frontier for Natural Language Processing

What is Dall E?

- **Dall E is a natural language processing (NLP) model** built and licensed by Open AI. Dall E can take textual commands and generate abstract, original, realistic images based on the prompt by combining concepts, attributes, and styles. Currently, in its second generation, Dall E is a groundbreaking NLP innovation that could lead to a future where AI-led commands govern content creation.
- **Dall E is derived from GPT 3,** an autoregressive language model with 175 billion parameters. GPT-3 is a third-generation language model built on a neural network that follows the Transformer model. It is trained on an extensive dataset that includes 410 billion tokens from Common Crawl, the archive that routinely crawls the world wide web.
- **Today, GPT-3 powers applications including** GitHub Co Pilot, AI Dungeon, and other commercialized AI-based content writers. Microsoft licensed exclusive use of GPT-3 while allowing for a wider public API.
- **Early applications of Dall E focus on** educational and research use. Longer-term, we believe the technology could extend from images to video, disrupting content production and news reporting, and creating opportunities for other applications.

Global X-generated DALL·E 2022-08-25 08.43.05 – "A robot coding software in an office on the moon, digital art"

Generative AI Systems Are the Vanguard of Next Computing Revolution

GPT-3, DALL-E 2, and other generative AI platforms can be given a limited number of parameters and create original work, such as social media, video games, coding, graphic design, and more. As the models get better, they're starting to deliver human-level results and, soon enough, they could start delivering superhuman-level outcomes.

First attempts | Almost there | Ready for prime time

	PRE-2020	2020	2022	2023*	2025*	2030*
TEXT	Spam detection Translation Basic Q&A	Basic copywriting First drafts	Longer form Second drafts	Vertical fine-tuning gets good (scientific papers, etc.)	Final drafts better than the human average	Final drafts better than professional writers
CODE	1-line auto-complete	Multi-line generation	Longer form Better accuracy	More languages More verticals	Text to product (draft)	Text to product (final) better than full-time developers
IMAGES			Art Logos Photography	Mock-ups (product design, architecture, etc.)	Final drafts (product design, architecture etc.)	Final drafts better than professional artists, designers, photographers
VIDEO / 3D / GAMING			First attempts at 3D/video models	Basic/first draft videos and 3D files	Second drafts	AI Roblox Video games and movies are personalized dreams

*Estimates
Sources: Huang, Grady, & GPT-3, 2022

AI Services Will Play a Central Role in Unlocking Developer Productivity

The cloud will be key to the delivery of As-a-Service automation tools, which could play a central role in boosting employer productivity and giving enterprises a scalable solution to address global talent shortages.[1]

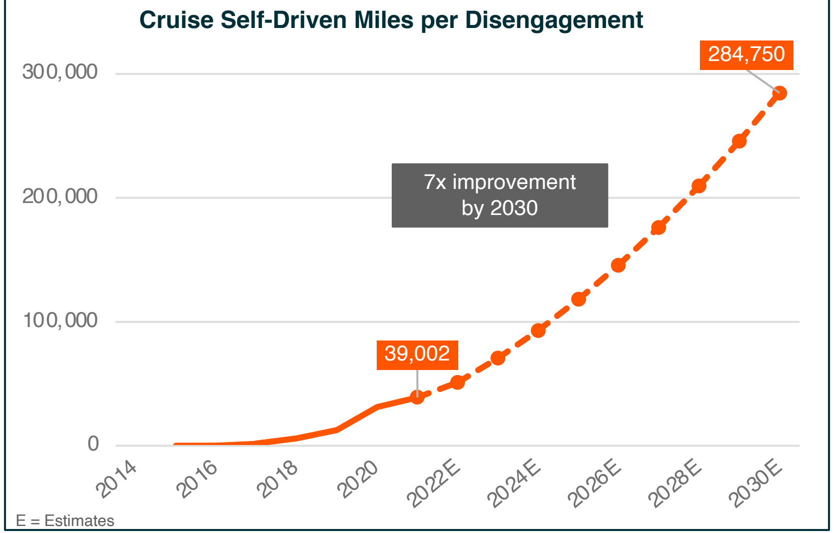
Leading AI Services	Comments	Stage
GitHub Copilot	A pair programming tool developed by Open AI and bought by Microsoft to assist developers of a select few integrated development environments (IDEs) with auto completion of software development. The service is now available for $10 per month for all paying users. GitHub reports that nearly 40% of code is written by the AI wherever it is enabled by developers.[2]	Available for open use
Open AI GPT-3	Autoregressive learning NLP model trained on over 175 billion parameters, capable of generating formatted text based on commands. GPT-3 derived tools are utilized to generate press releases, blogs, and other textual content.[3]	Beta, invite only
Amazon Code Whisperer	Helps developers improve code syntax and auto completes coding logic. Developers can outline logic in simple English, and the system performs the task, such as managing resources. Commands work through the AWS ecosystem.[4,5]	Open access, through AWS

Sources: 1. Dayaratna, 2021; 2. Markets and Markets, 2019; 3. Dall-E-2, n.d.; Midjourney, n.d.; 5. Desai & Deo, 2022

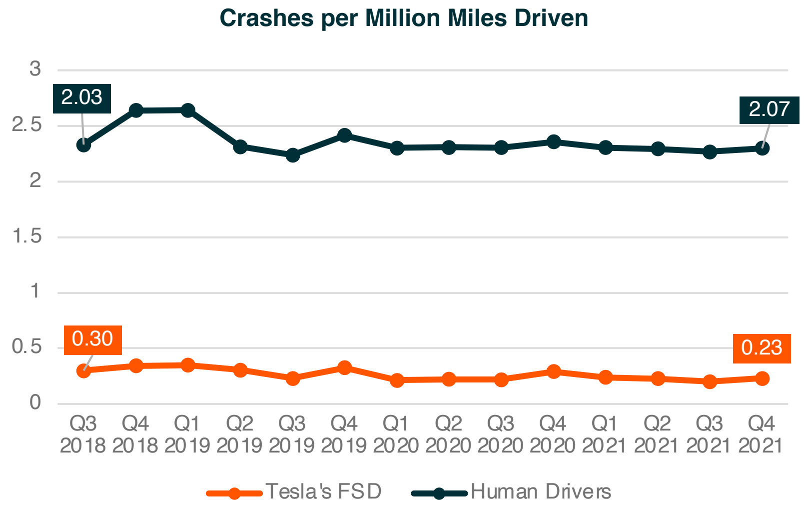
Autonomous Vehicle Technology Advancements to Improve AV Safety vs. Human Drivers

Autonomous vehicles constantly collect and process billions of data points from an array of cameras with sensors, radar, and LiDAR systems. AVs use this data to continually improve the AV network's driving skills and reduce the instances of software disengagement events and accidents.

By 2030, GM's Cruise AV could drive about 300,000 miles before a disengagement event prompts a test driver or operator to take over.



Tesla's Full Self Driving (FSD) AV technology is involved in accidents at a rate 10x less than human drivers.

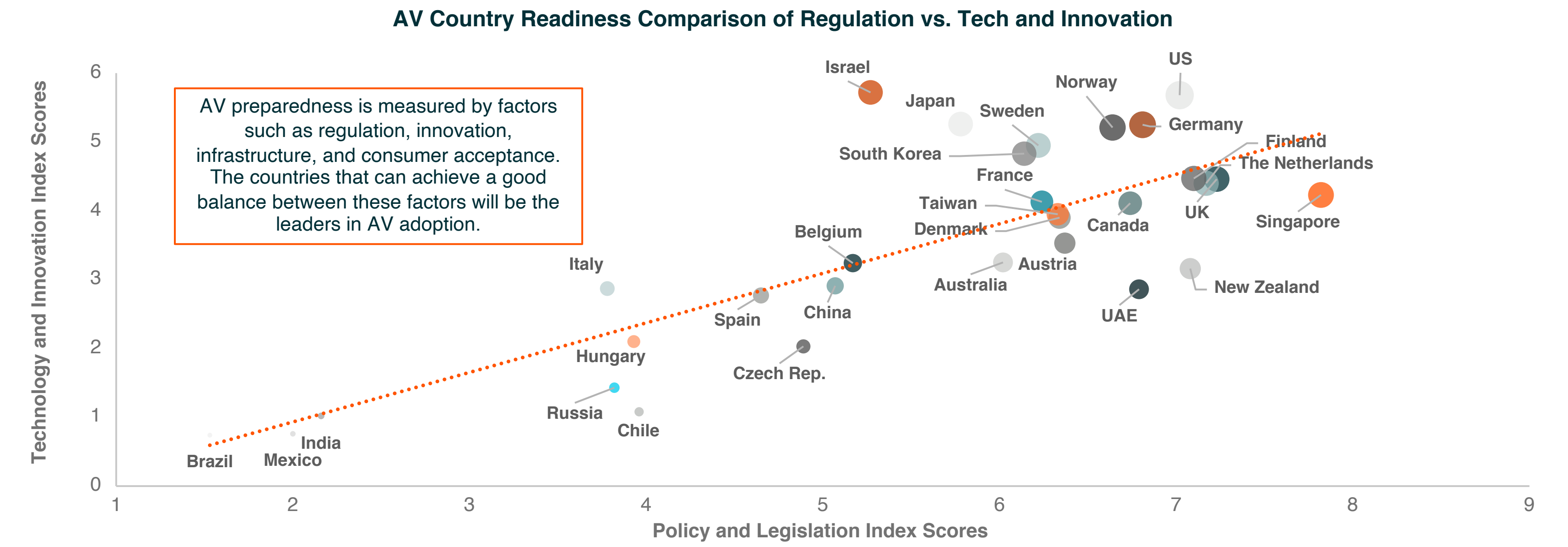


Sources: Visual (LHS): Global X analysis of data derived from: State of California Department of Motor Vehicles, 2021a; Global X Wrights Law on Autonomous Driving Stoppage Forecast based on data from State of California Department of Motor Vehicles, 2021b; Tesla, 2021; Visual (RHS): Tesla, 2021

Autonomous Vehicle Adoption Will Rise Faster in Countries with High Preparedness

In addition to technological development, AV technologies require policy and legislative support to make them viable.

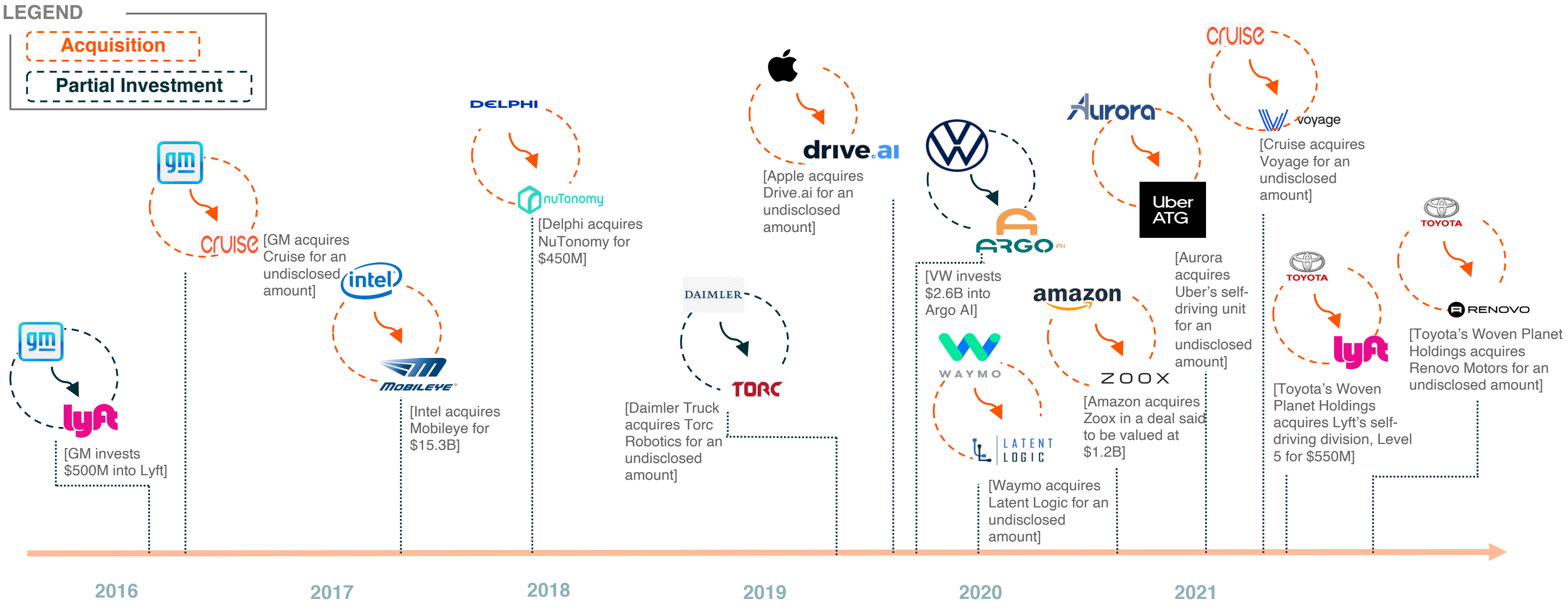
Finland, the UK, and the Netherlands have a healthy balance of regulation and innovation, as per KPMG Autonomous Vehicles Readiness Index.



Sources: Global X ETFs with information derived from: KPMG International, 2020

Companies Along the AV Supply Chain Investing to Make AVs a Reality

Merger and acquisition activity in the AV sector is increasing as companies recognize the need for wider collaboration.



Sources: Crowe, 2020; Bloomberg News, 2021

Quantum Computing on a Multi-Year Path to Achieve Quantum Advantage

Advancements in quantum computing over the past five years are significant. Major technology companies such as IBM, Alphabet, and Microsoft continue to invest in the space, and governments are ramping up support.

Quantum computing will be used alongside classical computers to solve complex problems.

The goal is for quantum computing to eventually be used alongside classical computers to solve complex problems, such as helping banks manage systemic risks.

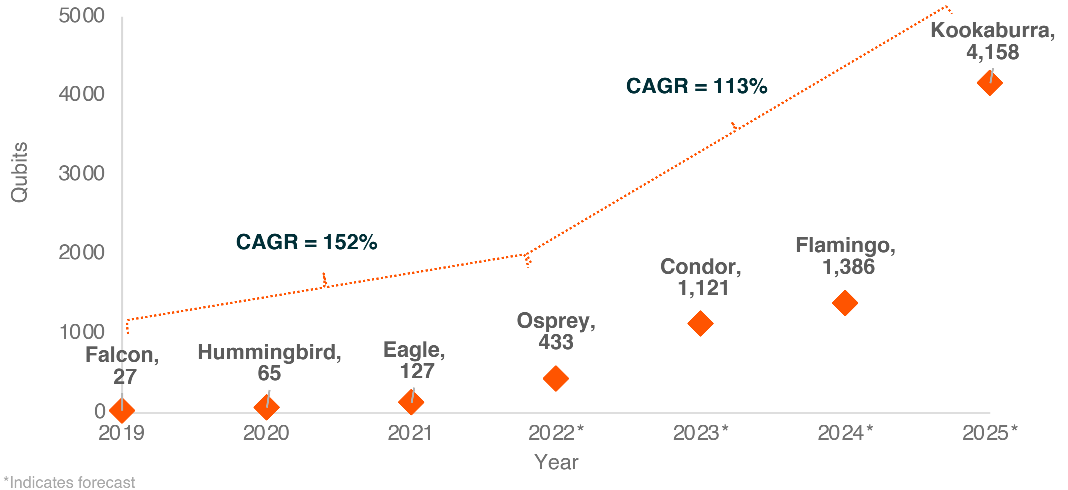
For context, quantum computers are about 158 million times faster than the most sophisticated supercomputer currently available. In other words, it takes four minutes for the quantum computer to complete a specific task, compared to 10,000 years for a traditional supercomputer.[1]

Quantum computing vendors and governments have started implementing strategic approaches to reaching quantum advantage over classical computers, "the point at which a system employs the technology to bring a step change in solving a practical computing task."[2]

Multiple countries have committed billions of dollars towards quantum computing, with the EU already investing more than $7 billion.[3] Investments like these set the stage for the quantum computing market to grow significantly in coming years. According to one estimate, it could reach $8.6 billion in 2027, up from $412 million in 2020.[4]

IBM recently unveiled its new roadmap to practical quantum computing, announcing its plans to produce the 433-qubit Osprey processor in 2022, deliver the 1000+ qubit Condor in 2023, and launch more than 4000 qubit processors by 2025.

IBM Quantum Processors Roadmap

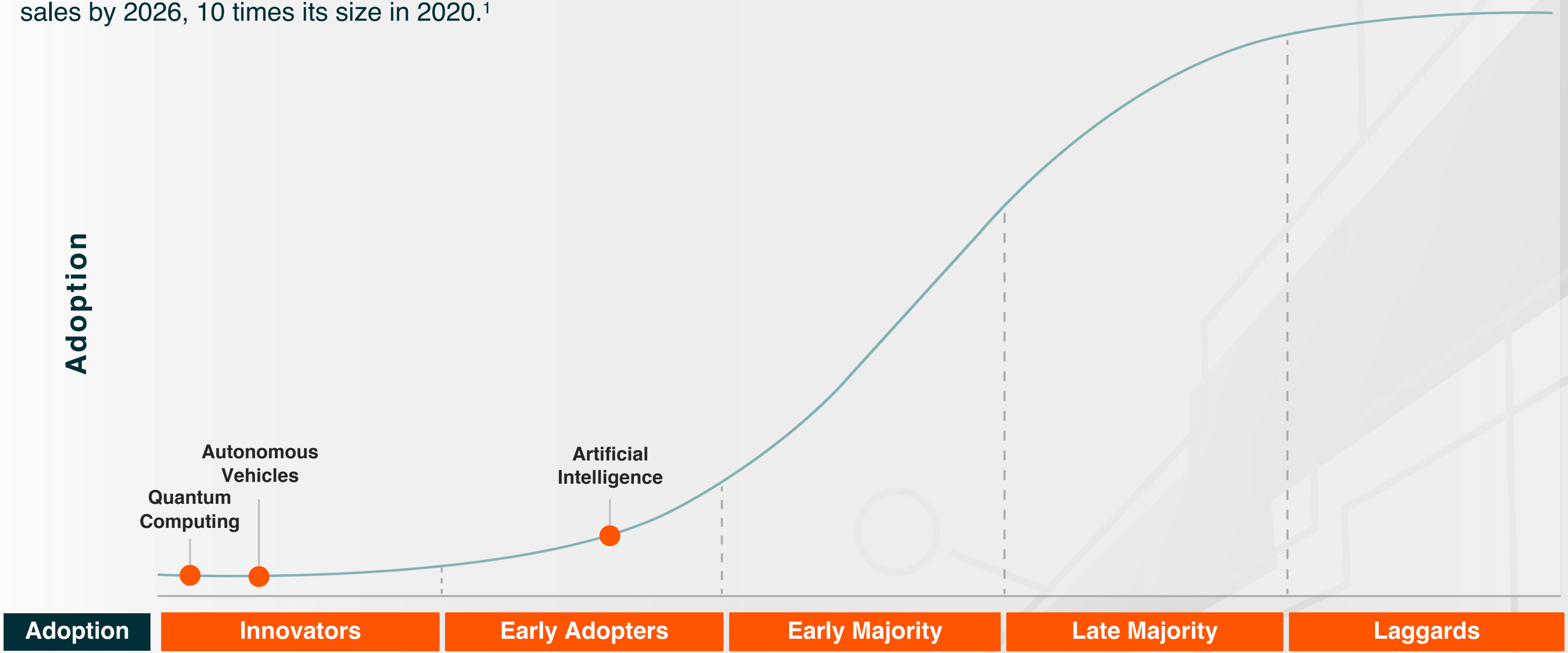


*Indicates forecast

Sources: Text: 1. Smith, 2022; 2. Waters, 2022; 3. Pflanzer, 2021; 4. International Data Corporation, 2021; Visuals: IBM, n.d.

