GLOBAL X MODEL PORTFOLIOS

INVESTING IN THEMATICS FROM A PM PERSPECTIVE

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INTRODUCTION

Expectations for technology are constantly changing. Just a decade ago, accessing the internet via a mobile device was clunky at best. Today, the slightest amount of buffering of HD video draws intense annoyance from smartphone users. As innovation begets innovation, the COVID-19 pandemic accelerated the adoption and use of important technologies spurring even more advancement. While the pandemic encouraged a step up in use, we think of this overarching trend as the continued shift from Innovation to Utility, where new technologies build on ideas that came before, turning the revolutionary into the day-to-day. As workplaces regain normalcy, the technological tools utilized during the pandemic look to have staying power, launching Americans into a "New Normal" of technology.

In this white paper, we seek to detail key themes shaping our world. This iteration of the report is focused exclusively on the Disruptive Themes category, but later this year we will be releasing our analysis into the People & Demographics and Physical Environment categories. This research and analyses support some of the thematic investing decisions made in the Global X ETF Model Portfolios. Used standalone or as satellite strategies, our thematic approach strives to position portfolios for the future. Global X's suite of Model Portfolios contains three strategies that are exclusively focused on thematic equity, and an additional seven model portfolios that include thematic equity in the context of a broader asset allocation. Our portfolios are actively managed (not static) and will enter and exit themes over time. As such, not all themes available will be directly represented at a given time. For more information on Global X Model Portfolios, including allocations, please consult our Advisor Login.

THEMATIC EQUITY ADOPTION

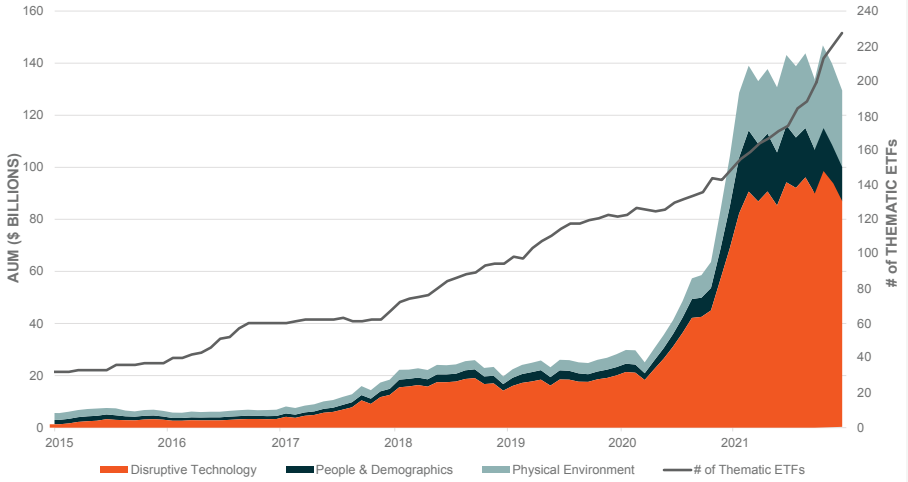
Interest in accessing thematic equity through ETF products increased significantly over the last few years. COVID-19 related lockdown restrictions and shifts in how society engages with technology drove a sharp increase in thematic adoption during 2020. While society is learning how to live with this virus as life is starting to return to normal, the technologies that enabled us to engage during the pandemic could be used as building blocks to the future.

"At the end of 2021, there were 229 thematic ETFs totaling **$129.4B** in assets under management (AUM), down 3% from Q3 2021 but still **up 24%** from Q4 2020.[1]"

[1] Global X Research as of 1/10/22

AUM OVER TIME

Source: Global X ETFs, Bloomberg Data as of 12/31/2021.



Note: AUM includes assets of funds closed until the last month of trading activity.

THEMATIC ADOPTION

The adoption of new technologies typically follows an S-shaped pattern, with the rate of growth accelerating as the product gains mass acceptance, until eventual deceleration as the technology becomes pervasive (see chart). Our thematic strategies target themes in the Early Adaptors and Early Majority phases, and reduce exposure to themes as they advance into Late Majority territory.

The scalability of key technologies typically rises at higher levels of adoption, boosting revenue and potentially also profitability. While most themes experience gradual improvements in scale along the adoption curve, for themes that rely on interconnectivity, such as Social Media and to a lesser extent Video Games & Esports, monetization opportunities accelerate once the technology has high adoption levels and network effects make it is more difficult to switch to a different service.

In the disruptive technology category, we can currently trace majority of the structural changes to data and connectivity. As we transition to a digital future, this established new frontiers for interconnectivity.

THEMATIC ADOPTION

Source: EM Rogers, "Diffusion of Innovations", 1962, and Global X Research, 2020.

Data points along the adoption curve utilize the Global X ETF tickers to represent each theme. This is an indication of thematic adoption within society. This analysis is as of October 2021 and is subject to change. The curve does not in any way reflect past or future performance of the ETFs.