S-Shaped Curve of Adoption – Artificial Intelligence

We expect the global AI market to grow at a CAGR of 35.6% to nearly $300 billion in sales by 2026, 10 times its size in 2020.[1]



Source: 1. Facts & Factors Research, 2021

Displayed for illustrative purposes. Curve shape not indicative of mathematical transformation

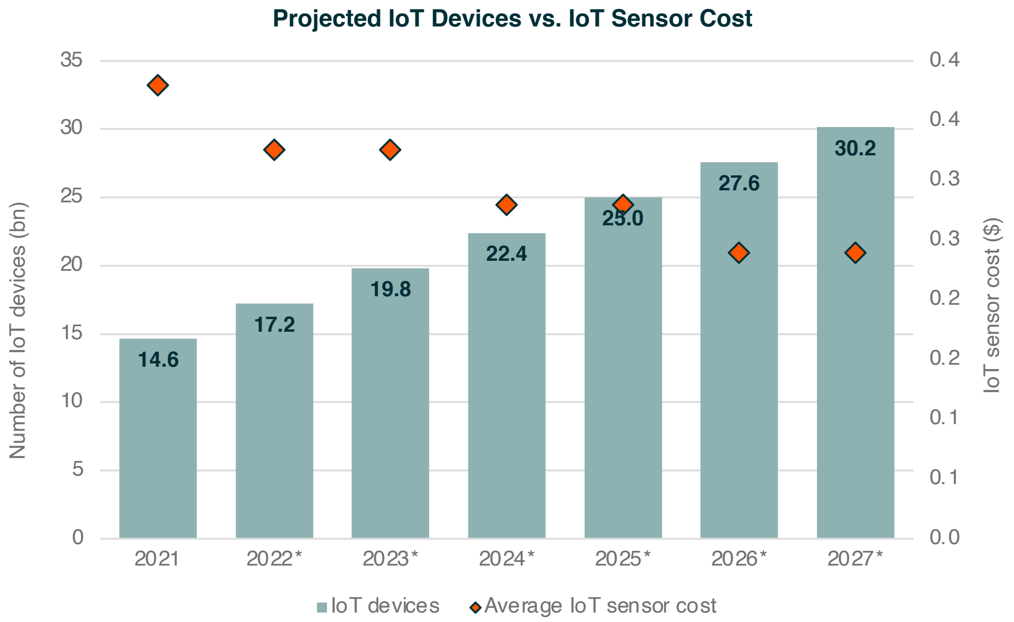
Chapter 14

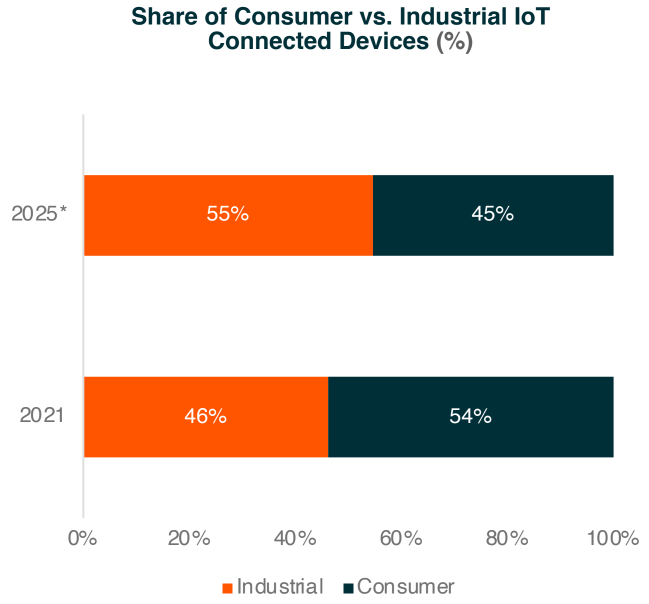
Connectivity

Core to the ongoing rise in Internet of Things (IoT) adoption is the rapid decline in IoT sensor costs and advancements in sensor technology spurring innovation and growth of connected devices. We expect greater connectivity offered by 5G network technology to drive adoption of IoT devices even further and at a faster pace than 3G and 4G drove the adoption of smartphones.

Growth of Connected Devices Driven by Rapidly Falling IoT Sensor Costs

Sensor costs declined nearly 70% from 2004 to 2018, which facilitated innovation and growth of connected devices. The continued decline in sensor costs is expected to increase the number of connected devices exponentially over the next five years.[1]



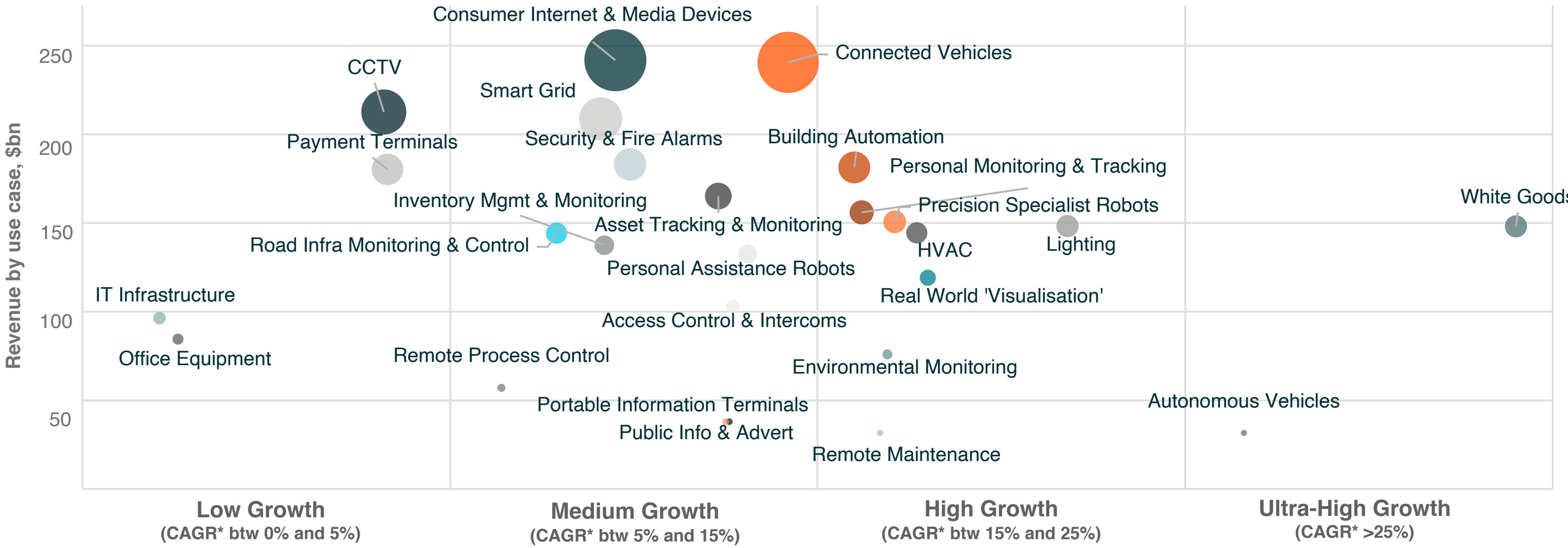


Sources: Text: 1. Leonard, 2019; Visuals: Global X ETFs with data derived from Ericsson, n.d.; Microsoft Dynamics, n.d.; Mordor Intelligence, n.d.

New Use Cases for IoT Devices Continue to Emerge

Traditionally, IoT applications focused on the enterprise side, but more and more verticals are emerging, representing new addressable markets. Autonomous vehicles are among the use cases expected to see ultra-high growth.

2030 Projected Global IoT Revenue by Use Case (In USD Billion)

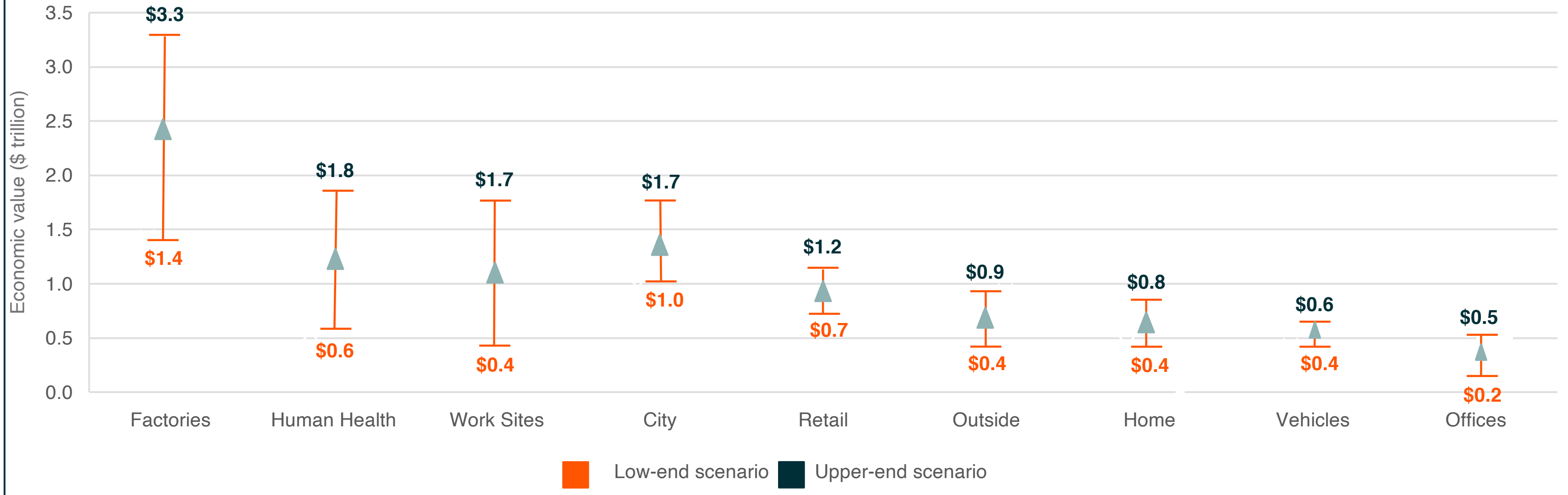


*Compound annual growth rate between 2021 and 2030
Sources: Global X ETFs with information derived from International Energy Agency, 2021; Vailshery, 2022

IoT's Adoption Expected to Add Significant Economic Value

By 2030, IoT adoption could generate $12.6 trillion in economic value, a nearly eightfold increase from 2020.[1] Adoption is set to continue its rise, in many instances accelerated by the pandemic shifting consumer behaviors. Strong adoption and value creation is particularly evident in healthcare.

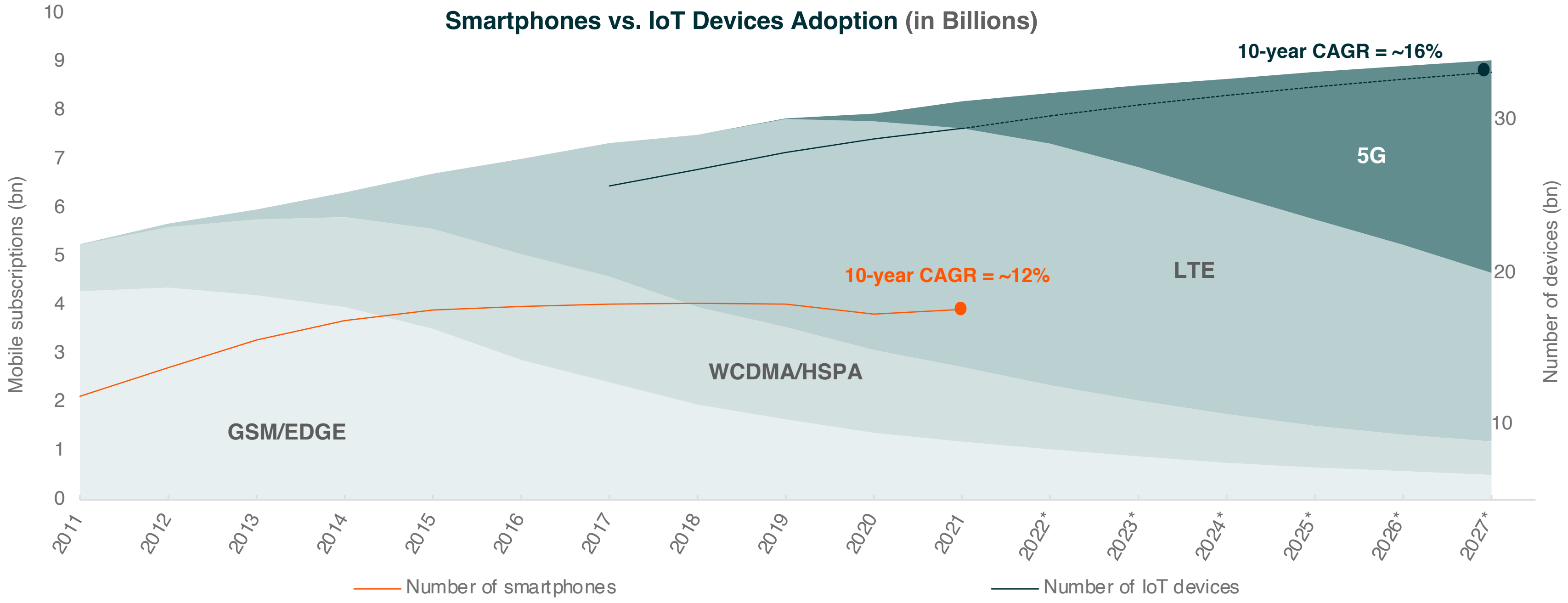
Potential Economic Value From IoT Worldwide in 2030 by Use Case (in Trillion $)



Sources: Text: 1. McKinsey, 2021; Visuals: Global X ETFs with information derived from: Vailshery, 2022

Smartphones vs. IoT Devices: Adoption Trends

Greater connectivity will be a major driver of IoT adoption. We expect 5G and next-generation networking technologies to drive adoption of IoT devices at a faster pace than 3G and 4G technologies drove the adoption of smartphones.



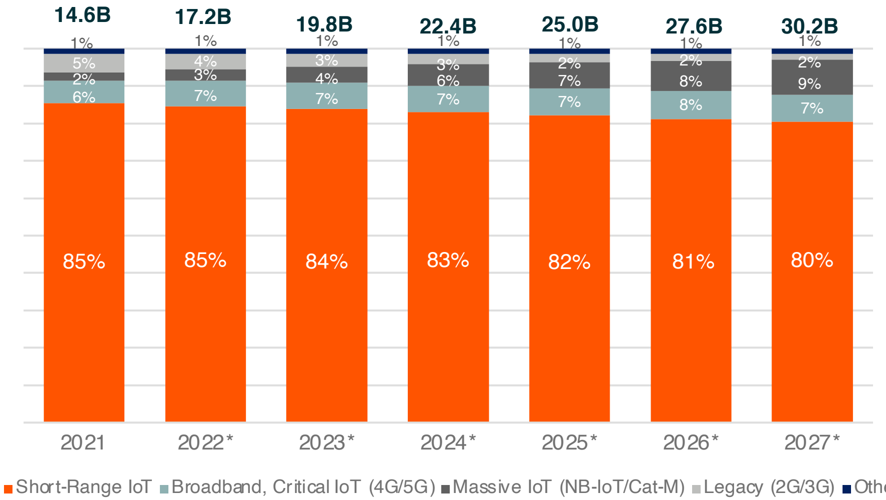
Sources: Global X ETFs with information derived from: Ericcson, n.d.; International Energy Agency, 2021; Laricchia, 2022

Advanced Network Capabilities Lead to Growth in Massive IoT

Massive IoT services are low-cost with long battery life and low throughput. Their growth is enhanced by spectrum sharing and a recently added network capability that enables their coexistence with 4G and 5G.

Broadband IoT overtook 2G and 3G in 2021 to connect the largest share of connected IoT devices. Massive IoT is expected to pass broadband by 2023.

Projected Share of IoT Devices by Connectivity Type



		Short-Range IoT	Broadband, Critical IoT (4G/5G)	Massive IoT (NB-IoT/Cat-M)	Legacy (2G/3G)	Other
2021	14.6B	85%	6%	2%	5%	1%
2022*	17.2B	85%	7%	3%	4%	1%
2023*	19.8B	84%	7%	4%	3%	1%
2024*	22.4B	83%	7%	6%	3%	1%
2025*	25.0B	82%	7%	7%	2%	1%
2026*	27.6B	81%	8%	8%	2%	1%
2027*	30.2B	80%	7%	9%	2%	1%

* Indicates forecasts

Sources: Global X ETFs with information derived from: Ericcson, 2022

Types of IoT Connectivity

Short-Range IoT

The short-range consists of connected devices with a range of up to 100 meters. These devices are powered by Wi-Fi, Bluetooth and Zigbee, with examples including smart home devices, wearables, and fitness trackers.

Wide-Area IoT

Wide-area IoT devices use connections that allow communication over large distances of at least 500 meters, such as cellular connections or unlicensed low-power technologies, like Sigfox and LoRa. Cellular connections can be broken down into:

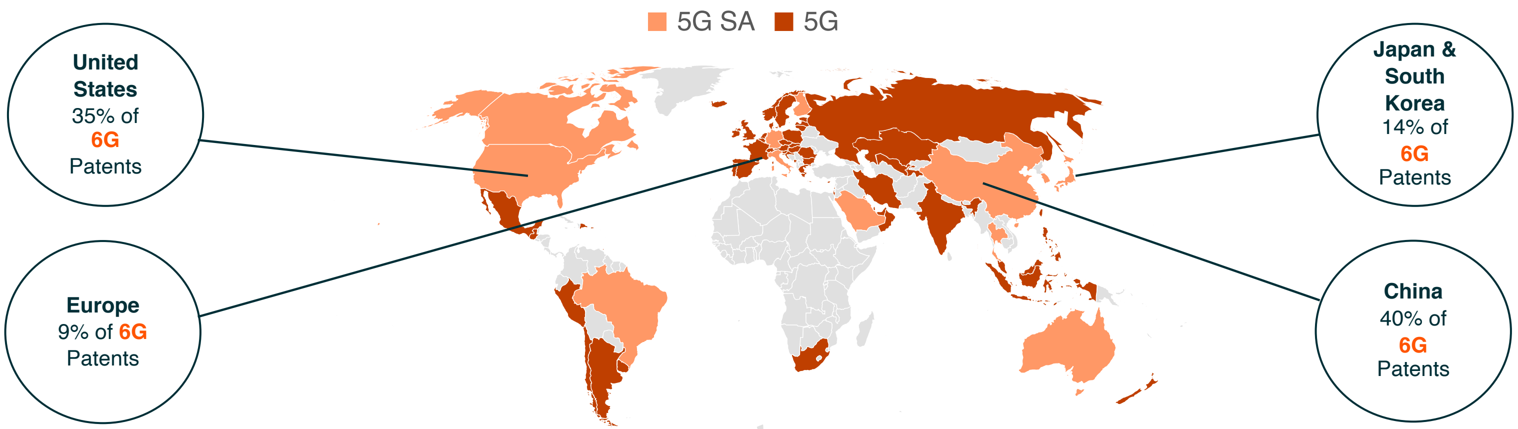
- **Massive IoT (NB-IoT/CAT-M):** Examples include smart cities and smart agriculture.
- **Broadband, Critical IoT (4G/5G):** Examples include bandwidth-intensive applications such as remote surgery and massive machine-type communications.
- **Legacy (2G/3G):** These devices include low-power, battery-operated devices that often use M2M SIM cards to connect.
- **Other:** Connectivity technologies include LoRaWAN and Sigfox, which connect low-power devices like smart meters.

Telecoms Exploring New Technologies That Could Further Enhance the Connected World

Smart cities, smart factories, and AVs require low latency and efficient, reliable connectivity. Pandemic-induced demand accelerated telecoms' innovation and adoption of new technologies. Demand for connectivity even has early exploration of 5.5G and 6G underway.

5G and 5G NR SA rollouts continue. Over 20 service providers launched public 5G SA networks in 2021, a number expected to double in 2022.[1]

Commercially Deployed 5G & 5G NR SA Networks

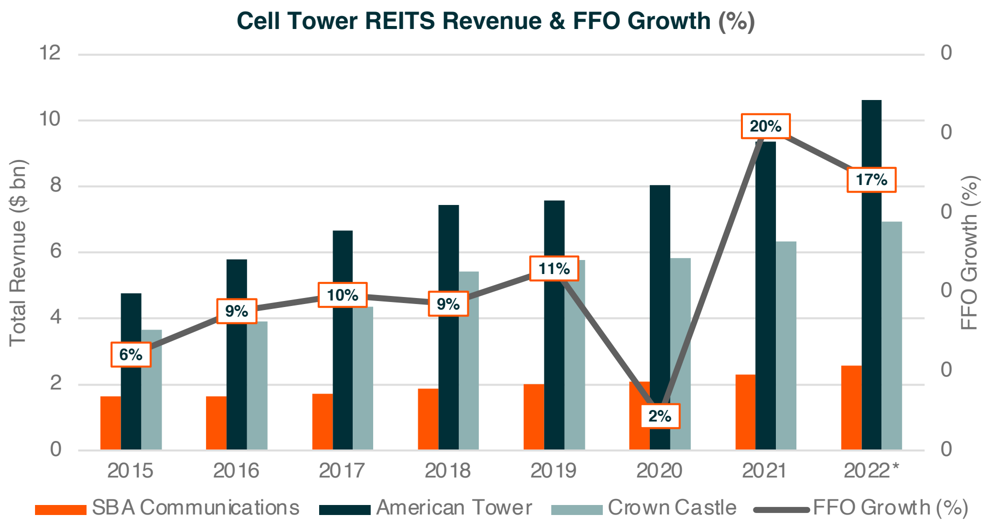


Sources: Text: 1. Ericsson, 2022; Visuals: Global X ETFs with information derived from: Spectrum Monitoring, 2021; Communications Today, 2022

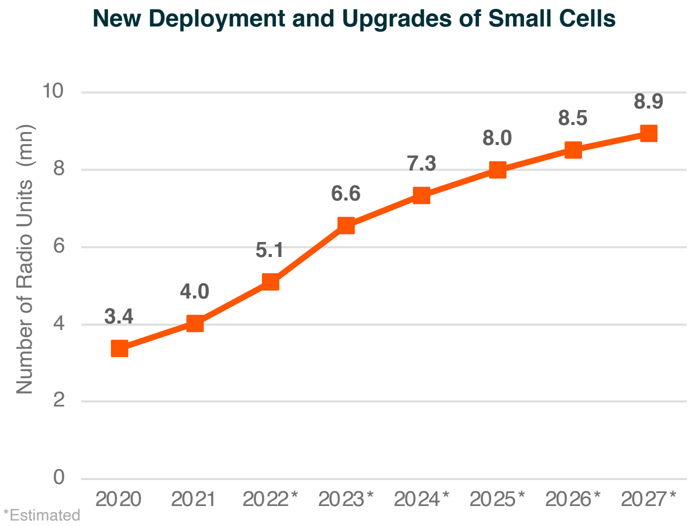
Cellular Towers: The Backbone of the Digital World

Funds from operations (FFO) and revenue growth of cellular tower real estate investment trusts (REITs) are near the top of the REITs sector due to surging demand for data.

FFO grew 20% in 2021 and is expected to increase a healthy 17% in 2022. [1]



Data demand driving a surge in small cell deployments.