THEMATIC CLASSIFICATIONS

Global X Research has developed a holistic Thematic Classification System, designed to help investors better understand, track, and analyze the evolving thematic landscape. Focused on identifying powerful themes and organizing them by common traits and drivers, the system consists of four layers of classifications: Categories, Mega-Themes, Themes and Sub-Themes, with each layer becoming increasingly granular in its focus.

As of publication, the classification system is comprised of 3 categories, 11 mega-themes, and 42 themes. The number of each is expected to change over time as the thematic landscape evolves. The table provides an overview of the Global X Thematic Classification System and our takeaways from each mega theme.

INVESTING IN THEMATICS FROM A PM PERSPECTIVE

Category		Mega Theme & Key Takeaway	Theme
DISRUPTIVE TECHNOLOGY	The Infrastructure of the Digital World	**Big Data** Big Data's cloud computing and cybersecurity technologies integrate exceptionally well from a portfolio perspective, as the data-dense cloud necessitates ongoing cybersecurity spending and investment.	Machine / Deep Learning
			Cybersecurity
			Quantum Computing
			Cloud / Edge Computing
		Connectivity If AI is a system's brains, the Internet of Things (IoT) acts as the digital nervous system. Connectivity enables real-time and remote monitoring of autonomous systems.	Digital Infrastructure
			5G / Next Gen Networking
			Emerging Market Internet
			Internet of Things
			Space / Satellite Communication
	How it Relates to the Physical World	**Robotics** The adoption of robotic and AI tools combined with internet of things (IoT)-based sensors and massive scale cloud computing could be sparking the Fourth Industrial Revolution, increasing the efficiency and effectiveness of factory-based production.	AI / Automation
			3D Printing
			Drones
		Mobility We expect the Mobility theme to be boosted by the integration of robotics & AI and internet of things (IoT) technologies that may result in the proliferation of connected, autonomous EVs.	Autonomous Vehicles
			Electric Vehicles
	UPCOMING		
	How it Relates to the Digital World	**Digital Experiences** Improved connectivity opens a world of possibilities for enhanced online engagement. The future is likely to be more interactive with improved cloud computing increasing the potential for video game streaming and increased blurring of physical and digital worlds.	AR / VR
			Video Games
			Social Media
			Streaming
		FinTech We expect continued innovations in mobile payments, online banking, and alternative lending platforms to bring financial services to previously unbanked and underserved populations.	Mobile Payments
			Peer-to-Peer Lending
			Crowd Funding
			Blockchain
PEOPLE & DEMOGRAPHICS		**New Consumer**	Millennials & Gen Z
			Emerging Market Consumers
			Urbanization
			E-commerce
			Education
			Sharing / Gig Economy
			Safety & Security
			Cannabis
			Sports Betting
			Professional Sports
		Health	Healthcare Innovation
			Aging Population
			Health & Wellness
			Emerging Market Healthcare
			Alternative Medicine
PHYSICAL ENVIRONMENT		**Climate Change**	CleanTech
			Clean & Renewable Energy
			Resource Scarcity
		Disruptive Materials	Disruptive Materials
		Infrastructure Development	Infrastructure Development

Infrastructure of the Digital World

We can currently trace majority of the structural changes to data and connectivity. A handful of key themes are foundational, providing the technological backbone for the digital future. Given interconnectivity between technologies and themes, these foundational themes link to both the physical and digital world.

KEY MEGA THEMES:

- Big Data
- Connectivity

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BIG DATA (CLOUD COMPUTING & CYBERSECURITY)

Perhaps no investment theme has been more important to the business world since the COVID-19 outbreak than Big Data. As workplaces went remote, access to key documents, applications, and computing resources made cloud computing essential. We expect the global economy to shift further into the cloud over time, though connectivity can be both a blessing and a curse, as readily accessible files can become an easy target for malicious actors. Fortifying cybersecurity measures are therefore necessary investments to protect remote treasure troves of sensitive data.

KEY TAKEAWAYS

- COVID-19 related pressure boosted the Big Data theme as it increased cloud utilization faster than previous estimates. Now an estimated 92% of enterprises use multiple cloud services, employing 2.6 public and 2.7 private clouds on average.[1]
- Cybersecurity spending is expected to increase significantly with the global economy going digital. Ninety-six percent of organizations increased their cybersecurity spending in 2020, according to a recent survey. And 91% increased their cybersecurity budgets in 2021.[2]
- Big Data's cloud computing and cybersecurity technologies integrate exceptionally well from a portfolio perspective, as the data-dense cloud necessitates ongoing cybersecurity spending and investment.

WHY CLOUD COMPUTING AND CYBERSECURITY ARE SUCH POWERFUL FORCES

Cloud computing offers proven efficiencies that modernize business practices.