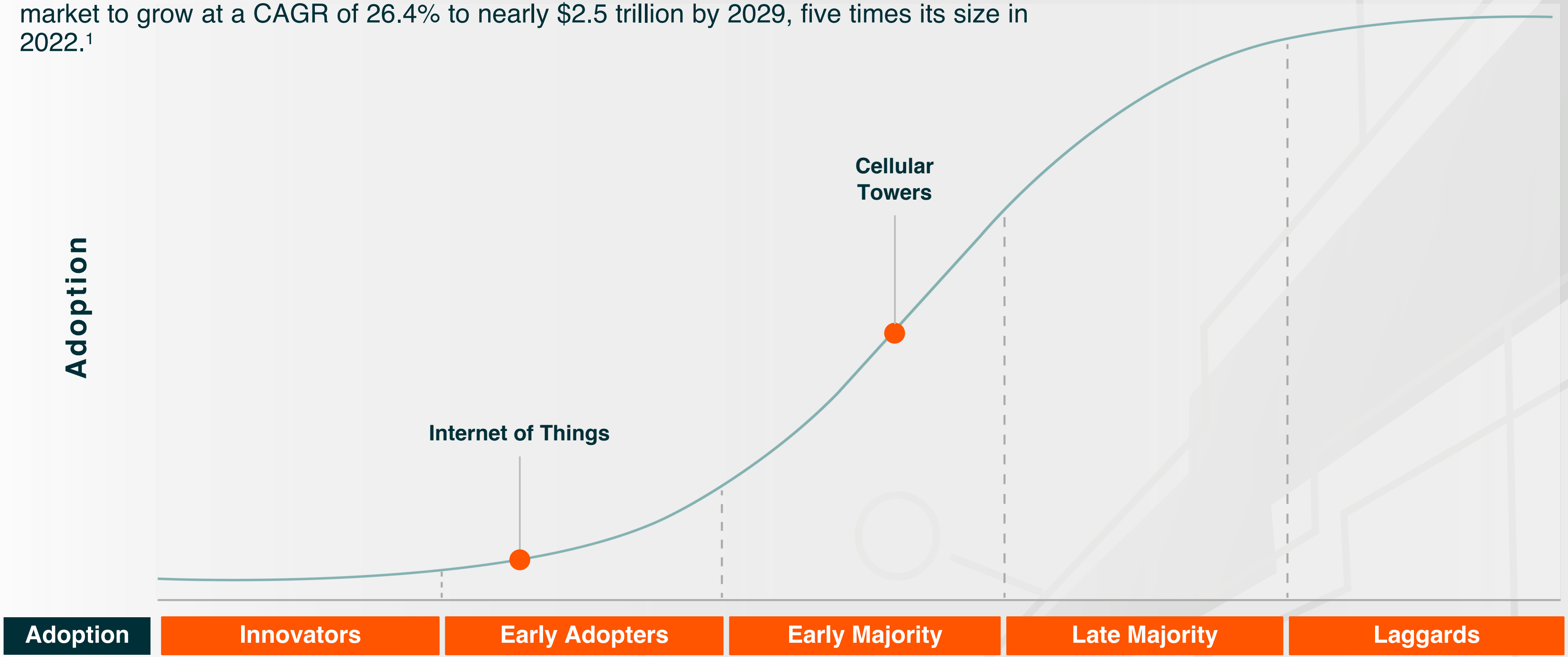


Note: All forecasts are based on numbers of radios deployed (integrated small cells or, in a disaggregated architecture, radio units), unless otherwise stated. 2022 forecast also includes distributed antenna systems (DAS), which are calculated based on numbers of antenna nodes. Funds from operations (FFO) refers to the figure used by REITs to define the cash flow from their operations. It is widely used as a measurement of operating performance. FFO growth is the average for American Tower, Crown Castle, and SBA Communications.

Sources: 1. Global X ETFs with data derived from: Bloomberg, L.P., n.d.; Small Cell Forum, 2022

S-Shaped Curve of Adoption – Connectivity

As IoT adoption continues to progress towards Early Majority, we expect the global IoT market to grow at a CAGR of 26.4% to nearly $2.5 trillion by 2029, five times its size in 2022.[1]



Sources: Text: 1. Fortune Business Insights, 2022

Displayed for illustrative purposes. Curve shape not indicative of mathematical transformation

Chapter 15

Future of Money

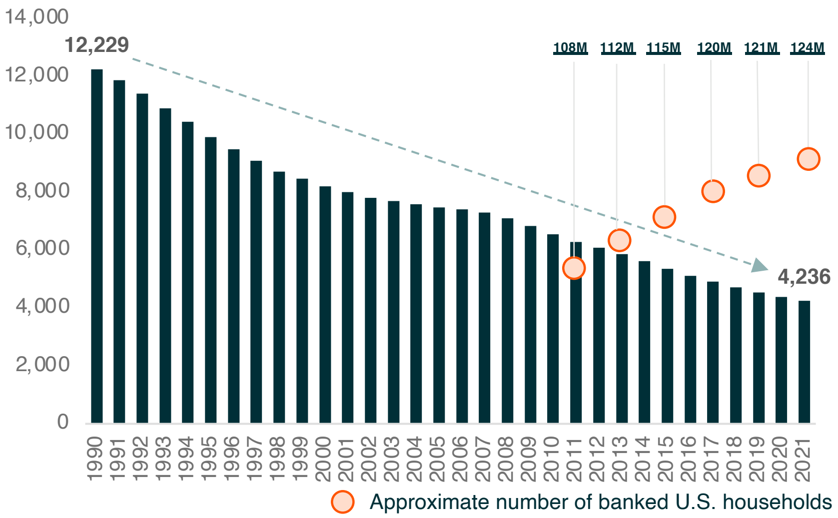
Digital financial services, spurred by younger generations, are disrupting legacy business models. Traditional banking relies on a distributed network of branches to operate and serve users, but compared with its digital counterparts, that model is expensive and inefficient. For example, digital wallets can onboard users for much cheaper and serve them across a portfolio of products. Digital native credit is on the same spectrum and upending traditional lending models.

Digital Native Banking Is Phasing Out the Legacy Banking Model

The geo-restricted traditional banking model is expensive. Banks spend millions a year on managing retail branches, leading to resource waste and higher costs for consumers.[1] Digital native banking is displacing the model.

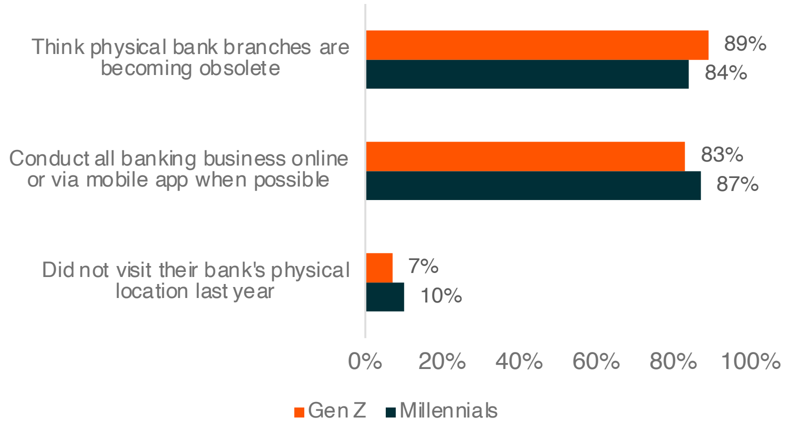
U.S. banks are cutting excess and streamlining operations by reducing their physical branches and leaning on technology services providers.

Number of FDIC-Insured Banks in the United States



A recent survey found that 3 in 4 Americans, including the vast majority of Millennial and Gen Z participants, prefer digital banking.

Generational Survey on In-Person Banking



Online survey of 936 Americans with a bank account.

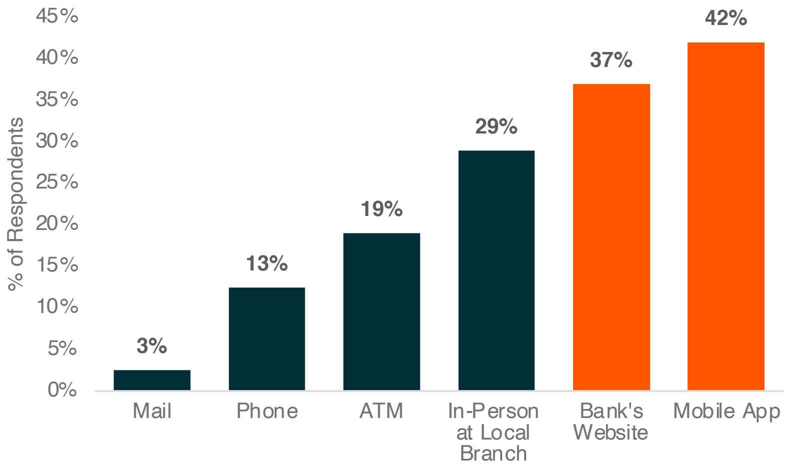
Sources: Text: 1. Lightico, 2021; Visual (LHS): Federal Deposit Insurance Corporation, n.d.; Visual (RHS): DeMarco, Shepard, & White, 2021

New Generation of Consumers Have Unique Preferences That Favor Digital Banking

Younger consumers prefer digital banking due to lower fees, transparency, and 24/7 availability.

Most American consumers prefer to access banking services digitally.

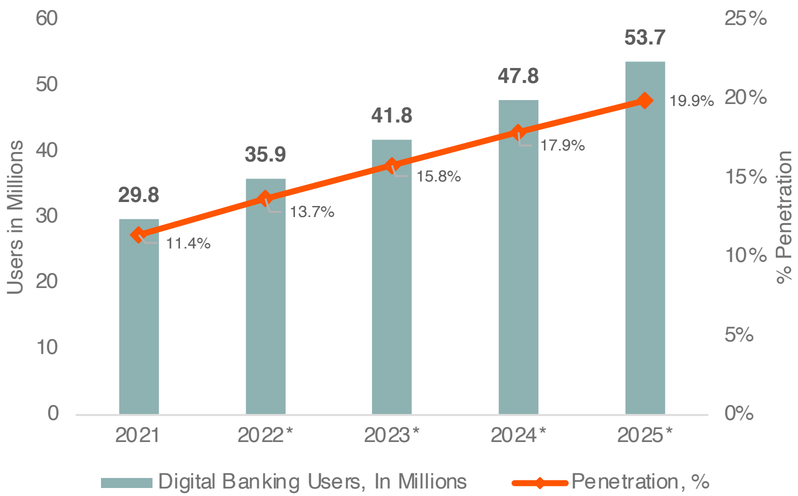
American Consumers' Preferred Method of Banking



Q: Which of the following methods do you prefer to do your banking?
N=884 those with bank account Respondents could choose more than one option.

Digital banking is forecast to achieve nearly 2x penetration by 2025.

Digital-Only Bank Account Holders in the United States

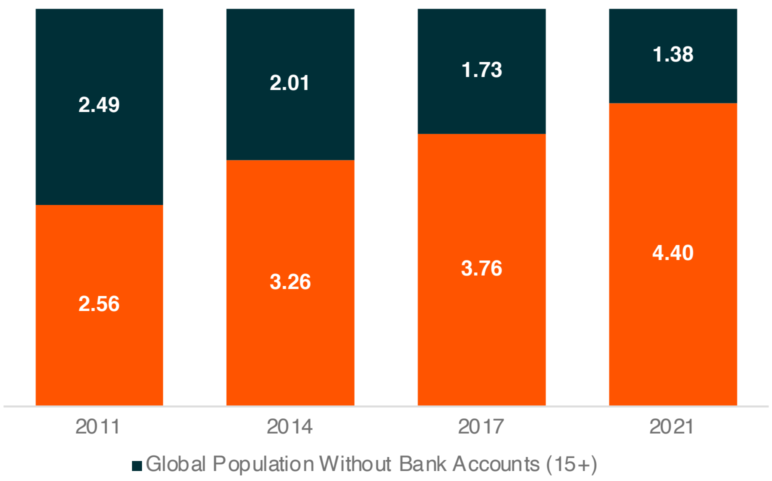


Sources: Visual (LHS): Strohm, 2022; Visual (RHS): Magana & Dyke, 2021. * Estimates

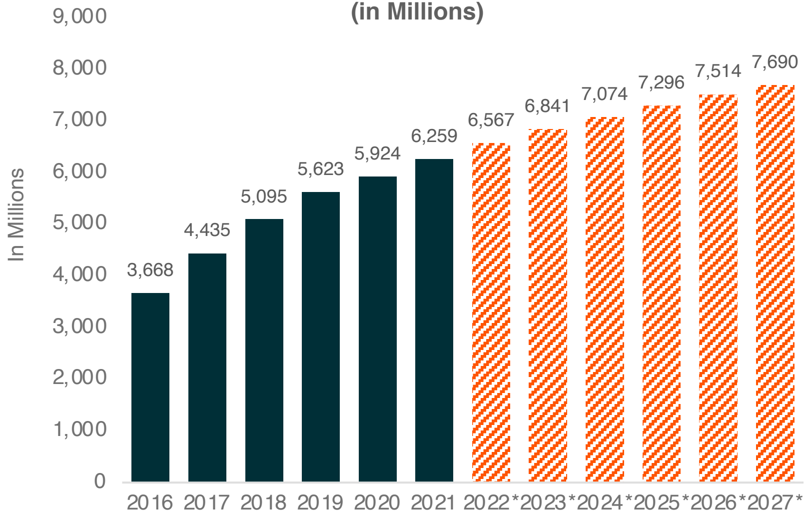
Digital Banking Will Play a Key Role in Improving Access to Financial Products

Brick-and-mortar banking failed to reach all corners of the world. Digital finance has the potential to bring access to billions.

The percentage of the global population with a bank account increased significantly in the last decade, yet 1.4 billion adults remain unbanked.



Global smartphone subscription growth suggests that mobile banking can increase financial services access exponentially.



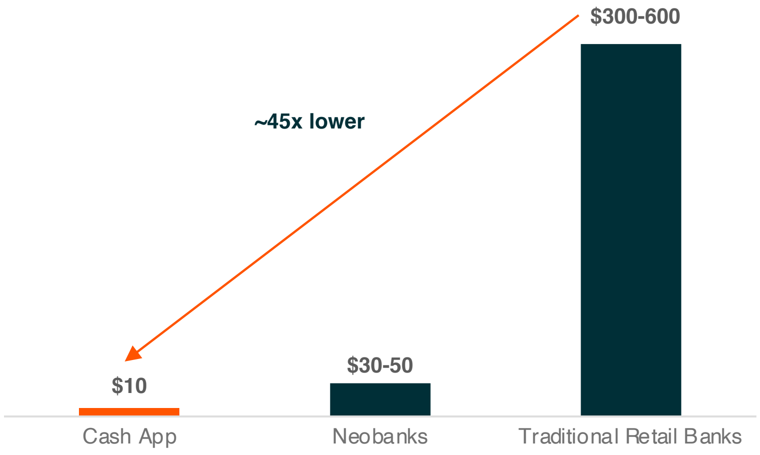
Sources: Visual (LHS): Kunt, Klapper, Singer, & Ansar, 2022; Visual (RHS): Ericsson, n.d. * Estimates

Mix of Digital Offerings Ensures Better Unit Economics Than Legacy Products

Fintech platforms can reach and onboard users at a much lower total acquisition cost than legacy financial institutions. As users increase, network effects strengthen, which helps bring costs down further.

FinTech platforms can acquire new users at a significantly lower acquisition cost than traditional financial players.

Per User Acquisition Cost for Cash App Compared to the Rest of the Industry ($)



FinTech platforms can expand quickly into adjacent products and increase their average revenue per user (ARPU).

Fintech Apps	Primary Offering	Additional Products
Cash App (Square)	P2P payments and wallet	**Consumer:** Debit card, Bitcoin trading, business banking, stock trading, lending. **SMB:** Loyalty, marketing, chat, banking, payroll
Venmo (PayPal)	P2P payments and wallet	Credit and debit card, crypto trading
Affirm	BNPL	Debit card, savings account
SoFi	Student debt refinancing	Checking and savings, credit card, investing suite, personal loans
Robinhood	Discount trading app	Debit card, cash management, crypto trading

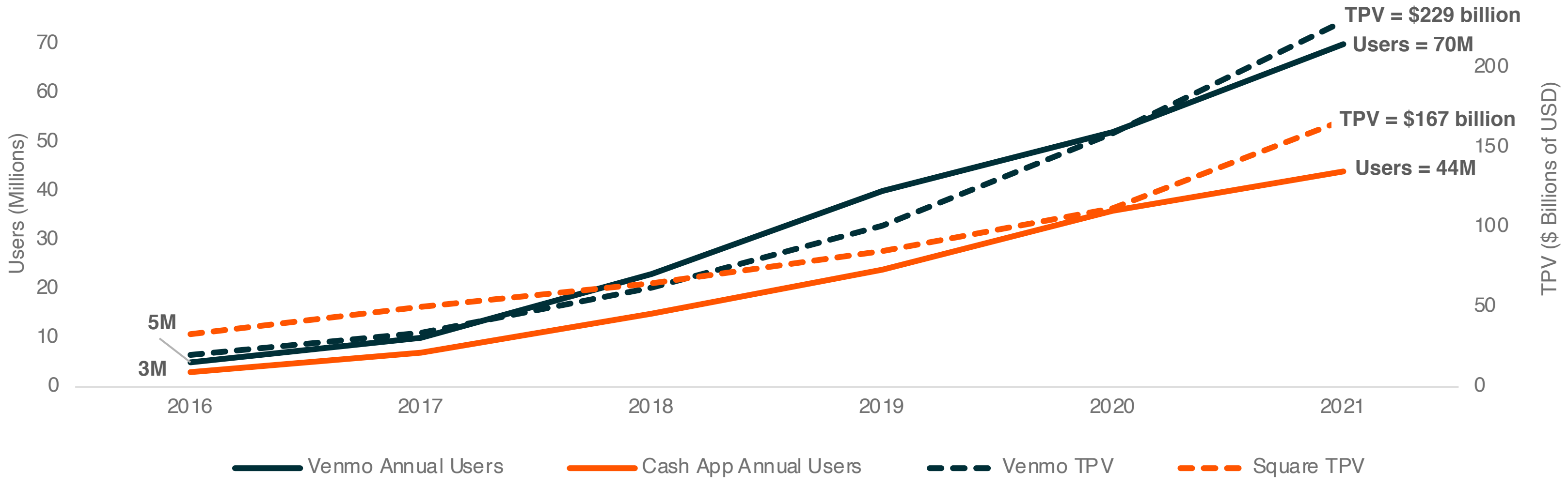
Sources: Visual (LHS): Cash App, 2022

Digital Payments Platforms Are Growing in Popularity as Newer Generations Choose Technology

Top digital wallets in the United States such as Cash App and Venmo grew their user base nearly 14x from 2016–2021, at a fraction of the cost of traditional banks. Embedded social features and network effects allowed for growth to multiply.

The convenience of Cash App and Venmo is a primary reason why their user base and payments volume have grown rapidly since inception.

Venmo and Cash App Annual Users, Total Payments Volume (TPV)



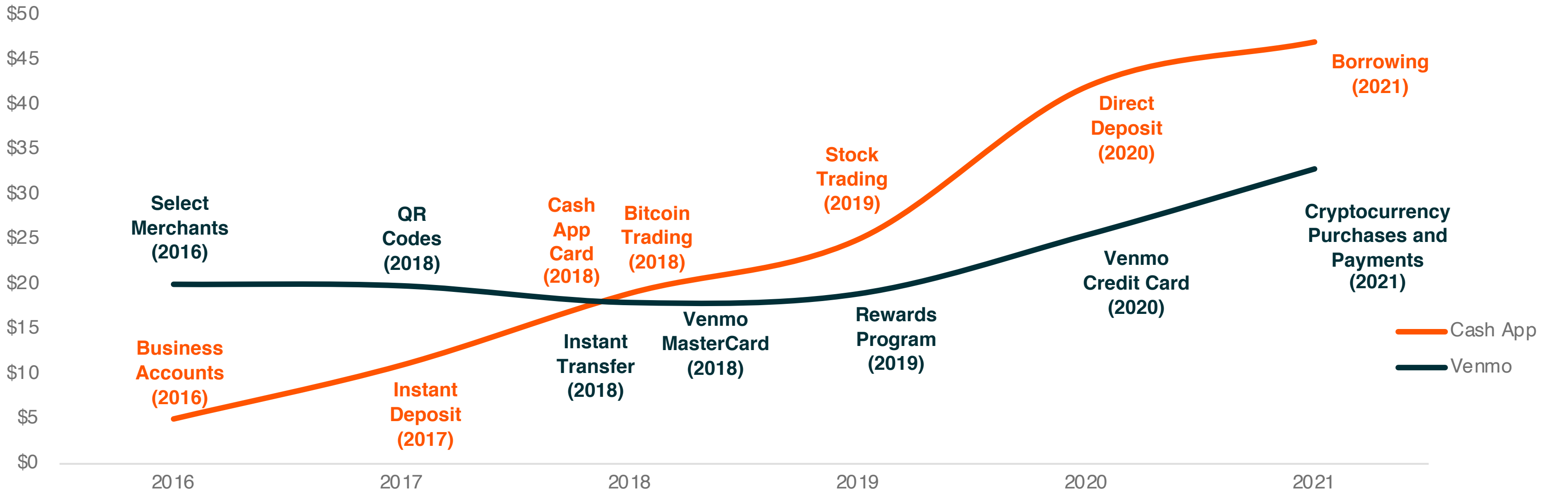
Sources: Curry, 2022a; Curry, 2022b

Wallet Platforms Routinely Expand Into Adjacent Verticals, Compounding the Addressable Market

Leading payment platforms such as Cash App and Venmo introduce new features incrementally to boost customer retention and profitability/revenue per user, resulting in better overall unit economics at scale.

New feature and product launches help increase gross profit per user for Cash App and average revenue per user for Venmo.