Of all the investment themes that we track, the Cloud Computing theme likely accelerated the most due to COVID-19 because it became essential to business continuity. In a survey by computer software company Flexera, 29% of respondents said that they increased their cloud usage significantly more than expected during the pandemic, while 61% made slight increases due to pandemic-related operational changes.[3] Today, an estimated 92% of enterprises use multiple cloud services, employing 2.6 public and 2.7 private clouds on average.[4]

With growing demand attributed to lower operating costs, better collaboration, increased flexibility, and improved turnaround times for server expansion, the largest enterprises by revenue accounted for 51% of the cloud market in 2020.[5] These firms were not new to the cloud, having used it to build applications or host corporate infrastructure. The next push looks to modernize core business applications and processes. Technology conglomerate Cisco expects 94% of all corporate workflows to run through some form of cloud infrastructure by 2021, as servers dedicated to individual tasks quickly become relics.[6]

The next stage of the cloud's evolution looks to be omni-cloud solutions that stitch together multiple platforms and services to create more integrated data sharing and access. Managed multi-cloud environments should help assuage security, cost, and governance issues, the top concerns of enterprise cloud decision-makers.[7]

Currently, supply chain constraints, including the ongoing semiconductor shortage, are a challenge. But we believe the shortage can enhance the Cloud Computing theme. Under more normal conditions, corporations have a choice. They can build out their own personalized data centers, spending the time, resources, and expertise to customize servers. Or they can contract a cloud provider that offers a more general but rapid turnkey solution. Currently, high costs and long lead times due to supply constraints disincentivize personalized server builds, forcing organizations into the cloud to avoid the risk of delays.[8]

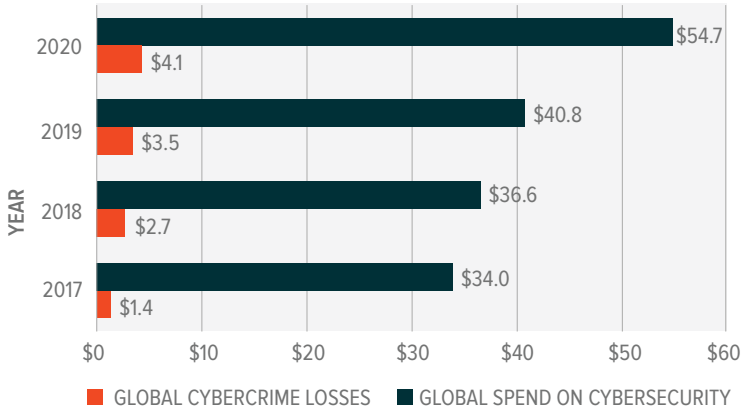
As the value of data increases, it requires more protections.

Cloud computing data centers aggregate and concentrate valuable data and processing power, increasing the speed and effectiveness of computing tasks. But that digitization makes protecting this valuable and sensitive data essential. The World Economic Forum marked cyberattacks as the 7th global risk by likelihood and 8th by impact in 2020.[9] It's estimated that global cybercrime costs will grow by 15% per year to $10.5 trillion annually by 2025.[10]

In 2020, ransomware attacks increased by 62% globally and 158% in North America compared to 2019.[11] These malicious attacks have real consequences for business, infrastructure, and end users beyond lost data and operational disruptions. According to FBI data, U.S. economic losses from more than 791,790 reported cybercrime incidents in 2020 exceeded $4.1 billion.[12] The effects of a successful breach, financial and otherwise, can be felt for years after the actual threat ends. As much as 22% of negative effects occur in the second year after the event, and another 11% surface in the third year.[13]

CYBER ATTACKS CONTINUE TO CAUSE DAMAGE EVEN AS SPENDING INCREASES DRAMATICALLY

Source: IC3, March 2021, Canalys, January 2021.

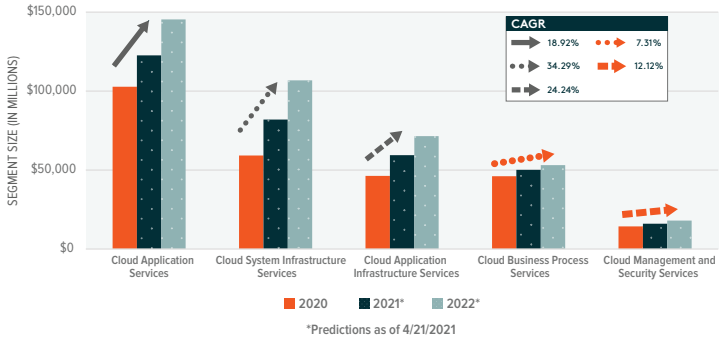


According to solutions provider Insight CDCT (Cloud + Data Center Transformation), 96% of surveyed organizations increased their cybersecurity spending in 2020, and 91% expanded their cybersecurity budgets in 2021. However, current solutions largely focus on closing immediate security gaps and addressing the easiest-to-deploy options first, not the most concerning threats, including state-sponsored corporate espionage, attacks on critical infrastructure, and disinformation campaigns.[14] For example, the Solar Winds hack discovered in December 2020 is believed to be the work of the Russian Foreign Intelligence Service. About 100 companies and a dozen government agencies were compromised, including the U.S. Treasury, Justice, and Energy departments, and the Pentagon.[15]