Cash App Gross Profit per User and Venmo Average Revenue per User Growth Over Time ($)



Sources: Curry, 2022a; Curry, 2022b; Cash App, 2022; PayPal, 2022

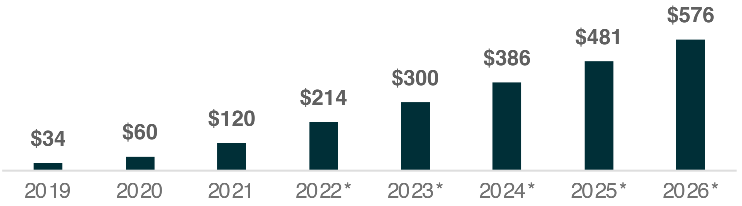
Note: Venmo ARPU calculated using scaled TPV divided by total userbase.

Digital Native Credit Is Disrupting the Legacy Lending Industry

Buy Now, Pay Later (BNPL) uses alternative consumer data such as transaction history, income, and payment history to power instant lending decisions on the internet without pulling credit history. Applications of the model extend far beyond consumer credit.

Buy Now, Pay Later's global transaction value reached $120 billion in 2021, growing 4x between 2019 and 2021.

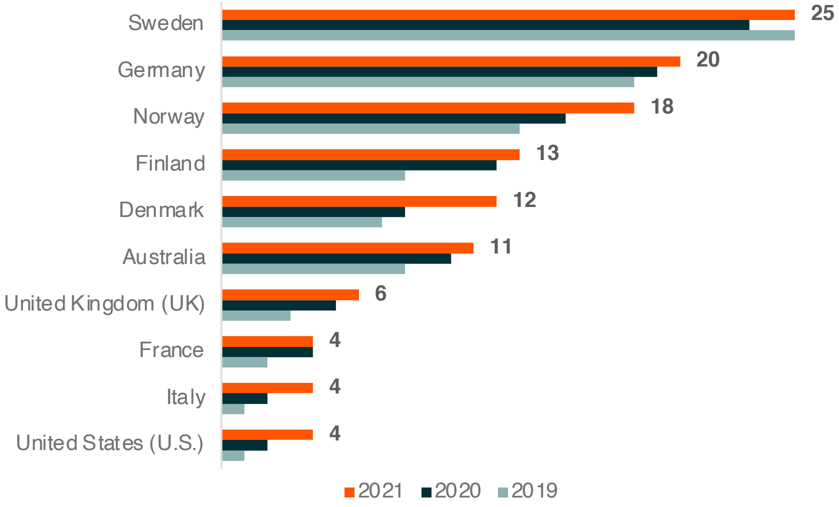
BNPL Global Transaction Value Forecast (in Billions of $USD)



**Indicates Forecast*

From 2019–2021, BNPL market share in domestic e-commerce payments showed meaningful growth in the 10 leading countries.

Leading BNPL Countries Market Share Growth From 2019–2021 (in %)



BNPL Goes Mainstream

Apple Pay Later integration into Apple Pay will bring significant attention to the BNPL market due to Apple's sizable consumer base.

Pureplay BNPL firms may look to offer card-based and account-to-account (A2A)-based payment methods to become increasingly competitive in the space.

BNPL use cases across regions vary significantly. For example, emerging markets with lower access to traditional credit systems can benefit from BNPL in ways that developed markets may not consider.

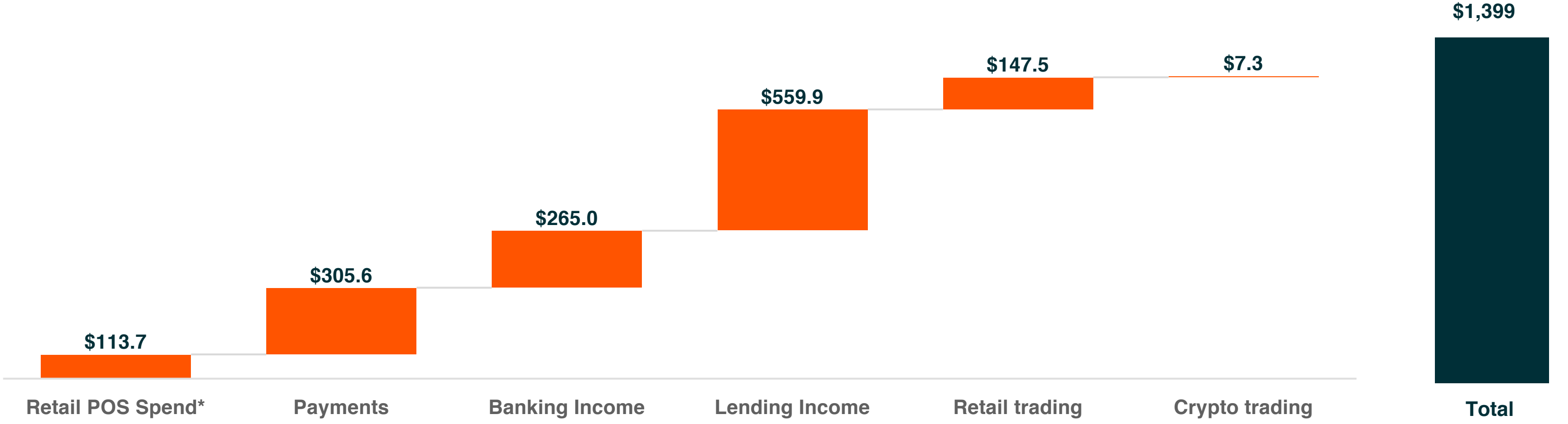
Sources: Visual (LHS): Global Data, 2022; Visual (RHS): FIS, 2022

Total Addressable Market for Fintech Platforms Is in the Trillions

FinTech platforms are expanding into adjacent areas to improve user stickiness and usage. In the process, they are multiplying their total addressable market and capturing a larger share of retail consumer spending.

Leading U.S. FinTech platforms could earn close to $1.4 trillion in commissions and fees by displacing legacy financial institutions in key verticals.

Total Addressable Market for U.S. FinTech by Categories (in $ Billions)



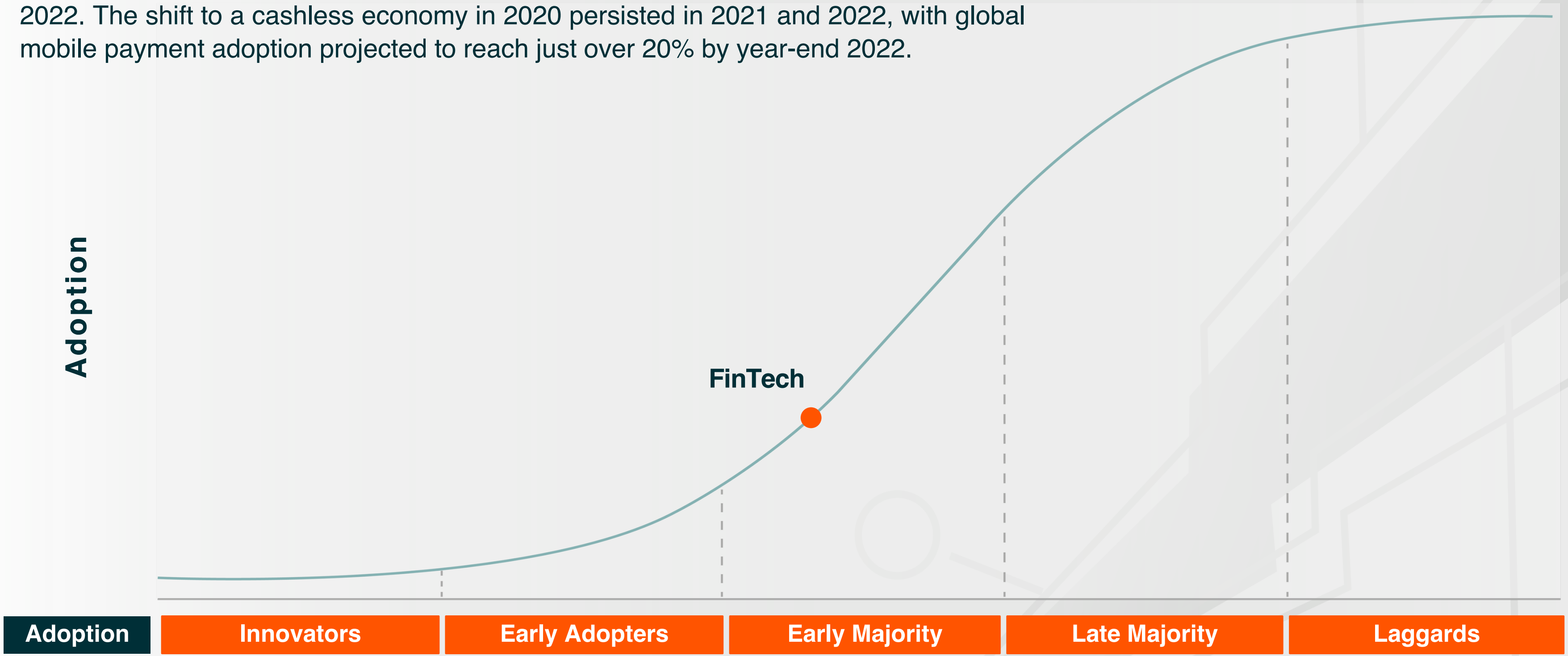
*Shows fees earned at the retail POS (online + offline) processors in the United States using 2021 data assuming an average 2.5% take rate.

Methodology: Total addressable market for U.S. fintech platforms calculated as a sum of total POS processing fees that FinTech platforms could address (via multiple products such as wallets, cards) and other basic banking, lending, investing functionalities that top platforms could end up displacing. Banking income is total non-interest annual income of U.S. banks. Lending income is total annual interest income earned by U.S. banks. FinTech platforms are most likely to compress take rates in all these markets, likely bringing fees charged and revenue earned down for the entire segment.

Sources: IBIS World, 2022; Khatri, 2021; Matthews, 2022; McKinsey & Company, 2021; Statista Research Department, 2021; Statista Research Department, 2022; Young, 2022

S-Shaped Curve of Adoption – Future of Money

FinTech continues to disrupt the way we transact and access financial services in 2022. The shift to a cashless economy in 2020 persisted in 2021 and 2022, with global mobile payment adoption projected to reach just over 20% by year-end 2022.



Displayed for illustrative purposes. Curve shape not indicative of mathematical transformation

Chapter 16

Blockchain

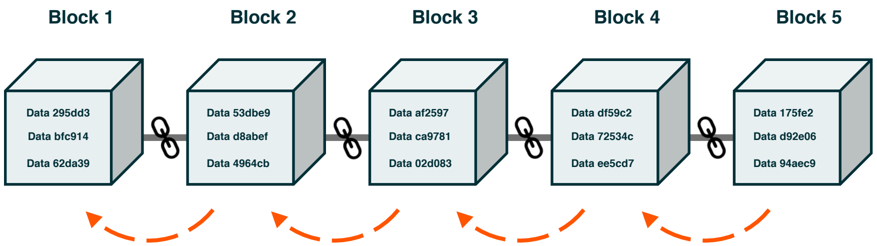
A blockchain is a unique type of database that is maintained and secured by a global network of participants in a trustless manner. This distributed design and blockchain’s unique approach to structuring and securing data allows traits such as scarcity to be embedded within digital assets. The implications of this technology are far-reaching. Blockchain technology is not only redefining existing industries but also propagating the rise of entirely new industries.

Blockchain: A Shared Database Distributed Across a Decentralized Network of Computers

As with any other database, the purpose of a blockchain is to store information digitally. However, a blockchain is a unique type of database that can be viewed, accessed, and updated by anyone within its distributed network. Most importantly, blockchains provide data accuracy and security while minimizing trust needs, removing the need for intermediaries.

A Blockchain: Visualized

In a blockchain, data is aggregated into "blocks" that are linked together with prior "blocks" to form a chain, hence the name "blockchain." The chain grows with the addition of each new block.



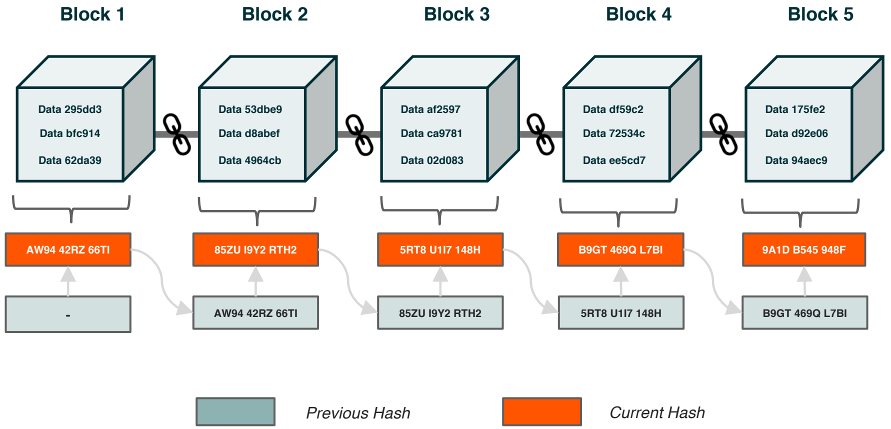
Advantages of Blockchain Technology

- Strong Security Characteristics
- Greater Data Transparency
- Instantaneous Traceability
- Pseudonymity & Privacy
- Increased Efficiency & Adaptability
- Decentralization

Blocks Remain Secured via Cryptographic Hash Functions

A hash is a unique identifier that represents a block in an encrypted format. A hash is based on numerous inputs including the data content of the block and the hash of the previous block in the chain. Hashing algorithms allow network participants to identify the correct network state.

The Hash Is a Unique Block Identifier



Fostering Network Security

A blockchain's hashing mechanism ensures that even the smallest change to historical data is immediately perceptible to all network participants or nodes.

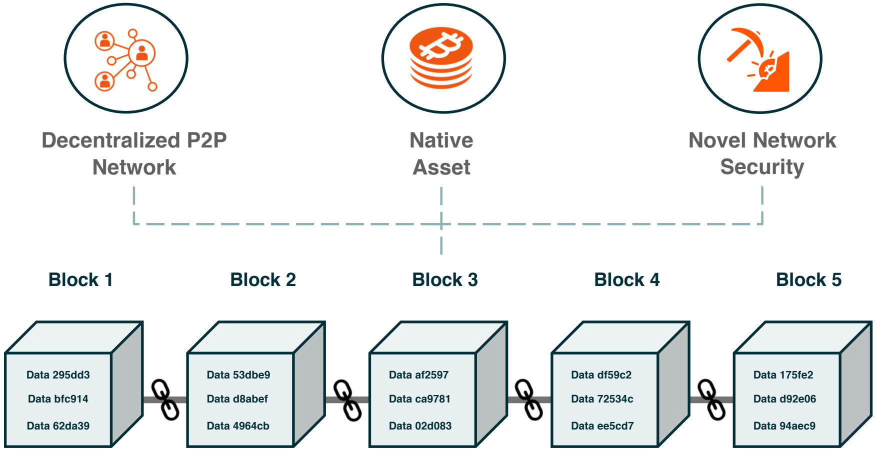
To successfully alter historical data, a participant would need to recalculate updated hash functions for every preceding block up to the present state, all while the chain continues to be propagated by the rest of the network.

The number of resources necessary to accomplish this on a major blockchain makes altering historical data economically unfeasible.

Bitcoin: The First Successful Decentralized Blockchain Application

Bitcoin, the first successful implementation of a digitally native currency. Leveraging the security, immutability, and tamper-resistant qualities of a blockchain, the Bitcoin network facilitates the storage and peer-to-peer transfer of bitcoin (BTC) across a decentralized network. BTC is divisible, fungible, and easily transferable with a programmatically defined monetary policy that ensures its scarcity.

Confluence of a Blockchain with a Native Asset and Novel Security Mechanism



Bitcoin: The Fundamentals

Decentralized Peer-to-Peer Network

The first successful application of a global, transparent, distributed, and decentralized peer-to-peer payment network.

Digitally-Native Asset with a Scarce Supply

Immutable code guarantees that bitcoin's supply will never exceed 21 million coins.

A Robust Security Mechanism

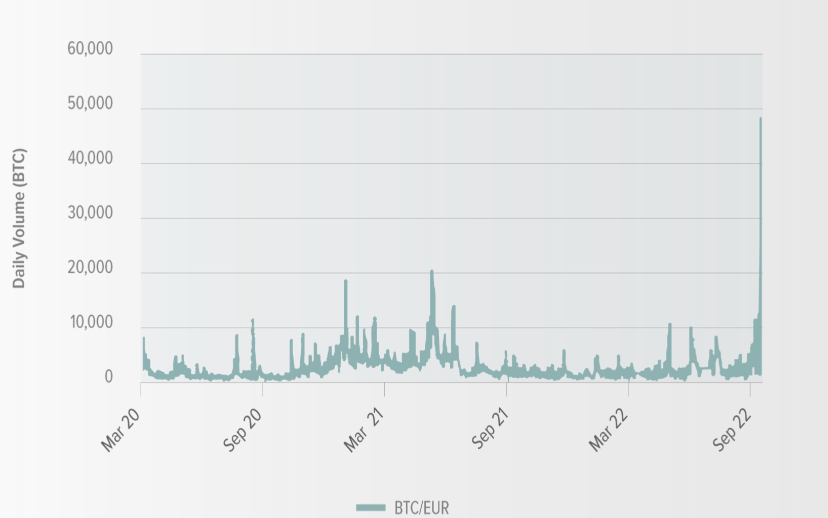
Today, the Bitcoin network operates under Proof-of-Work (PoW) for network security.

Bitcoin's Use as a Currency Volatility Hedge

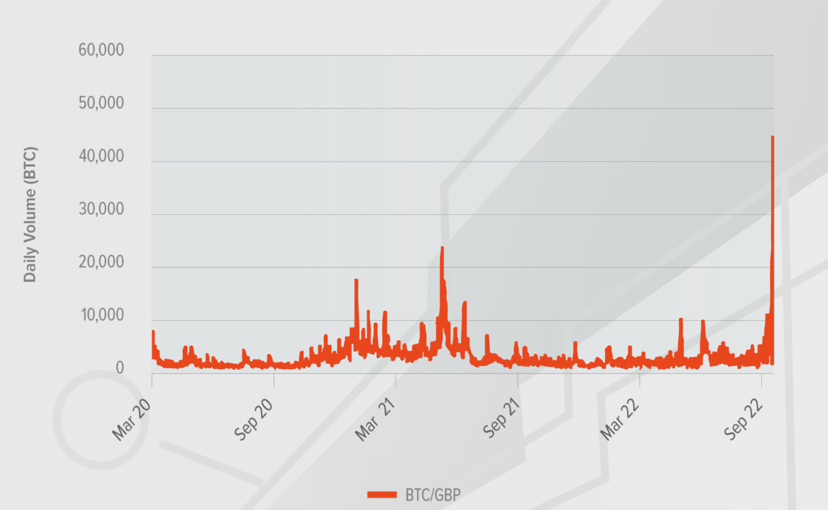
Ryan Selkis

Some investors are starting to think of Bitcoin as a potential risk-off asset. Recently, euro and pound investors traded local currency for BTC in record numbers.

Daily BTC/EUR Trading Volume



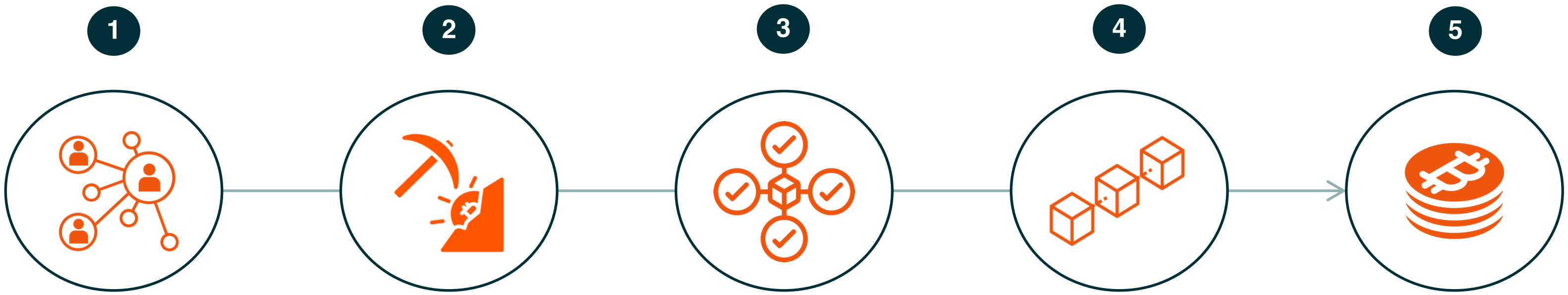
Daily BTC/GBP Trading Volume



Sources: Kaiko Data, n.d.; Messari, n.d.

Bitcoin Mining: The Process Explained

Bitcoin mining is the process of securing the Bitcoin network and recording new blocks of transactions by way of brute-force computation, also referred to as Proof-of-Work (PoW). The process requires advanced hardware and significant amounts of energy. All Bitcoin nodes verify transactions, but mining nodes aggregate transactions into the “blocks” recorded onto the “chain.”