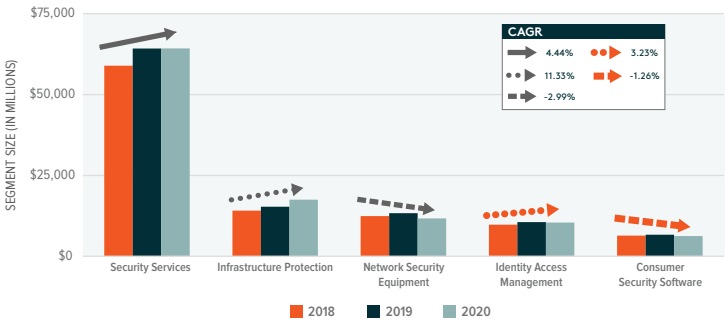
The increased sophistication of state-sponsored cyber threats requires equally sophisticated state responses. The Biden administration recently issued a new mandate for federal agencies to patch cybersecurity vulnerabilities in government software. This mandate covers about 200 known security flaws, making it one of the most widespread initiatives of its kind.[16] Additionally, the House passed the Small Business Administration (SBA) Cyber Awareness Act, requiring small businesses to notify Congress of cybersecurity breaches. A second component includes the Small Business Development Center Cyber Training Act for cybersecurity counseling certification programs.

VISUALIZING THE MARKET OPPORTUNITY

GLOBAL CLOUD COMPUTING SPENDING BY LARGEST SEGMENT
Source: Gartner data as of 4/21/2021.



GLOBAL CYBERSECURITY SPENDING BY LARGEST SEGMENT
Source: Embroker data as of 11/2/2021.



RISKS TO THE BIG DATA THEME

Supply chain disruptions could affect development of critical cloud infrastructure.

A concern for Big Data and the broader technology space is the supply chain constraints limiting the availability of certain types of semiconductors. This shortage has nuanced effects on the Cloud Competing theme as increased demand from end users is offset by capacity growth restrictions. Data center development is necessary for the continued expansion of service offerings and staying competitive in an industry with regular hardware advancements and data demand increases.

Shortages aren't affecting every type of semiconductor. High-margin microchips, such as the server-level central processing units (CPUs) and graphics processing units (GPUs) that make up the backbone of data centers, are generally available. But other necessary components like power supplies and network switches face lead times in the 40–60 week range, more than double the pre-pandemic norm.[17,18] Semiconductor foundry capacity is growing at 1–3% per year, but that growth is outpaced by the demand for computing power, so constraints are expected to persist. Industry leaders expect tightness through Q2 2022.[19,20]

Cybersecurity is an inherent risk in the digital age.

Data is gold today, which means data centers must become virtual fortresses. Concentrating such a valuable resource only increases the interest of malicious actors, and when they see an opening, they take it. For example, attacks on cloud infrastructure providers increased 630% between January and April 2020 compared to the previous four-month period as cyber criminals looked to exploit COVID-related confusion.[21]

Unauthorized access can occur even without malicious activity due to incorrect settings or user and employee errors. In 2019, more than 540 million user records from a large social media company were exposed by a leading cloud provider due to improper data protections.[22] Absolute protection of data is likely impossible because there is a direct trade-off between data security and accessibility, but many risks can be mitigated by adequate cybersecurity spending and security awareness training.

From a risk perspective, the Cybersecurity theme looks well-insulated. Cybersecurity technologies work to proactively shield against possible attacks while mitigating and repairing the damage from attacks that already occurred. As a result, there is little risk at the broad theme level because the factors spurring adoption are unlikely to ever wane. Risk remains acute at the individual company level, where malicious actors constantly stress-test specific cybersecurity approaches and tools.

Should a breach occur under a cybersecurity provider's nose, markets are likely to devalue that company compared to its peers. However, in such instances, interest actually increases for the space overall. Cybersecurity stocks and ETFs have a history of positive price performance following the announcement of large-scale hacks, including the Solar Winds incident. In a situation where a data center or application developer falls victim to a large breach, negative share performance could be offset by broader cybersecurity gains.

THEMATIC INTERSECTION: INTERNET OF THINGS AND ARTIFICIAL INTELLIGENCE

Internet of Things (IoT)

The proliferation and advancement of connected devices driven by IoT technology looks to enhance the opportunities for Big Data themes. The integration of microchips and networking into more products creates more opportunities for data collection, as well as unauthorized access. Distributed sensors require a central data processing location to receive and aggregate collected information. And as the number of connected devices expands alongside increasingly sophisticated data analysis, so does the need for processing power and cloud computing resources.