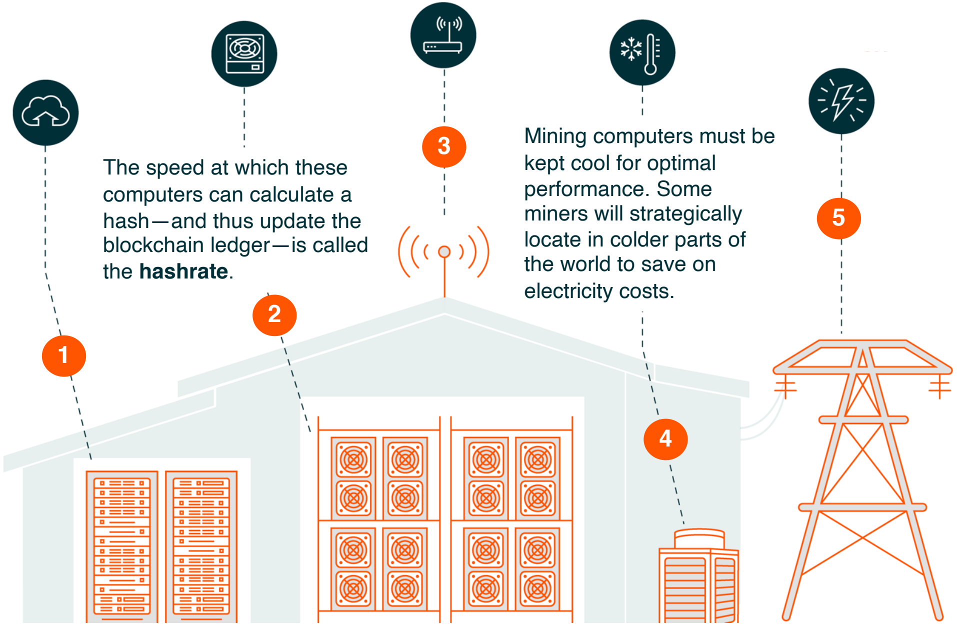
1. New transactions are sent continuously between network nodes and are stored as pending transactions until they settle on the blockchain.
2. Mining nodes compete to “solve” new blocks, earning them the right to include pending transactions in the block. With PoW, miners use special computers to find an arbitrary number that unlocks the block.
3. After a miner finds the solution, the block and its component transactions are transmitted and verified by the network.
4. The new block of verified transactions is attached to a chain of prior blocks. A new block is added every 10 minutes on average.
5. For their efforts, miners are rewarded with bitcoin (6.25 BTC) and transaction fees paid by network users.

Bitcoin Mining: The Components of Today's Proof-of-Work Infrastructure

The bitcoin mining space has evolved into a competitive field with complex infrastructure requiring capital investments in hardware, software, and energy.

The Anatomy of a Bitcoin Miner

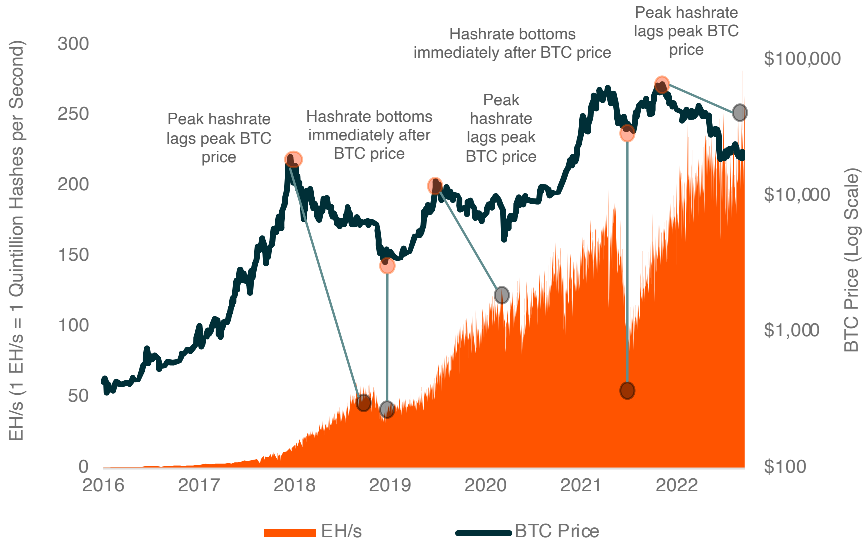
1. **Network Infrastructure**
   Computers must be connected to the Bitcoin Core software.
2. **Special Computers (Mining Nodes)**
   Miners require expensive, specialized, and in-demand Application Specific Integrated Circuits (ASICs).
3. **Internet Connectivity**
   Access to updated network state requires internet connectivity.
4. **HVAC (Temperature Control)**
   ASIC devices require temperature control and cooling infrastructure.
5. **Electricity Availability**
   Miners require significant sources of energy to fuel their operations.



Energy Is the Commodity Securing the Bitcoin Network

The purpose of Proof-of-Work's energy requirement is to impose financial costs on miners. The costs serve as a powerful economic incentive to ensure miners only confirm valid transactions. Proposing a valid hash function allows miners to offset electricity costs with the block reward. Proposing an invalid hash function results in electricity expenditure with no offsetting block reward.

Hashrate and Electricity Consumption Is Reactionary to BTC Price



Sources: Glassnode, n.d.-a; Glassnode, n.d.-b

The Role of Electricity in PoW Mining

Is the network's electricity consumption correlated with bitcoin's price?

Yes. Because block rewards are denominated in BTC, price appreciation of BTC increases revenue for miners when denominated in a fiat currency, holding all else equal. The growth of incremental revenue generated from a fixed level of computing power incentivizes new entrants to join the market and existing miners to expand their operations. The opposite holds true as the price of BTC depreciates. The result is a hashrate, an indicator of electricity consumption of the Bitcoin network, that is reactionary to the price of BTC.

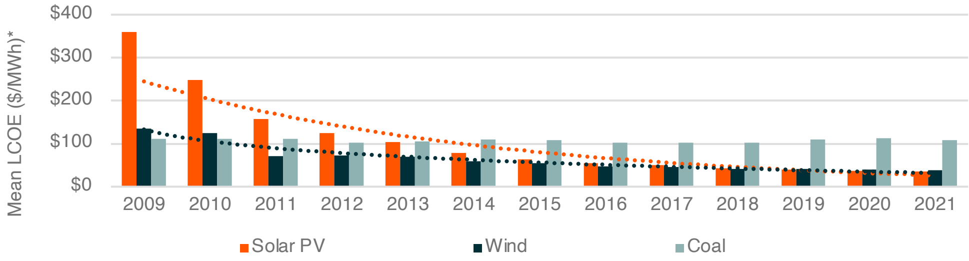
How does hashrate respond to BTC price appreciation vs. depreciation?

Hashrate responds to BTC price appreciation on a lag. This lag is due to the time needed to purchase and operationalize mining-specific hardware and infrastructure. The hashrate responds to BTC price depreciation immediately. Once the cost of electricity becomes greater than the value of block rewards, miners can simply unplug their hardware to cease unprofitable operations.

Structural Incentives of Bitcoin Mining Align with Green Energy Adoption Trends

Enterprise-scale bitcoin miners seek to maximize energy efficiency and minimize electricity costs. As electricity generated from renewable sources becomes increasingly cost-competitive, the industry's embrace of green energy will be inevitable.

Lower Costs Make Renewables Increasingly Attractive for Bitcoin Miners



Large Miners Riding the Renewable Wave

Company	Location	Mining Rigs	MW of Renewable Power	Electricity Source
Argo Blockchain	Texas	55,000	200 MW	Wind & Solar
Marathon Digital	Texas	100,000	280 MW	Wind
Genesis Digital	Texas	Unknown	120+ MW	Wind & Solar

How Do Bitcoin Miners Generate Profit?

- **Revenues:** Denominated in BTC. Earned in exchange for validating transactions and securing the Bitcoin network. Roughly proportional to a miner's share of the network's hashrate—the total computing power of the network.
- **Expenses:** Predominantly related to the procurement of hardware ("mining rigs"), utilization of electricity, and operations.
- **Profit Margins:** Grown by maximizing hashrate and minimizing electricity expense.

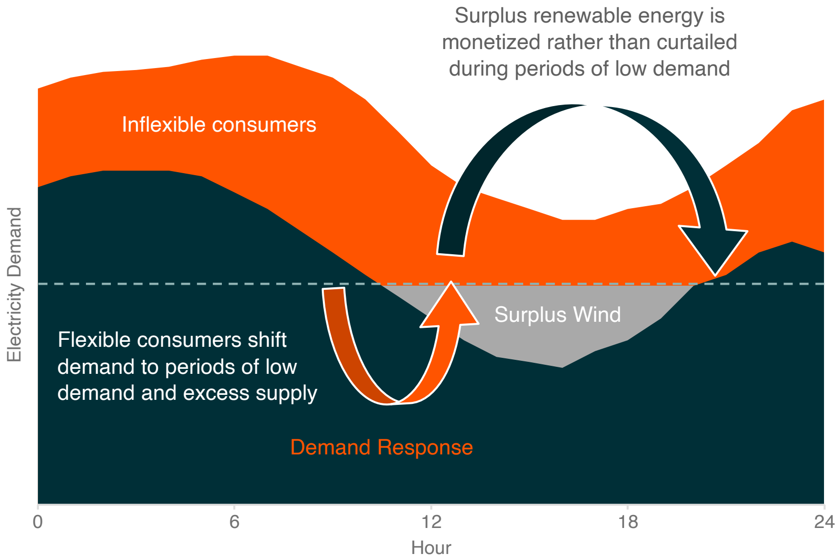
*Levelized Cost of Electricity (LCOE) represents the average revenue per unit of electricity generated required to recoup the cost of constructing and operating a utility-scale power plant over the course of a given life cycle. Commonly cited metric in comparisons of relative competitiveness of various types of power plants.

Sources: Ashraf, 2022; Marathon Digital Holdings, 2021; Ramirez, 2022; Ray & Douglas, 2021

Bitcoin Miners Support Integration of Renewable Energy to the Grid

Demand response programs allow bitcoin miners to monetize renewable energy by providing flexible load management to the grid and serving as a “consumer of last resort” of otherwise-curtailed green energy.

Miners Act as an Ideal Flexible Load Manager



Source: Denholm, 2016

Demand Response

Problem: The variability of renewable energy means that thermal plants cannot reduce production to meet demand. With load met by fossil fuel generation, excess renewable energy is regularly curtailed leading to higher costs.

Solution: Flexible consumers willing to reduce consumption of electricity during peak demand and shift consumption to periods of excess supply.

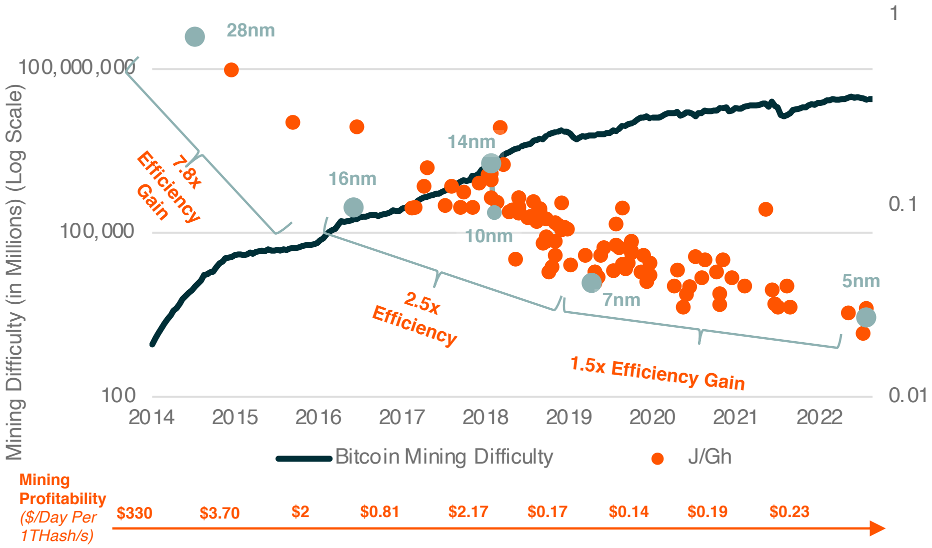
How Do Incentives Align?

- Electric utility companies provide miners with discounts, rebates, and other financial incentives in exchange for curtailing energy use during periods of high demand.
- Flexible energy users support the grid’s load management efforts. As load peaks, the grid can free up reserves by shutting off electricity otherwise consumed by miners.
- Flexible load management monetizes renewable energy by reducing curtailment. When load is low but supply of renewable electricity is plentiful, excess energy is transmitted to participants willing to increase their electricity consumption rather than unloading it from the grid.

ASIC Manufacturers Drive Energy Efficiency

As the benefits from advances in silicon become increasingly marginal, ASIC manufacturers will need to refocus their efforts towards alternative energy-saving technologies and strategic partnerships supporting renewable energy mining.

Advancements in Mining Hardware Reduce Over Time



Sources: ASCI Miner Value; Bit Info Charts, n.d.; CBECI, 2022; Deutsch, 2022; Lu, 2022

Strategy Repositioning Ahead

Today's Application Specific Integrated Circuits (ASICs) are roughly 36x as energy efficient as their 2014 counterparts. Shrinking chips drove the gains and attracted billions of dollars of annual revenue from industrial miners seeking to maximize profit margins.

With the mining industry's demand for the most advanced hardware set to remain high, ASIC manufacturers will continue to optimize their products to maximize hashpower performance and minimize energy consumption.

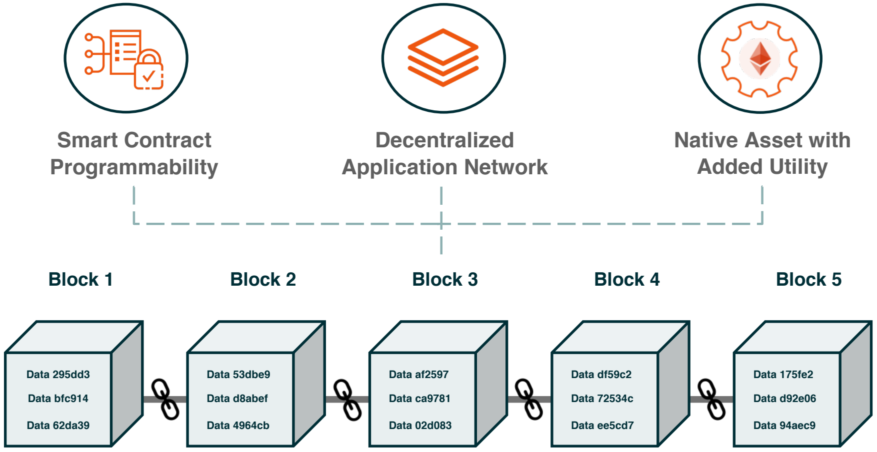
As efficiency gains from advances in silicon become increasingly marginal, however, ASIC manufacturers will need to identify new sources of competitive advantage to maximize performance, including:

- **Non-Silicon Hardware Optimization:** Heat dissipation technology including immersion and air-cooling systems.
- **Strategic Partnerships:** Collaborations with solar and wind farms seeking to vertically integrate bitcoin mining into operations.
- **Service-Based Offerings:** Worldwide service centers providing white-glove support to remotely-located mining operations utilizing trapped renewable energy.

Ethereum: A Smart Revolution in Blockchain Utility

Ethereum expanded on Bitcoin's innovative use of blockchain technology by creating a platform capable of storing and executing computer code on the blockchain, powered by Ethereum's native asset, Ether (ETH). This innovation introduced the concept of smart contracts and laid the foundation for decentralized applications (dapps).

The Programmability of Smart Contracts Allows for Expanded Utility



Ethereum: The Fundamentals

A General Computing Blockchain

Introduced embedded logic and advanced functionality beyond simple payments, allowing for the creation of smart contracts.

Smart Contracts Create an Ecosystem of Dapps

Smart contracts allow for the creation of programmable dapps and utility with varied use cases and rules.

ETH Powers and Connects the Network

ETH can be used as a currency to transfer value across the network, but it also acts as a commodity consuming block space on the Ethereum network.

Smart Contracts Are the Fundamental Building Blocks for Decentralized Applications

Smart contracts are programs that automate the execution of an agreement once stated conditions are met. Instead of relying on input from a trusted intermediary, the rules and conditions embedded in smart contract code dictate how they run. Any dapp can deploy a smart contract and leverage the benefits.

Smart Contract Use Cases

Smart contracts can do essentially anything that other computer programs do, which led to the wave of novel applications built on top of smart contract blockchains.

- DeFi Dapps
- Token Creation
- On-Chain Gaming
- Insurance
- Enterprise Systems
- Supply Chain
- Authorization & Identity
- Conditioned Transfers

Key Smart Contract Features

- **Dapp Creation:** Smart contract functionality provides dapps with application logic.
- **Data Storage:** Dapps use blockchains to store records securely.
- **Enhanced Security:** The code lives within the immutable ledger distributed across the entire network, eliminating any single point of failure.
- **Trustless Reliability:** The code executes as written.
- **Cost Efficiency:** Fees are lower because no intermediaries are involved.
- **Speed:** Transaction finality is almost instant, depending on the specific block times and rules of the blockchain being used.

New Smart Contract Blockchains Rise, Offering Novel Architectures

Ethereum (ETH)
Market Cap $165 billion
Ethereum is the largest decentralized computing platform for decentralized applications (dapps).

BNB Chain (BNB)
Market Cap $49 billion
BNB Chain is the native smart contract chain from Binance, offering great scalability.

Solana (SOL)
Market Cap $12 billion
Solana is a smart contract blockchain that optimizes for scalability and high throughput.

Polkadot (DOT)
Market Cap $7.5 billion
Polkadot is a smart contract blockchain that supports various interoperable chains.

Avalanche (AVAX)
Market Cap $5.1 billion
Avalanche aims to increase scalability and security without compromising decentralization.

Cosmos Hub (ATOM)
Market Cap $3.8 billion
The Cosmos network allows for interoperable blockchains and features a strong software stack.

Sources: CoinGecko, n.d.; Messari.io, n.d.

Smart Contract Blockchains Enable a New Web Stack

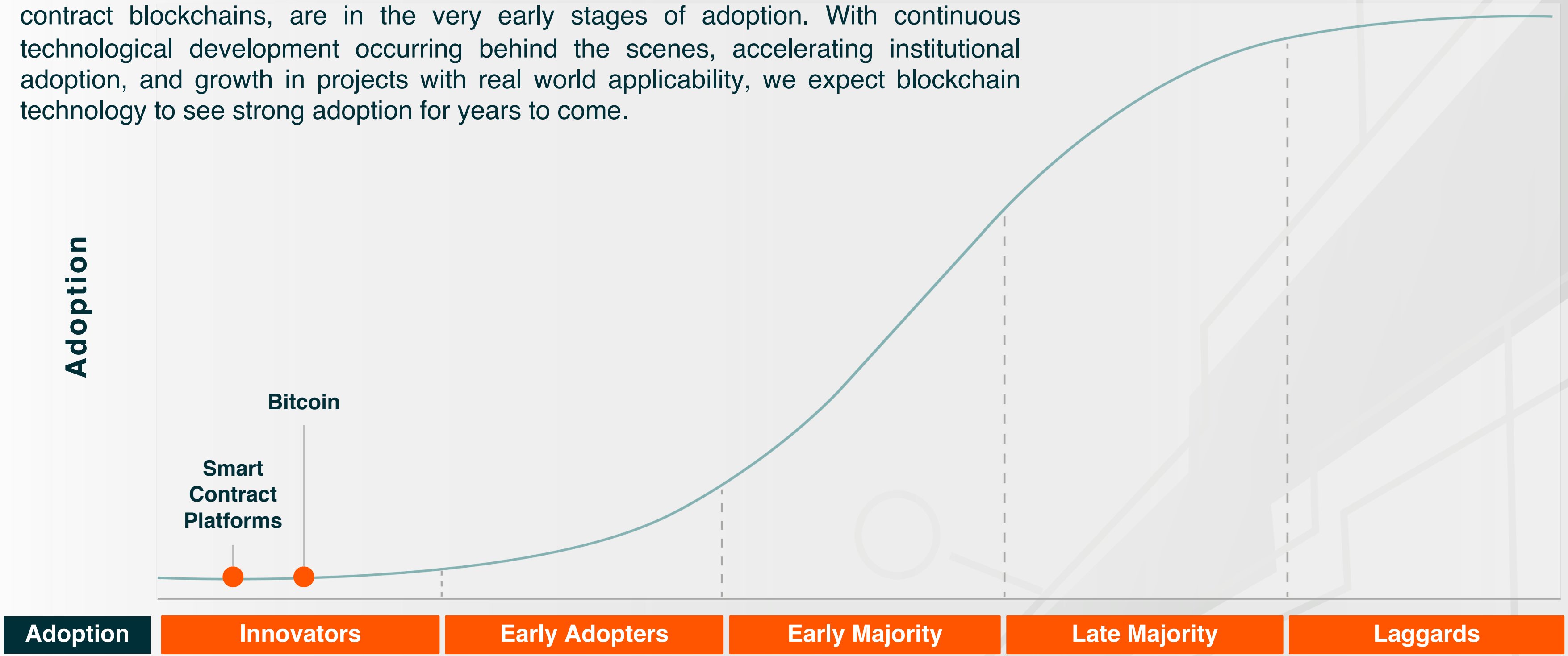
The rise of smart contract blockchains has catalyzed the development of a new software stack that provides users with the tools to harness the potential of these general-purpose computing platforms.

Web3 Value ($) Generation Accrual Starts with the App Layer

5 Identity Processing & User Interaction	**Wallets:** Metamask, Ledger; **Domains:** ENS, Unstoppable, Handshake; **Decentralized Identifier (DID) Processing Platforms**	The interfaces connecting users with dapps.
4 Application Layer	**DeFi:** Aave, Uniswap, Maker, Lido; **Gaming:** Illuvium, Gala Games; **NFTs:** BAYC; **Social:** Lens; **Other:** Nexus	The value enabler of smart contract platforms (the Web3 experience).
3 Infrastructure/ Middleware Layer	**Oracles:** Chainlink, UMA; **Indexing & Queries:** The Graph, Covalent; **Storage:** Arweave, Filecoin, Ocean; **Tooling & Enablers:** Brave, Helium	The building blocks supporting blockchain functionality and utility.
2 Data Access & Interaction Layer	**Block Explorers:** Etherscan, SnowTrace, BscScan; **Development:** Hardhat, Alchemy; **Clients & SDKs:** mev-geth, Cosmos SDK; **Node Services:** Infura, Pocket	Allows for interpretation and data extraction from the blockchain, data to be accessed, verified, and utilized.
1 Composable Blockchains	**Smart Contract Blockchains:** Ethereum, Solana, Avalanche, Polkadot, Cosmos, BNB Chain, Cardano, Fantom, Near	The general-purpose architecture hosting rules, execution layers, consensus mechanisms, and computing software.