But sensors are next to useless if they aren't secure, so IoT also positively impacts the Cybersecurity theme. For a malicious actor, the IoT is a cornucopia of opportunities to attack. Ninety-eight percent of all IoT device traffic is unencrypted, which translates to 57% of IoT devices being highly vulnerable to cyberattacks that can expose personal and confidential data.[23] Successful IoT deployments require multi-layered, end-to-end security that ranges from upfront, baked-in security requirements to the ongoing management and protection of sensitive machine-generated data.[24]

Artificial Intelligence (AI)

The cloud and AI and are also a fitting match. The cloud can democratize access to AI, providing turnkey solutions without significant upfront investment or specialized experience. AI can enhance cloud infrastructure through computing resource management, streamlining workloads, and automating repetitive tasks without human interaction. Additionally, growth in AI capability and complexity requires expanded computing resources. In 2018, AI research lab OpenAI reported that the amount of computational power used to train the largest AI models doubled every 3.4 months, an appetite that cloud providers can quickly satisfy.[25]

AI technology is a boon for the Cybersecurity theme, given its use of pattern recognition and predictive intelligence to detect unusual network activity or penetration attempts. As cyberattacks grow in complexity, regularity, and intensity, AI can bolster human-based cyber defenses. Spending on AI cybersecurity tools is expected to grow faster in the coming five years than hardware or services, indicating wholesale adoption of the technology.[26]

BIG DATA IN A PORTFOLIO CONTEXT

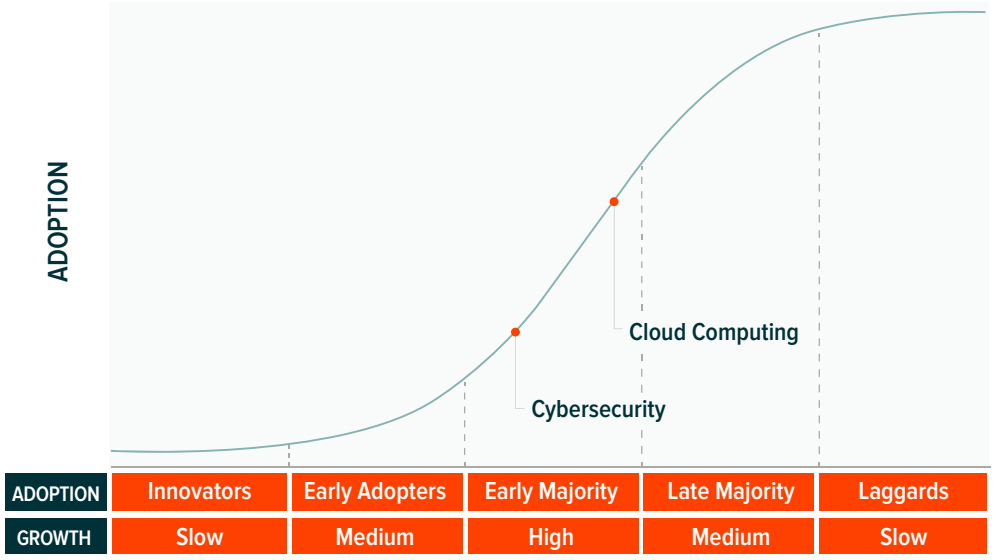
Big Data is foundational to our digital future, and is comprised of core themes that we believe have a place in most thematic portfolios. Both Cloud Computing and Cybersecurity fall squarely into the Early majority phase, indicating that adoption levels are high and rising, and that the market has begun to accept these themes at scale.

The companies that implementing Big Data technologies are global and stand to benefit as thematic adoption rises across the world. The pie charts below breaks down the geographic exposure of the largest Big Data ETF products. We believe there is ample innovation occurring outside of the states, and that limiting exposure to the U.S. will exclude key players to the detriment of investors over the long term.

In our view, thematic equity should be targeted, using screens to ensure the underlying companies provide the desired thematic exposure. This pure play exposure minimizes overlap between themes while also differentiating the exposure provided by the theme relative to broad beta products. An overlap analysis between Big Data thematic ETFs and XLK, the Technology Select Sector SPDR Fund, shows that average overlap by weight is 6.4% and 2.5% for cloud computing and cybersecurity funds, respectively.[27] As shown above, cloud computing scores higher on adoption than cybersecurity, and this is reflected in the theme's larger level of inclusion in broad tech sector ETFs. The names that overlap tend to be large, well known and active in many business segments, such as Microsoft and Cisco, while those that don't overlap are smaller and relate specifically to the theme. This highlights a key advantage of thematic investing - gaining exposure to key players early in their business lifecycles before they are included at any significant weight in broader indexes.

THEMATIC ADOPTION

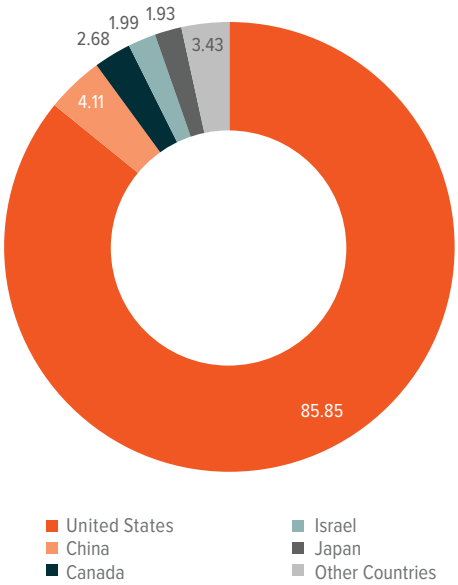
Source: EM Rogers, "Diffusion of Innovations", 1962, and Global X Research, 2021



We believe both Cloud Computing and Cybersecurity could grow in importance over the next decade. Migrating to cloud-based infrastructure and software affords enterprises greater flexibility, predictability, and scale. While the market nears mass adoption, opportunities remain for firms to expand Software-as-a-Service and Infrastructure-as-a-Service offerings. The cloud's effectiveness has been proven; the next leg will maximize its potential. Helping the cloud reach its potential will be the cybersecurity industry, which seems well-positioned to capitalize as people and economies move further online. Cyber threats continue to increase in occurrence and severity, demonstrating the permanent need for cybersecurity spending. Both these Big Data themes benefit from subscription revenue models, helping establish more stable and predictable income streams.

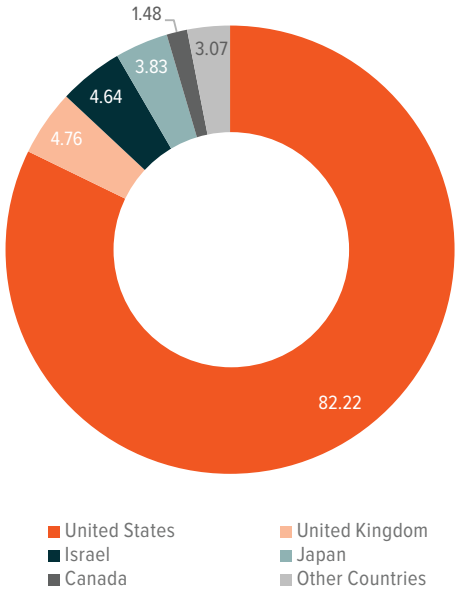
CLOUD COMPUTING: AVERAGE GEOGRAPHIC EXPOSURE BY THEME

Source: Morningstar data as of 12/31/21.



CYBERSECURITY: AVERAGE GEOGRAPHIC EXPOSURE BY THEME

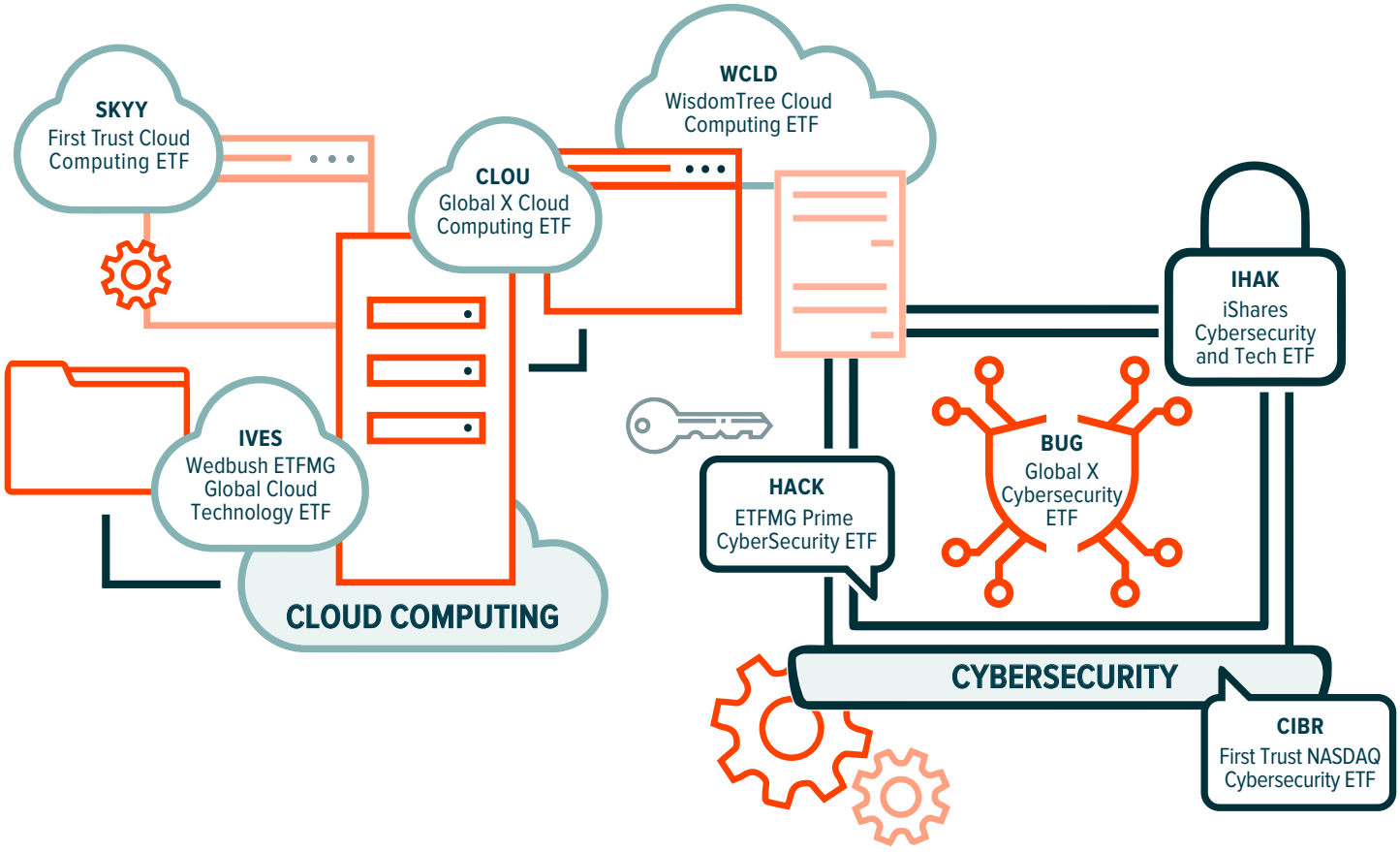
Source: Morningstar data as of 12/31/21.