S-Shaped Curve of Adoption – Blockchain

Blockchain technology, including use cases like the Bitcoin network and smart contract blockchains, are in the very early stages of adoption. With continuous technological development occurring behind the scenes, accelerating institutional adoption, and growth in projects with real world applicability, we expect blockchain technology to see strong adoption for years to come.



Displayed for illustrative purposes. Curve shape not indicative of mathematical transformation

Chapter 17

Web3

Web3 is a paradigm shift in how the web is structured. Through permissionless and decentralized applications powered by smart contract computing platforms, blockchain innovation is redefining how we interact with the digital world.

Momentum Continues to Build Despite Price Action

Ryan Selkis

Talent
1000s of Hires

Capital
$10s of Billions

Generation Change

Bitcoin
Legal tender for emerging economies

Stablecoins
Settlement volumes rivaling incumbents

VISA

Computing
Web3 computing protocols re-decentralize the internet

DeFi
DeFi market capitalization is less than 1% of banks

NFTs
NFTs offer 10x creator incentives and user IP rights

DAOs
DAOs can scale entities at internet speed

ConstitutionDAO

Bit

Long-Term Success

These innovations will not be "uninvented."

Sources: Federal Reserve Economic Data, n.d.; Messari, n.d.

The Evolution of the Web

Read
(1990–2005)

Open-source and neutral internet protocols. Creators owned the content they produced and were able to reach audiences directly and reliably.

Web1 offered limited interactivity, as web pages were static and text-based. Its content lacked diversity, as content-creation required expertise in web development.

Read, Write
(2005–Present)

Closed-source web governed by proprietary algorithms of dominant companies featuring improved and interactive web pages and applications.

While these advancements led to exponential growth in user-generated content, publication is subject to the rules and policies of corporate entities.

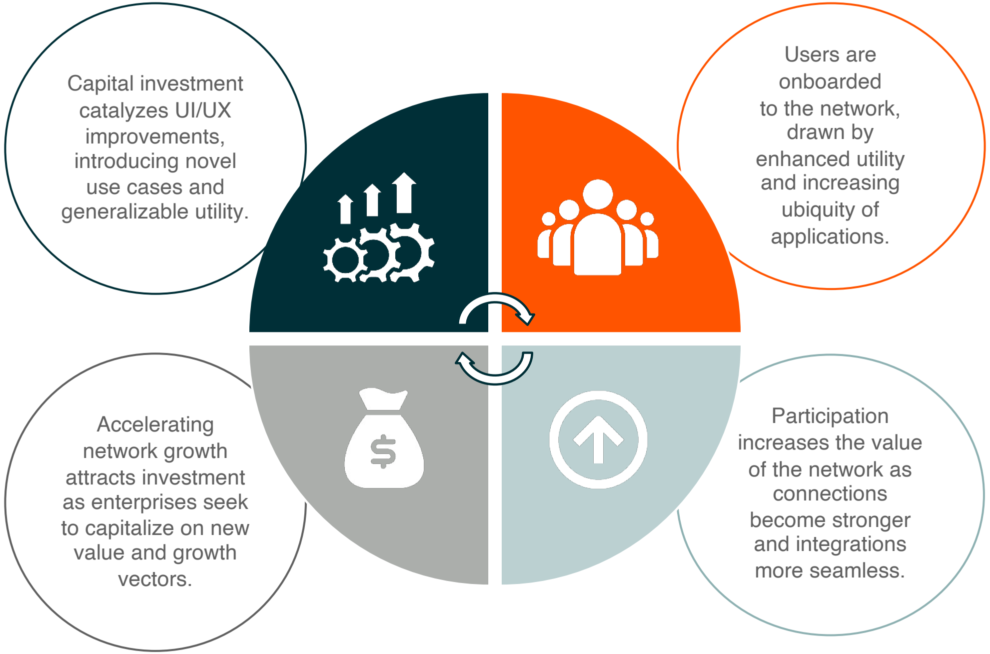
Read, Write, Own
(2015–)

Open-source, neutral, and decentralized protocols featuring dynamic applications hosted on smart contract blockchains.

Web3 combines the neutrality, reliability, and disintermediation of Web1 with the advanced functionalities, interfaces, and democratization of content publication of Web2.

The Internet vs. Web3: Network Effects Set in Motion as Innovation Accelerates

As innovations across Web3 hardware and software stacks accelerate, evidence suggests a positive feedback loop between application development, user adoption, and investment has been set in motion.

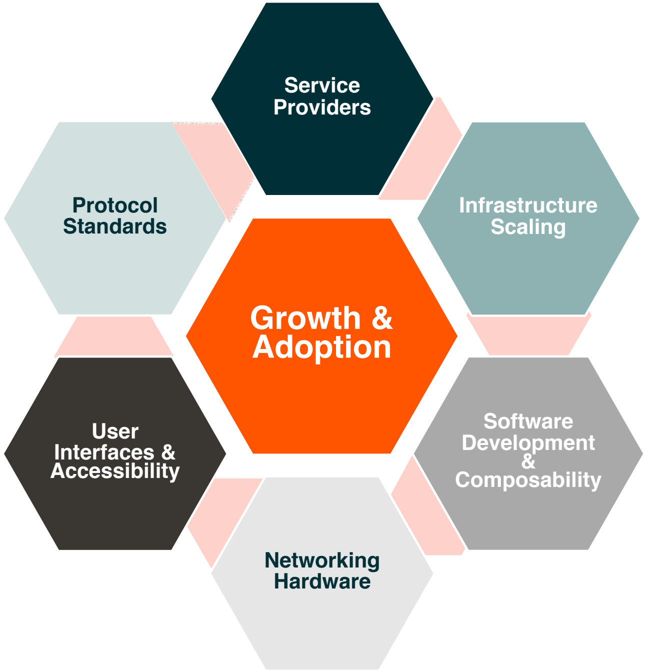


Hardware and Software Work Together to Drive User Adoption

- The internet and Web3 are base layers on top of which data and information are accessed and enabled. As the foundations of global networks, their value is derived from their utility.
- The utility of the internet has been enabled by a positive feedback loop inspiring continuous innovations in hardware and software.
- As the base layer to a decentralized computing network, Web3 exhibits many structural similarities to the internet. We believe these structural characteristics predispose Web3 to the same synergistic relationships between hardware and software innovation.
- If this turns out to be the case, our base forecast is for Web3 to gain Internet-scale mass adoption over the next few decades.

Collaborative Buildings Blocks Build the Web Infrastructure & Trigger Adoption

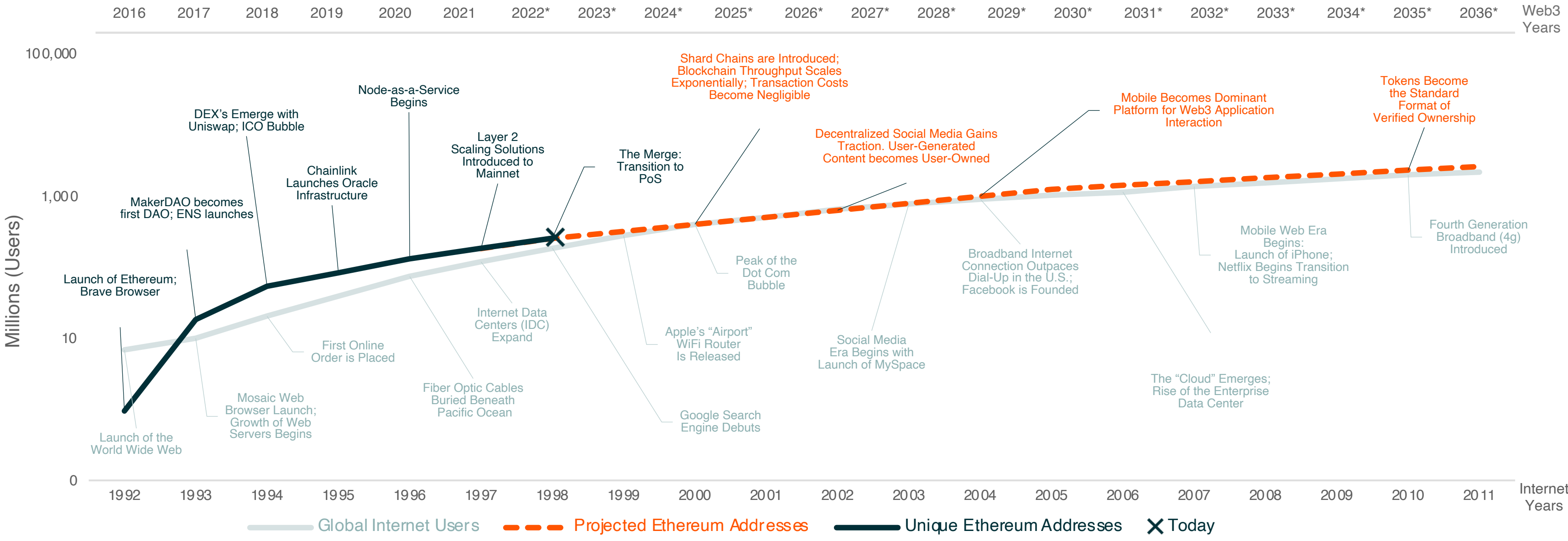
The building blocks that supported the rapid expansion of the internet are comparable to those supporting the growth of Web3.



	Internet	Web3
Protocol Standards	TCP/IP, HTML, HTTP, SMTP, RPC	Computation Standards (Ethereum Virtual Machine), Token Standards (ERC-20, ERC-721), EIP-1559, EIP 4844, Inter-blockchain Communication Protocol (IBC)
User Interfaces & Accessibility	World Wide Web, Web Browsers, Search Engines, Email	Dapp Front-Ends, Browser Extension Wallets, Web3 Native Browsers, Aggregators
Networking Hardware	Web Servers, Data Centers, Wi-Fi Routers, PCs, Cell Phones	Hardware Wallets, ASICs, Validator Nodes
Software Development	JavaScript, APIs, SDKs	Solidity, Rust, Smart Contracts, Money Legos, Clients, Infrastructure-as-a-Service
Infrastructure Scaling	Fiberoptic Cable, Cloud	Sharding, Layer 2 Solutions, Node-as-a-Service
Service Providers	Internet Service Providers (ISPs), DNS	ENS Domains, Centralized Exchanges, On-ramps, Oracles, Decentralized Cloud Services

The Internet vs. Web3: Similar Adoption Trajectories Expected

Since the launch of Ethereum, the leading smart contract blockchain, innovation within industry-specific hardware and software has supported accelerating adoption of the network. If this self-reinforcing feedback loop continues, the expectation is for Web3's adoption trend to closely follow that of the internet and to become a global and ubiquitous ecosystem in the decades to come.

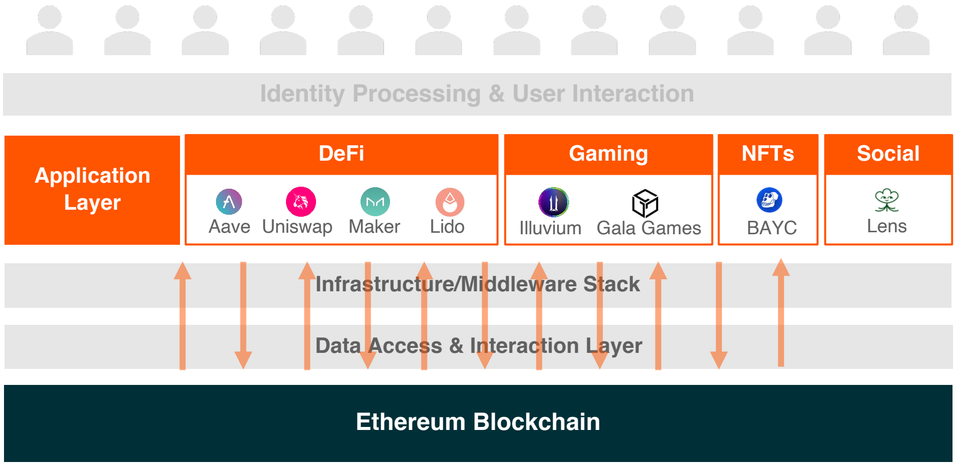


Sources: Etherscan, n.d.; International Telecommunication Union, n.d.; The World Bank Group, n.d. * Estimates

ETH: A Powerful Asset Fueling the Web3 Economy

Interacting with decentralized applications requires a small fee for the transaction to be recorded on a blockchain. On the Ethereum network, these fees are paid in Ether (ETH). Because demand for ETH is intrinsically linked to activity on the network and the supply of ETH is algorithmically-limited, ETH has emerged as a unique and valuable digital commodity.

ETH Is Needed to Power the Largest Dapp Ecosystem Today



ETH Has a Strong Value Proposition as a Novel Form of Digital Money

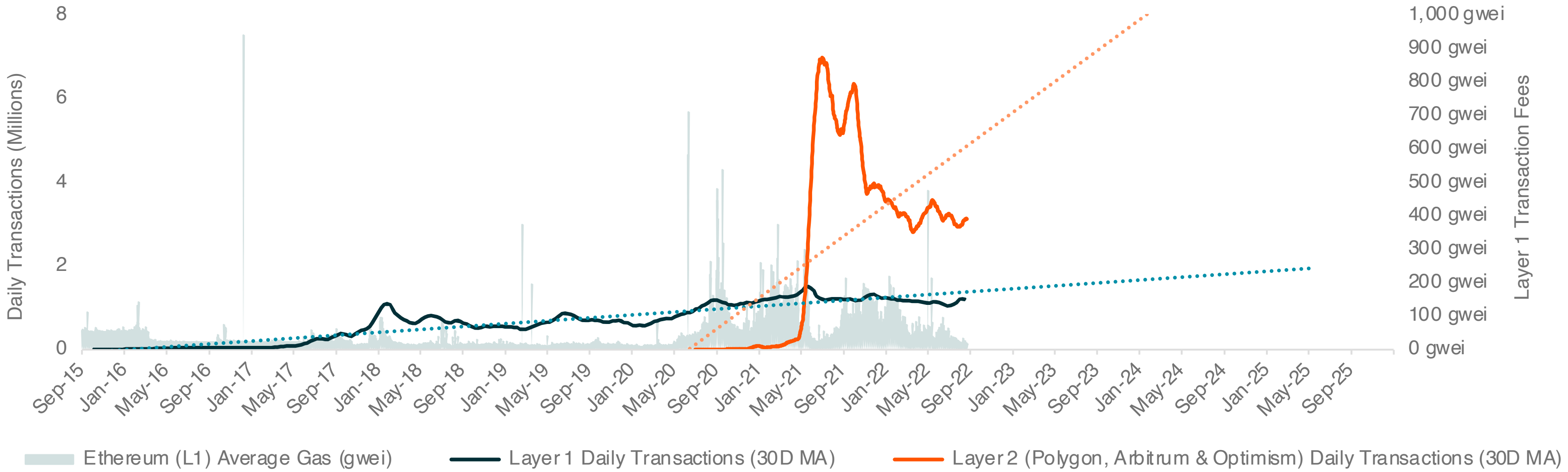
Strong forms of money act as a functional store of value, a unit of account with an ecosystem that depends on its utility, and as a medium of exchange that is widely trusted. Ether checks all these boxes and expands on them:

- A unit of account and a medium of exchange within its digital economy.
- A store of value asset due to the unique mechanisms that govern its supply and demand.
- A multi-functional asset with native yield-generating properties.

A Medium of Exchange Powering the Web3 Movement

ETH is in the early stages of adoption as the native medium of exchange for the decentralized web. Layer 2 scaling solutions, increasing application support, and technological developments are reducing the cost of transacting on-chain. As these advancements accelerate, we expect Ethereum to host tens of millions of daily transactions, using ETH as payment for settlement.

ETH Is Used in Multiple Layers of Applications Within the Ethereum Ecosystem and Powers All Transactions

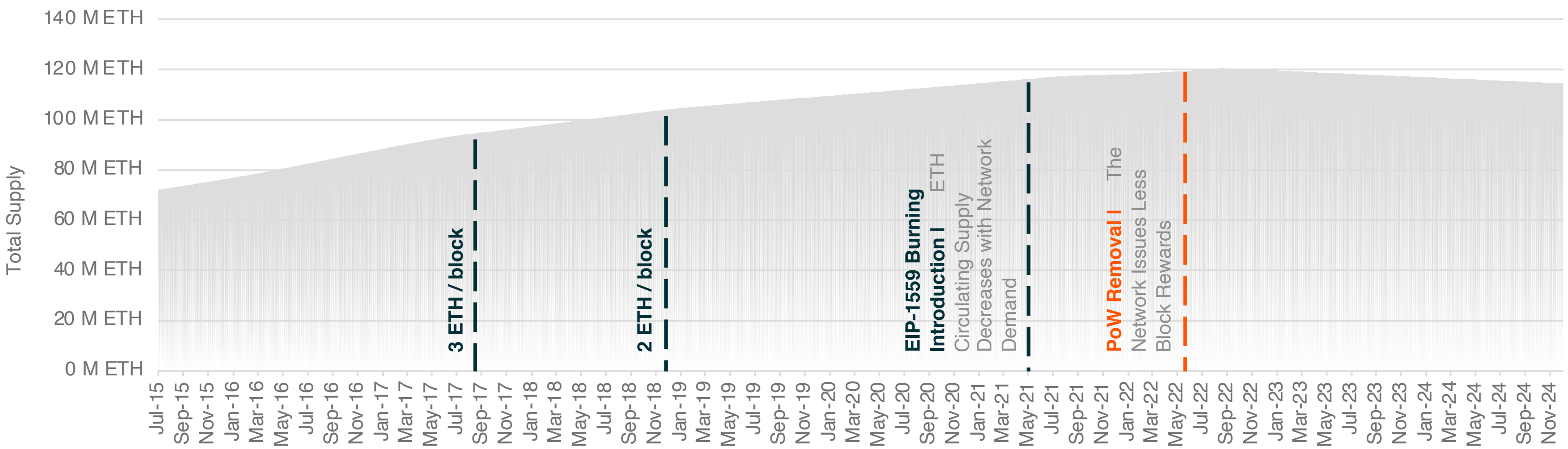


Sources: Arbiscan, n.d.; Etherscan, n.d.; Optimism, n.d.; Polygon Scan, n.d.

ETH Features Strong Store of Value Characteristics

The Ethereum network elegantly balances supply of new tokens with demand to interact with the network. The result is that net new ETH issuance has the potential to remain unchanged or even become deflationary over long time horizons.

Less Supply Due to Proof-of-Stake Consensus and a "Buyback" Mechanism That Burns a Percent of the Circulating Supply



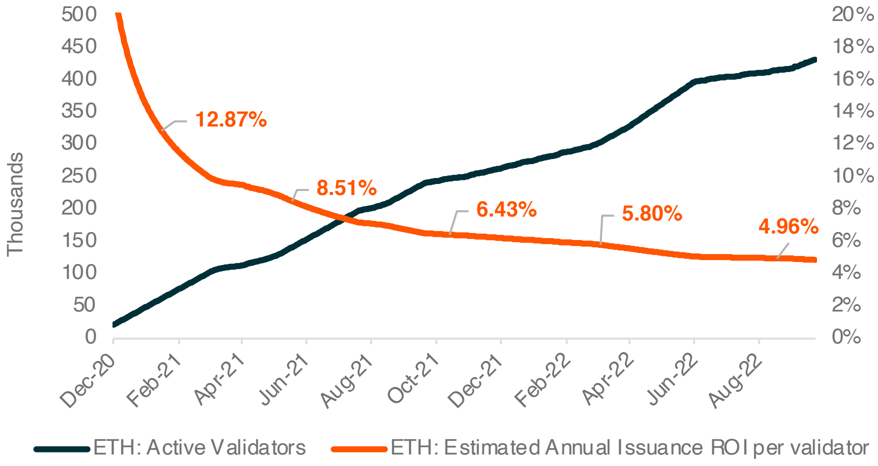
The study above assumes a beacon Chain staking amount of 14M ETH, which represents an issuance of 1.7k ETH per day. Additionally, the study assumes a 2-year average of 90 gwei (gas), which is estimated to burn approximately 9k ETH per day. The final assumption is Ethereum conducts its merge to the PoS Beacon Chain on September 15th, 2022.

Sources: Global X analysis with data derived from Ethescan, n.d.; Ultra Sound Money, n.d.; Mansour, n.d.

Novel Economic Utility by Having Liquid Yield-Generating Traits

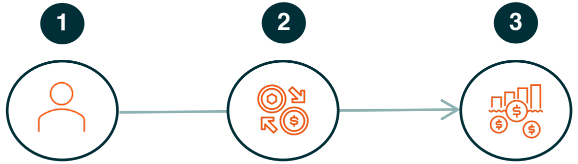
ETH is a highly efficient monetary asset. While ETH can generate yield in decentralized finance (DeFi) applications via lending and borrowing, ETH can also generate real yield natively via "staking." Staking is the process of collateralizing ETH to participate in network validation, earning real yield from block rewards, transaction tips, and other block-building opportunities, referred to as MEV.