Note: Pie charts include the largest four cloud computing and the largest four cybersecurity ETFs according to our thematic classification. All Thematic ETFs weighted the same.

HOW TO ACCESS BIG DATA

The graphic below identifies some U.S. listed ETFs that provide direct exposure to the Big Data theme through Cloud Computing and Cybersecurity technology.



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[27] ETF Action data as of 2/9/22

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CONNECTIVITY (INTERNET OF THINGS & DIGITAL INFRASTRUCTURE)

Connectivity creates opportunities, and we expect the Connectivity theme to grow as the internet of things (IoT) connects more devices across sectors. Sparked by the continued miniaturization of microchips and receiving a powerful tailwind from the speed and capacity of 5G networks, IoT sensors and connected devices are set to harness the power of collected data. While these technologies appear to occur effortlessly, they rely on an extensive network of towers and data centers. Core to the Connectivity mega theme's growth potential is the significant investment being made to enhance this digital infrastructure.

KEY TAKEAWAYS

- Industrial IoT (IIoT) could be a key component of the Fourth Industrial Revolution (Industry 4.0), which we expect to transform manufacturing and supply chains. IIoT is expected to account for over 70% of all IoT connections by 2024.[1]
- Increased connectivity increases the need for investment in digital infrastructure. Between 2016 and 2020, the U.S. wireless industry invested $140 billion in infrastructure enhancements, building over 417,000 new cell sites in 2020 alone.[2]
- The Connectivity theme lives up to its name by connecting numerous themes, both innovation-based and physical infrastructure-based. We believe this attribute makes Connectivity particularly dynamic from a portfolio perspective.

WHY THE INTERNET OF THINGS AND DIGITAL INFRASTRUCTURE ARE SUCH POWERFUL FORCES

Connected devices are everywhere and growing more powerful.

Connected devices produce an almost unimaginable amount of data. Technology conglomerate Cisco estimates that IoT devices produced 500 zettabytes (1ZB = 1 trillion gigabytes) of data in 2019, and it expects that number to grow exponentially each year as more devices come online.[3]

In 2021, the average American household had 25 connected devices, up substantially from 11 at the end of 2020.[4,5] In total, the U.S. had 468.9 million connected devices online by the end of 2021, including 190.4 million data-only devices such as smartwatches or medical sensors. Data only IoT-focused connections have increased 272% in the U.S. since 2013.[6] Globally, the number of connected IoT devices is expected to grow from 11.3 billion in 2020 to 27.1 billion by 2025 as the chipsets and wireless communication services that enable connectivity become more available.[7]

Cheap and readily accessible sensor and communications chips enhance the capabilities of everyday devices. Microsoft data shows that the average price of an IoT sensor declined from $1.30 in 2004 to $0.44 in 2018.[8] This trend combined with computing power increasing by a factor of 10 roughly every four years has resulted in even basic products such as toasters receiving a digital upgrade.[9]

In the short term, the semiconductor shortage has increased the prices of chips and other electronic components, demonstrated by the semiconductor producer price index rising from 54.1 to 55.3 in 2021.[10] The long-term trend of declining costs per unit compute is expected to resume once manufacturing catches up with demand, further aiding IoT adoption.