ETH Staking: A Public Good for the Ethereum Ecosystem



Removing the Opportunity Cost of Staking ETH

Liquid staking is a mechanism that brings liquidity to otherwise frozen ETH tokens. With this staked value unlocked, the Ethereum network can maintain a high level of network security without hindering the growth of the network's economy. Here's how it works:



1. User deposits ETH in a liquid staking contract.
2. The user receives a liquid token that represents their yield-generating stake.
3. The token allows users to interact with any DeFi dapp while continuing to accrue staking yield.

This chart reflects the ETH denominated annual return (%) on a 32-ETH stake validator, with ETH issuance determined based on the number of validators participating in consensus.

Sources: Glassnode, n.d.

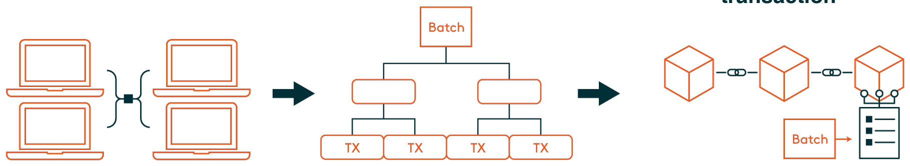
Ethereum's Plans to Onboard a Billion Users

Ethereum's transition to Proof-of-Stake (PoS) reduced the network's energy use by 99.95% and its net annual token issuance by over 90%. It also laid the foundation for future scalability upgrades, which will be critical to onboarding the next billion users.

PoS September 2022 — **Rollup Upgrades** Q4 2022 Onwards — **Shard Chains** 2023 / 2024

Rollups Are Scaling Frameworks Built on Top of the Layer 1 Blockchain

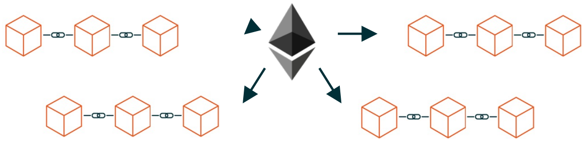
Transactions on rollups are computed off-chain — **Transactions are compressed and batched** — **The batch is uploaded to Layer 1 as a single transaction**



- Rollups can support around 1000–4000 TPS, deriving their security from the parent Layer 1.
- There are two main types: Optimistic and ZK-rollups. Optimistic rollups can support general-purpose smart contracts. ZK-rollups offer faster finality but are more complex in nature.
- **General-purpose ZK-rollups are coming late 2022.[1]**

Splitting a Chain Into Multiple, Smaller Shard Chains

Shard chains achieve scaling by parallelizing computation in individual shards.



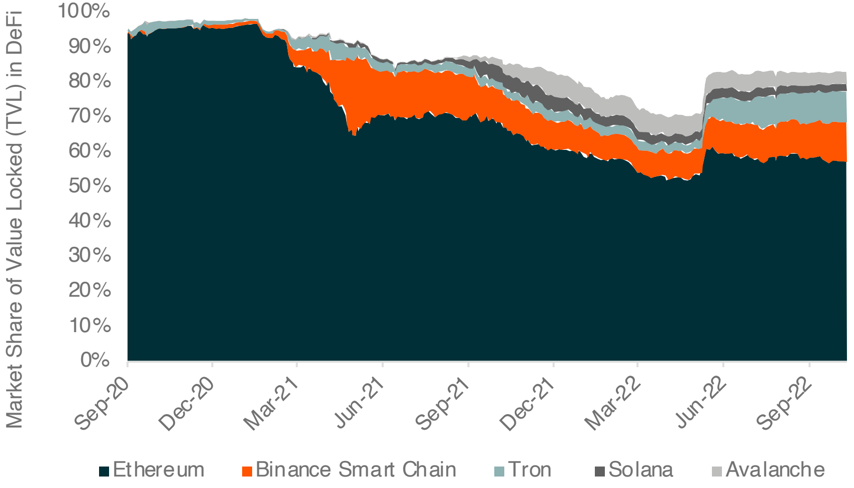
- The first version of shard chains will split the data layer, which will increase data availability by a factor of 20.[2]
- **Rollups' throughput is expected to increase by 20x and predicted to process up to 100,000 transactions per second once shard chains are activated.[3]**

Sources: Text: 1. Ethereum, 2022; 2. Matter Labs, 2022; 3. Buterin, 2021

Beyond Ethereum: A Multi-Chain World

Several other smart contract blockchains gained traction amid growing demand for a cheap and fast blockchain experience. With the blockchain ecosystem more diverse, the need to transfer data across siloed chains has become a priority.

The Layer 1 Landscape Is Increasingly Diverse



Sources: DeFi Llama, n.d.

Why Do We Need Multiple, Connected Chains?

Specialization

Blockchains come with tradeoffs of security, scalability, and decentralization—they are not one-size-fits-all. For example, security is paramount for a DeFi protocol, throughput is secondary, whereas a blockchain game might need high throughput. We need multiple dapp deployment frameworks to suit all use cases.

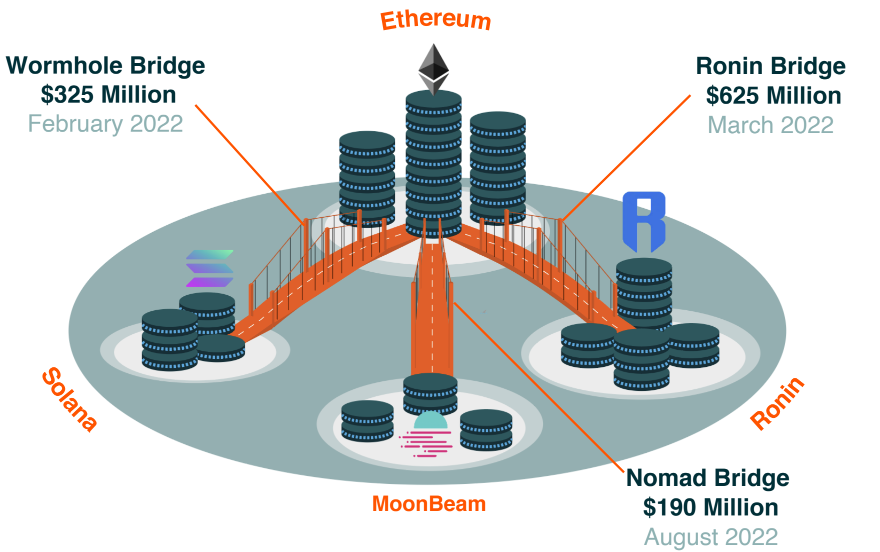
Value & Information Transfer

Chains that live as silos impose challenges to the transfer of value and information. Reducing these barriers will greatly expand the potential use cases of these platforms.

The Blockchain Connectivity Landscape

Cross-chain bridges are currently the main system enabling data transfer between blockchains. However, cross-chain bridges have a history of data breaches and lack the security assurances that are needed for long-term dependability.

Most Prominent Bridge Exploits: A Total of $1.4 Billion Lost



Sources: DefiYield, n.d.

Better Solutions for Connected Blockchains

While bridges allow existing independent blockchains to connect to one another, they have notable drawbacks:

- Bridges are not fully composable.
- Bridges restrict asset utility.
- Bridges contain vulnerabilities.

Interoperable smart contract platforms address these issues by building networks that are designed from the ground up to host and connect individual blockchains within their ecosystems.

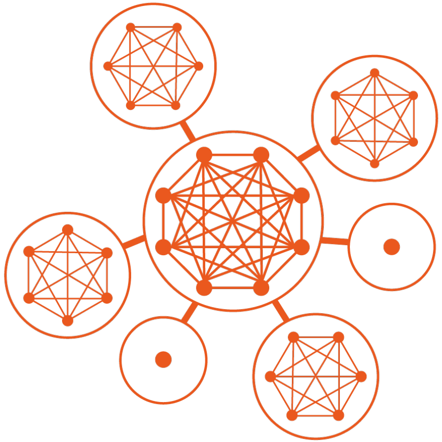
Connectivity | Scalability & Sovereignty | Transfer Optimization

Interoperable Blockchain Networks Are an Increasingly Compelling Solution

Interoperable blockchain networks provide a secure framework to build application-specific blockchains, enable greater freedom in blockchain design, and support nascent blockchains by allowing them to access the liquidity and security of the parent network.

The Benefits of Interoperable Blockchains

- **Interoperable blockchains** allow chains to specialize for specific functions or use cases, providing better performance and user experience and scalability.
- **Native interchain communication** allows data to be transferred securely between chains and enhances the composability of dapps.
- **Shared security** allows smaller chains to be secured by the resources of larger chains.



Better Solutions for Connected Blockchains

Polkadot features a hub called the Relay Chain that connects unique blockchains, called Parachains. Parachains construct and propose blocks to validators on the Relay Chain.[1]

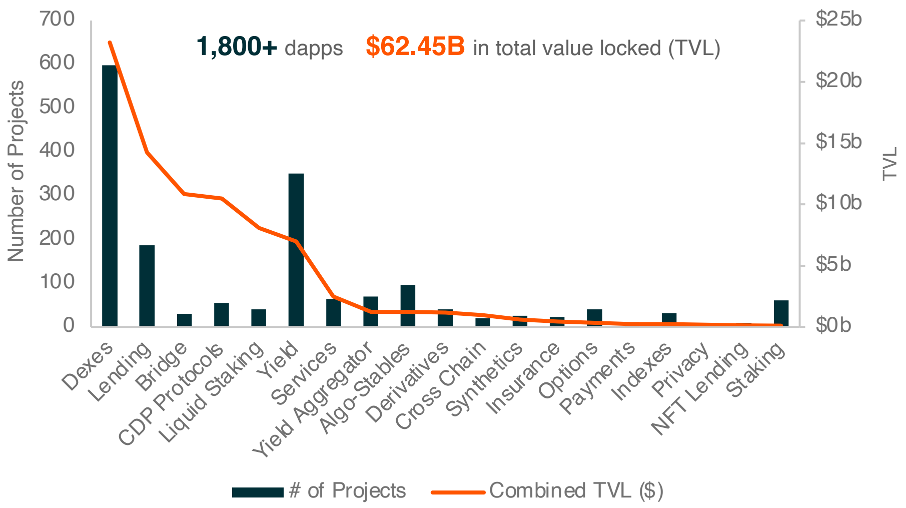
Cosmos features a central hub and application-specific chains called zones. Zones can communicate with each other via inter-blockchain communication protocol (IBC).[2,3,4]

Sources: Text: 1. Alfaro, 2022; 2. Cosmos Network, n.d.; Cosmos SDK, n.d.; IBC Go, n.d.

Decentralized Finance (DeFi) Aims to Make Finance More Efficient and Globally Accessible

DeFi is a rich ecosystem of decentralized financial applications (dapps) striving to create a permissionless and disintermediated alternative to the incumbent financial industry. Enabled by composable smart contracts and programmable money, DeFi dapps have already recreated many segments of traditional financial services and are beginning to introduce new and innovative products.

The Ecosystem Has Expanded to Host Novel Blockchain Utility



Sources: Chen, n.d.; Defi Llama, n.d.

Building On-Chain Financial Infrastructure

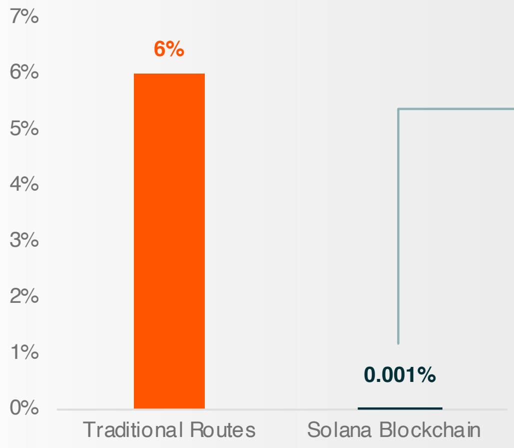
Stable Assets:	USDC	DAI	FRAX	USDT
Asset Exchange:	Uniswap	Pancakeswap	Balancer	Curve
Lending & Borrowing:	Aave	Compound	Maker	Euler
Derivatives & Options:	dydx	Ribbon	GMX	Dopex
Insurance:	Armor	Risk Harbor	Nexus Mutual	InsurAce
Yield Aggregators:	Yearn	TokenSets	Beefy	Badger DAO

Stablecoins: A Leading DeFi Use Case

Ryan Selkis

The average cost of sending money internationally is 6%, according to the World Bank, or $16 billion a year in fees. Stablecoins are a highly cost-effective solution for global value transfer and represent a clear use case to catalyze blockchain adoption.

Today's Cost of Transferring $200



Less than $0.1/Tx

It costs $0.00025 to send a USDC transaction (Tx) through the Solana network, a 99% reduction in fees.

75,000 TPS

Highly scalable blockchains can support thousands of transactions per second (TPS).

1 Second Finality

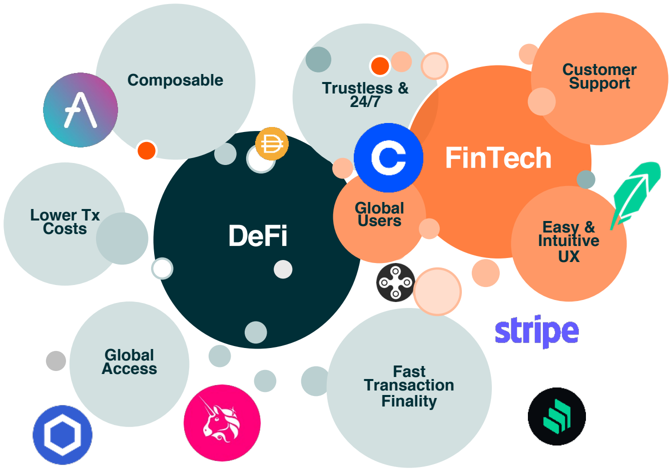
Solana transactions are settled instantaneously, with funds made available immediately.

Sources: Dashi, 2022; Messari, n.d.

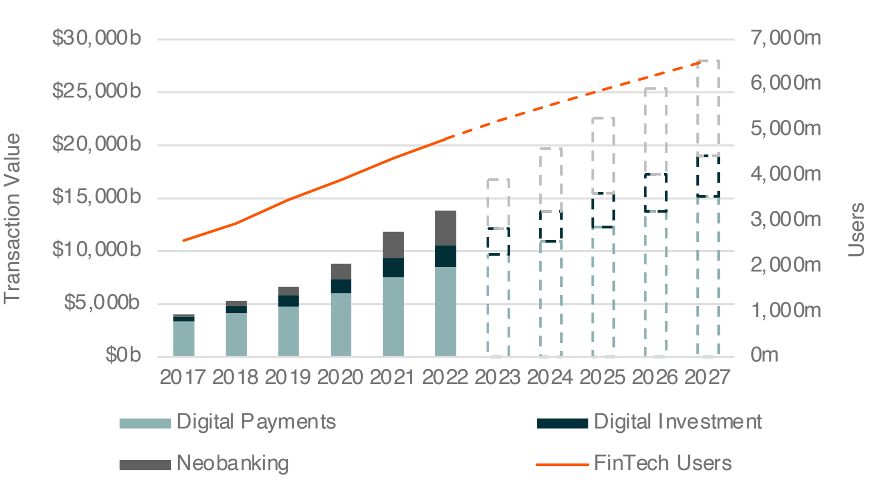
DeFi and FinTech's Synergies Can Revolutionize Digital Payments and Consumer Finance

Integrating DeFi infrastructure as the back-end to user-friendly FinTech applications has the potential to unlock significant value. This collaborative approach could drive exponential user growth to DeFi and provide FinTech platforms with new revenue streams, greater operational efficiency, and composability with the Web3 economy.

Mutual Benefits From Leveraging Core Competencies



FinTech: A New Frontier for DeFi Expansion



Sources: Statista, n.d.

FinTech x DeFi: In Practice

Major FinTech and payment companies recognize the potential of DeFi and are in the early stages of exploring how to integrate this technology into their business models.

coinbase

Launching a **hybrid custodial wallet** with the ability to claim ENS domains, interact with DeFi dapps, and connect to Coinbase's NFT marketplace.

VISA

Integration with Anchorage that allows for the **support of USDC stablecoin transaction** settlements.

stripe

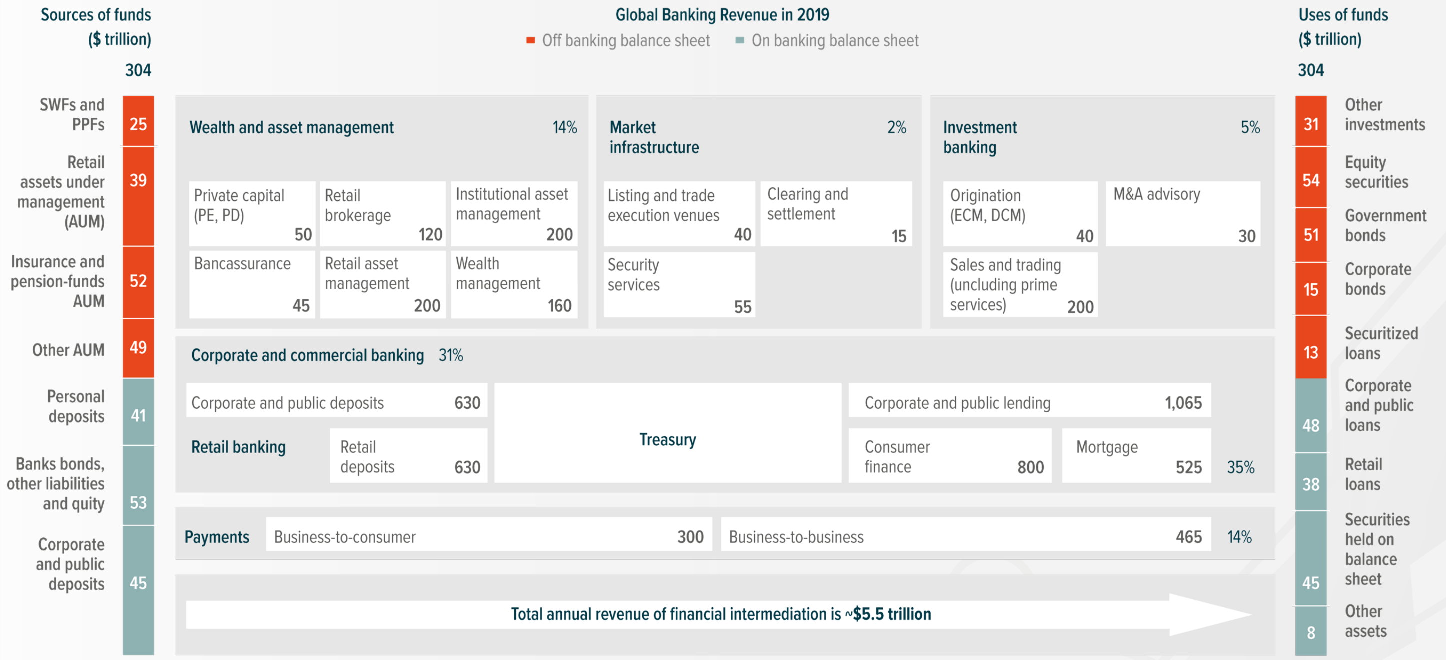
Adding Stripe Connect support for **USDC stablecoin payments** through the Polygon network.

Robinhood

Launching a **non-custodial Web3 wallet** with plans to cover gas (transaction) fees for users. Allows for frictionless DeFi and NFT access.

DeFi Can Address a $5 Trillion Market

Ryan Selkis



McKinsey estimates that financial intermediaries accrue ***$5.5 trillion in annual revenue (2019)***

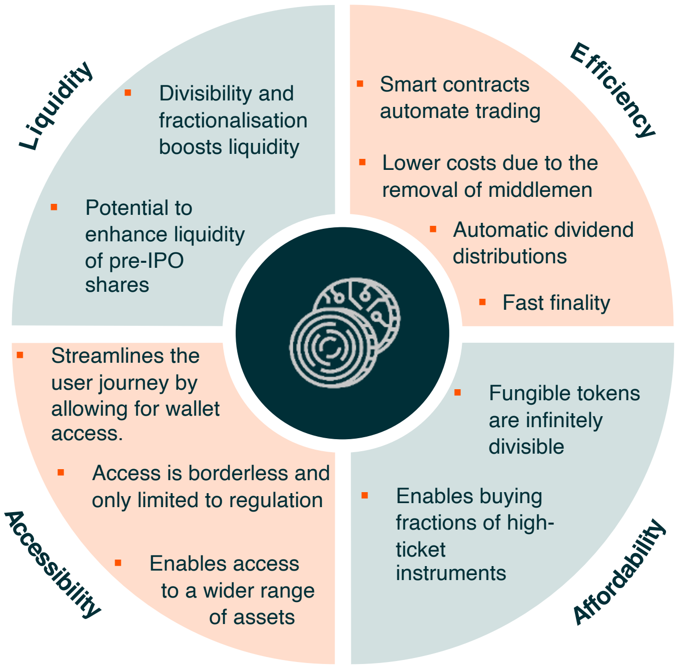
From an economy's perspective, this is a $5.5 trillion operating expense.

Rather than concentrate these costs into the dedicated financial services sector, ***permissionless blockchains socialize the costs of creating and maintaining financial markets to network users***

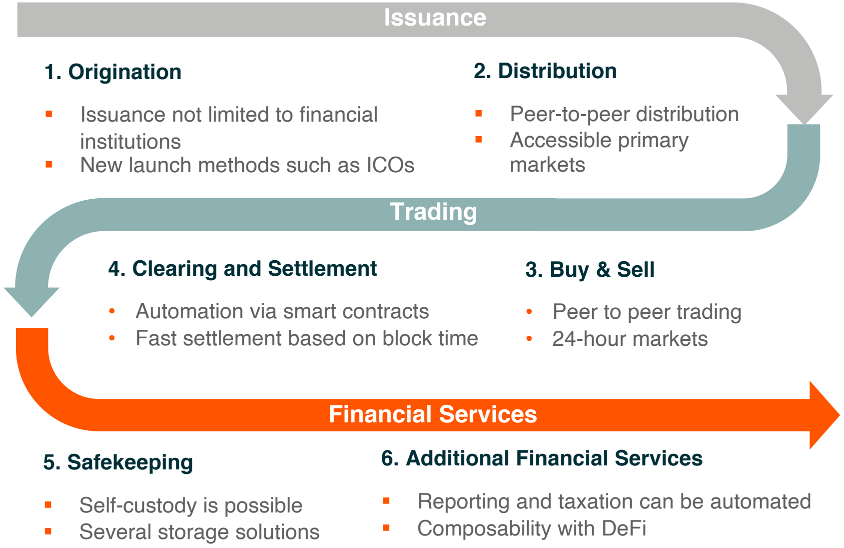
Sources: Dashi, 2022; Messari, n.d.

On-Chain Tokens: The Assets of Tomorrow

Blockchains can serve as the settlement layer for all types of assets through “tokenization.” Bringing financial and real-world assets onto the blockchain has the potential to bring liquidity to otherwise illiquid assets, providing greater flexibility and access.



Distributed Ledger Networks Serve as a Software Layer That Can Power the Full Value Chain of Assets



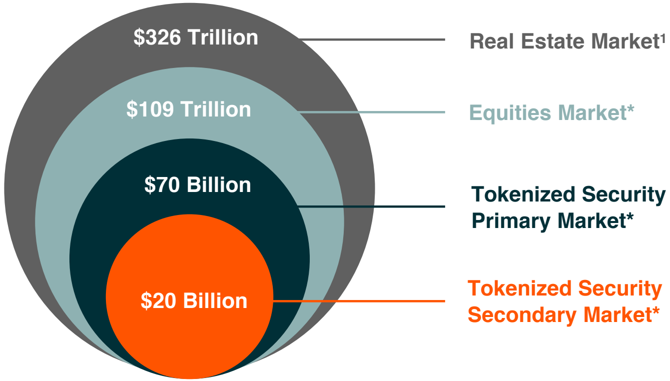
Sources: Deloitte, 2020; Hays, Gehra, Thoma, Liebi, McCormack, Khurdayan, Schneider, Boehnke, Spicher, Smith, Völkel, Hollmann, Flury, & Malkin, 2021

Tokenized Securities: High Growth Prospects

Security Token Market

Tokenized securities are transitioning from proof-of-concept to a main issuance vehicle. Their growth can be attributed to distributed ledger technology facilitating more efficient markets and enabling a better investor experience.

Tokenized Securities Have Huge Room for Growth

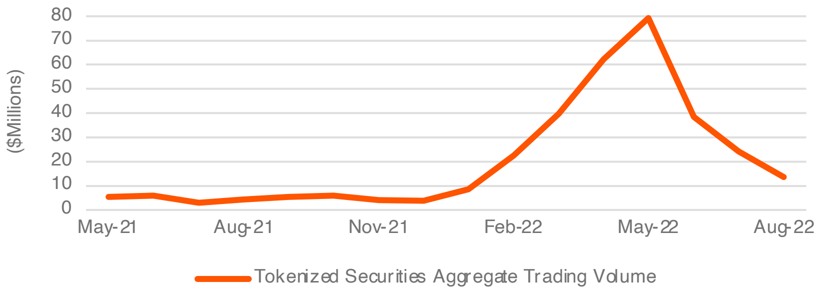


- Tokenized securities are at a very nascent stage. The total market cap of these securities was estimated at $90 billion in September 2022.
- The primary market is dominated by proof-of-concept projects or testers.
- We expect the market size of tokenized securities to increase rapidly as proof-of-concepts evolve to more mature products.

*Based on Security Token Advisors' estimates as of September 2022

Sources: Text: 1. Tostevin, 2021; Visuals: Security Token Advisors

Tokenized Securities Are Beating the Crypto Bear Market



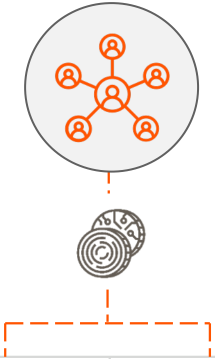
Security token trading volume saw a sharp rise despite the crypto bear market starting in November 2021. Some notable offerings include:

INX (Tokenized Securities Exchange)	Enegra Group (Minerals Company)	KKR (Private Equity Fund)
Raised **$85M** through an Ethereum ICO	Issued **$20B** of equity-backed security tokens	Tokenization of a portion of the **$491B** HCSG II fund

Tokenization Creates New On-Chain Markets for Non-Traditional Assets

Tokenization has the potential to bring value and liquidity to assets that were previously non-tradable. The creation of on-chain marketplaces for these assets can expand their utility by endowing them with universal transactability.

Creating New Markets



Securities	Memberships
Real Estate	Intangibles
Collectibles	Tickets
Loyalty Points	Reward Points

Token Standards

Fungible Tokens

Crypto assets that represent a non-unique unit of value.

Key Properties:

- Non-unique
- Divisible
- Unlimited owners

Non-Fungible Tokens

Unique crypto assets where the immutable record of their originality and ownership is attached to a unique address.

Key Properties:

- Unique
- Non-divisible
- Limited owners

Disruptive Use Cases

Tokenized Rewards

- Tokenization of loyalty rewards and the creation of liquid markets can change the nature of consumer perks. By allowing for price discovery and flexible denomination of value, free markets can introduce real value to loyalty programs and drive sustainable incentives for participation.
- The global loyalty management market is **projected to grow from $5.57 billion in 2022 to $24.44 billion by 2029.**[1]

Members-Only & Exclusive NFTs

- Membership NFTs can unlock access to exclusive events, discounts, early access to new releases, and more.
- For instance, Starbucks announced Odyssey, a Polygon-powered Web3 program that will offer customers the ability to earn and buy NFTs. The program can **"unlock access to new, immersive coffee experiences."**[2]

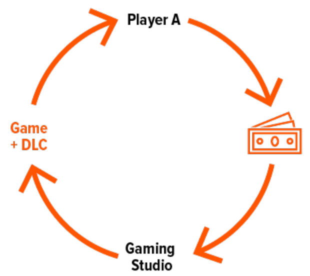
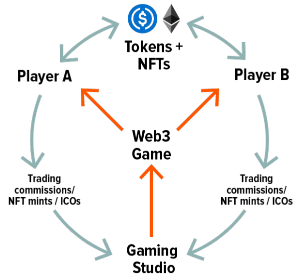
Sources: 1. Research & Markets, 2022; 2. Polygon Team, 2022

Game & Earn: A Revolution of the Gaming Economy

By empowering players to own assets and monetize their time, Web3 gaming can redefine the gaming economy. Gamers, who are currently sidelined consumers, can become an integral part of games by actively participating in in-game economies.

How Game & Earn May Change the Gaming Industry

Monetization of In-Game Assets	▪ In-game assets are scarce and may take a long time to earn, giving them value. ▪ Tokenized gaming allows gamers to monetize their efforts.
Revenue Streams	▪ Roughly 40% of game spending is generated from in-game sales. Roughly 60% is from downloadable content (DLC) and subscriptions.[1] ▪ With tokenized gaming, users may be able to access more games and content for free, as trading commissions could become a main source of revenue.
Competitive Scene & E-sports	▪ Well-designed game economies can reward gamers based on their efforts and skill rather than initial investment. ▪ As the incentive to be a competitive player becomes greater, tokenized games could bring more people into E-sports.

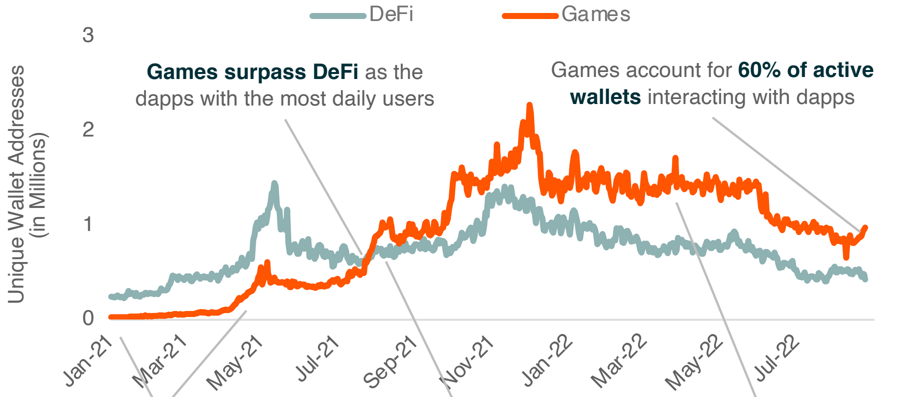
Current Gaming Industry[2]	Game & Earn Industry[3,4]
	
Market Cap: $196.8B	**Market Cap:** $6.6B *(3.3% of Gaming industry)*
Users: 3,200M	**Users:** 6M *(0.2% of Gaming industry)*
Y/Y Growth: 2.1%	**Y/Y Growth:** 700%

Sources: Text: 1. Piscatella, 2022; 2. Newzoo, 2022; 3. CoinGecko, n.d.; 4. DappRadar, n.d.

Game & Earn Is Set to Be a Driver of Blockchain Adoption

Improvements in blockchain infrastructure have made on-chain gaming viable. With gaming dapps already hosting the most daily active users of any other Web3 sector, continued investments will likely position the sector as a driver of blockchain adoption.

The Adoption of Scalable Infrastructure Like App-Specific Chains and Layer 2s Have Accelerated Gaming's Growth

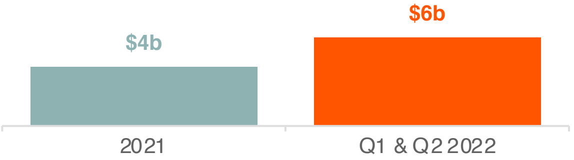


Axie Infinity moves from **Ethereum** to the **Ronin sidechain**

Sorare moves from **Ethereum** to **Starkware**, a Zk-rollup layer 2

DeFi Kingdoms expands to an **Avalanche Subnet**

Gaming Projects Raised 50% More in Venture Capital in the First Half of 2022 Than in All of 2021[1]



As new capital floods the market, improved and novel gaming concepts will inspire the next wave of blockchain users.

Several Highly Anticipated Games Are Coming[2,3,4]

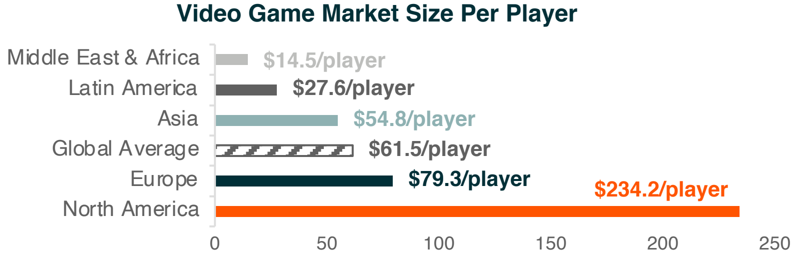
Illuvium	Guild of Guardians	Big Time
MMO Autobattler	Mobile RPG	MMO RPG
Expected 2023	*Expected 2023*	*Expected 2022*

Sources: Text: 1. Gherghelas, 2022; 2. Herrera, 2021; 3. Mirza, 2022; 4. Sergeenkoy, 2021; Visuals: Global X ETFs with information derived from DappRadar, n.d.

Game & Earn Could Be a Paradigm Shift With Powerful Social Effects

Game & Earn has the potential to become a sensational social mobility force, where players in emerging economies have the potential to become outsized earners.

A Net Flow of Funds From Developed to Emerging Economies



- Blockchain games are zero-sum games with added entertainment value.
- Players in developed economies are the greatest spenders in gaming, while gaming aptitude is independent of income and geographical location. Games that reward skill could entail net capital flows from developed to emerging economies.
- A prominent example is Axie Infinity, the leading game by market cap. In the Philippines, players were earning more than the country's average wage at its peak.

Democratizing Gaming Access: Gaming Guilds

- Gaming Guilds (GGs) are decentralized autonomous organizations (DAOs) that aim to knock down financial barriers to blockchain gaming. GGs allow people with gaming assets such as NFTs to loan them to other players. Gamers can enjoy the game and accrue rewards without an initial investment.
- Anyone can invest in the guild and earn commissions from in-game rewards, thereby creating a model that could favor all parties involved.

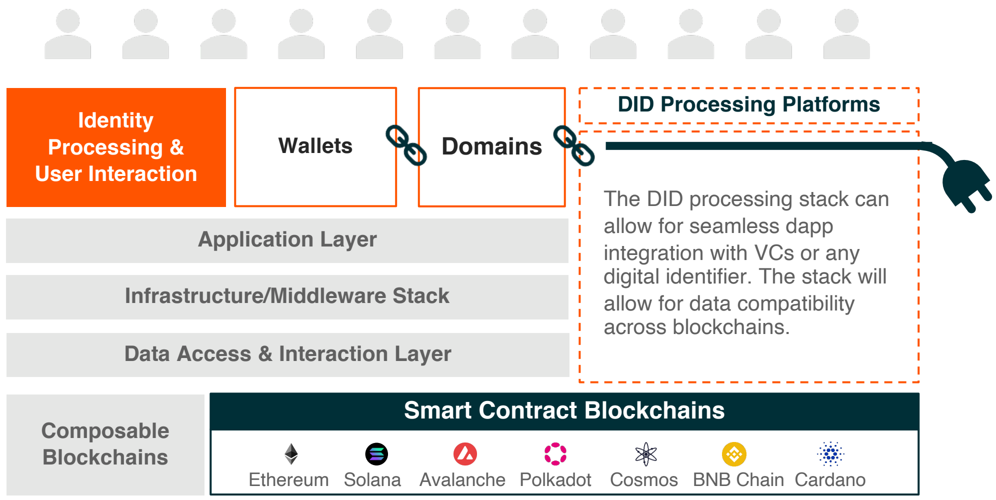
Gaming Guild	Scholars	Partnerships	AUM
YYG	30,000	50+	$100M + est.
Merit Circle	3,750	50+	$107M
GuildFi	NA	35	$111M

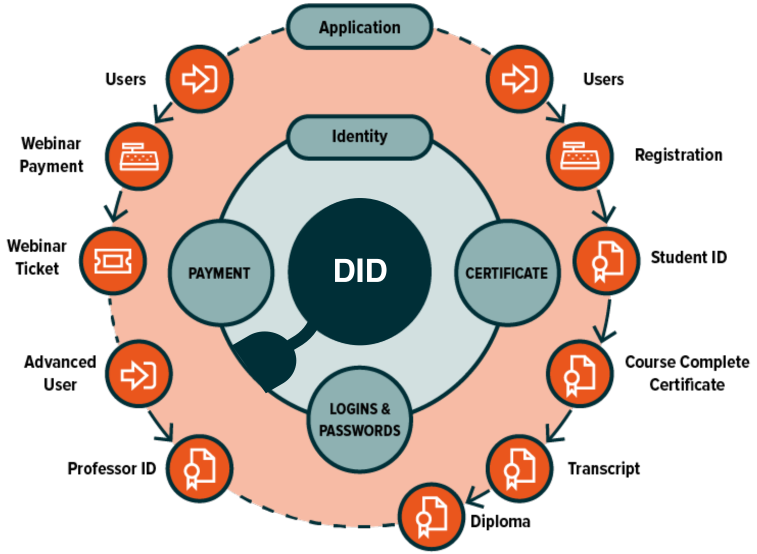
Sources: Visual: Global X ETFs with data derived from Newzoo, 2022; 1. Butler, 2022; 2. DappRadar, 2022; 3. GuildFi, 2022; 4. GuildFi, 2022; 5. Merit Circle, n.d.; Yield Guild Games, 2021; Yield Guild Games, 2022a; Yield Guild Games, 2022b

Decentralized Identifiers (DIDs): The New Digital Identity System

We expect a shift in online identity management to DIDs. DIDs are universal, open-source, and user-owned digital identifiers that can empower individuals to preserve their digital privacy, selectively disclose verifiable credentials (VCs), and more.

DID Processing Platforms Can Serve as the Bridge Between Global DID Standards and Blockchain Applications





Sources: W3C, 2022

Privacy in Blockchains: Paving the Path for More Enterprise Uses

The transparency of public blockchains is a barrier for institutional adoption, as companies value the privacy of business-critical data. Zero Knowledge (ZK) technology offers a means of proving information without revealing it.

Why Privacy Matters

Today's top blockchains like Bitcoin and Ethereum are pseudonymous and transparent by default. A degree of privacy only exists so long as a user's address is not linked to the identity of a person or an entity.

Today, privacy solutions can make blockchains commercially suitable, protecting users and entities' privacy.

Privacy for Enterprise

- **Privacy protects business-critical information.** Companies can protect data such as sales, financials, client lists, and inventories.
- **Scalable privacy solutions for enterprises are close to production standards**. One of the most notable projects is the Polygon Nightfall chain, a collaboration between Polygon and EY.
- **ZK is dynamic.** The technology can be used in multiple blockchain privacy solutions.

ZK Proofs: A Revolutionary Innovation in Privacy

Company A (Prover)

Company A makes a transaction (ex. orders 10 tons of lithium from company B).

ZK-Proof

The computation is encoded into a mathematical problem.

Verifier

Verifies the validity of the transaction without seeing any information.

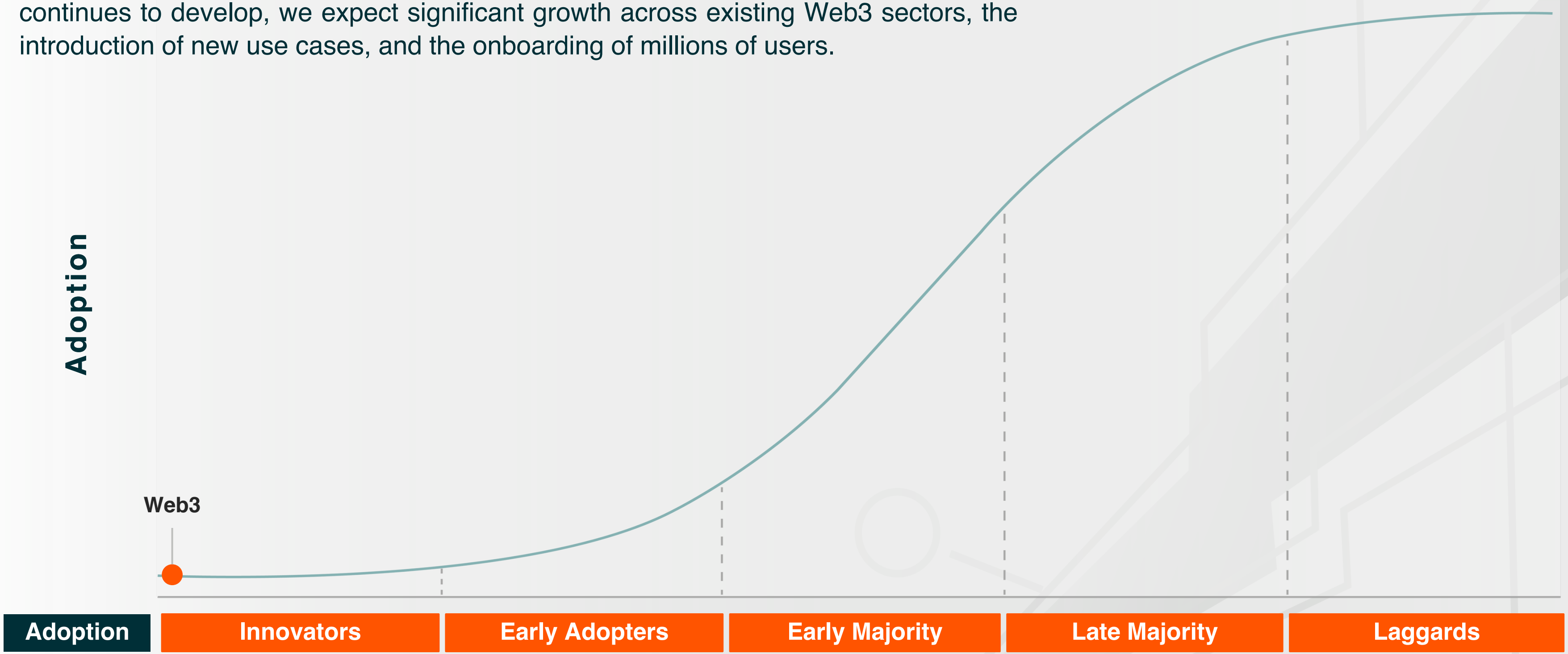
Powerful Applications of ZK-Proofs

- **Privacy:** It is possible to prove a transaction without revealing any specific information, which can allow businesses to leverage the benefits of public blockchains without revealing any sensitive information. Transactors would be able to observe their history while external observers would only see the ZK-proof.
- **Scalability:** Computation can be completed off-chain and then quickly verified through ZK-proofs, speeding up processes.

Sources: Brody, 2022; Buterin, 2017; Buterin, 2021

S-Shaped Curve of Adoption – Web3

As the infrastructure supporting smart contract blockchains and Web3 applications continues to develop, we expect significant growth across existing Web3 sectors, the introduction of new use cases, and the onboarding of millions of users.



Displayed for illustrative purposes. Curve shape not indicative of mathematical transformation

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Appendix:
Genomic Sequencing & Diagnostics

Appendix: Sources – Genomic Sequencing & Diagnostics

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Appendix:
Telemedicine & Digital Health

Appendix: Sources – Telemedicine & Digital Health

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