Industrial IoT creates dynamic growth opportunities in the manufacturing sector.

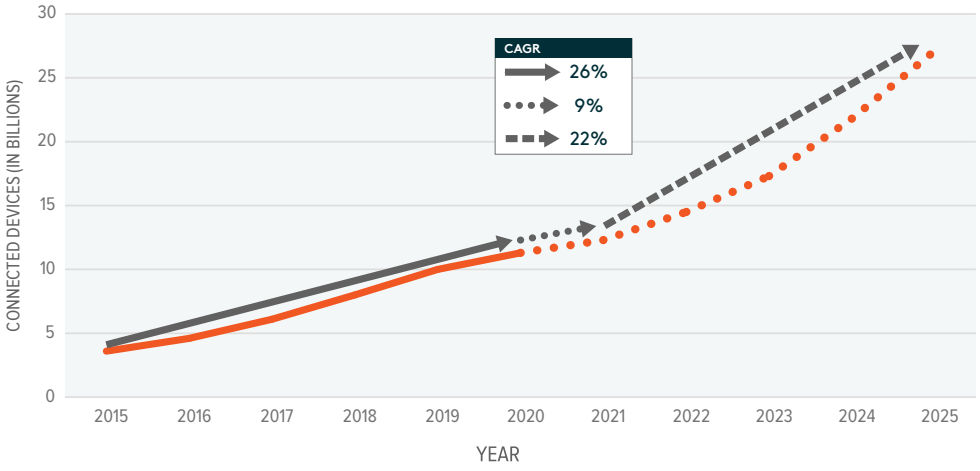
Recent kinks in supply chains indicate that the current production paradigm isn't sufficiently equipped to handle system-wide stress. The solution is to transform traditional and linear manufacturing supply chains into dynamic, interconnected systems. Bringing Industrial Internet of Things (IIoT) technologies into manufacturing facilities will change how products are made and delivered. Adding sensor technology and adaptive control systems to production lines could transform real-time data into actionable insights that may be used to increase manufacturing efficiency.

A key advantage of Industry 4.0 compared to just-in-time manufacturing is a reduction in downtime due to predictive repairs. Production downtime, even for necessary maintenance, can have large costs. By monitoring the current condition of machinery, reacting to warning signs, and cross-checking input and finished good levels, IIoT-enhanced factories can optimally schedule repairs, thereby reducing downtime and increasing facility throughput.

Further efficiency gains can be derived by utilizing IoT for inventory and asset tracking. With GPS technology, complicated logistics can be monitored and simplified. For example, a manufacturer can know in real time when a shipment of raw materials will arrive at a facility or when finished products arrive at a distribution center. This information can help companies maximize profitability by giving them insight on when to replenish inventory or help them locate and recover lost or stolen equipment and goods. McKinsey data

GLOBAL IoT CONNECTED DEVICES

Source: IoT Analytics data as of September 2021.



"Globally, the number of connected IoT devices are expected to grow from 11.3 billion in 2020 to 27.1 billion by 2025."

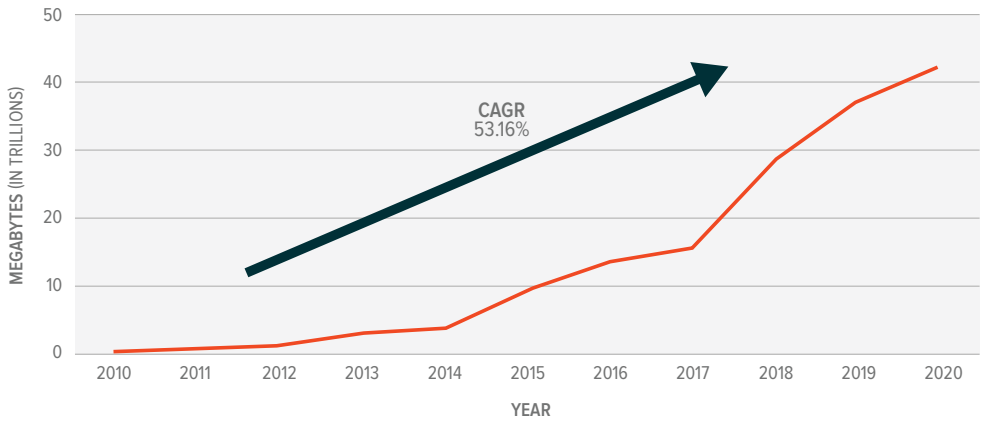
shows that firms who implemented Industry 4.0 technologies were able to respond to the COVID-19-induced supply chain crisis in 96% of cases, while those firms without these technologies were able to respond just 19% of the time.[11]

Towers and data centers combine innovation and real estate.

Communications networks are essential digital infrastructure because they facilitate connections between the massive processing power of data centers and end users. Significantly, towers and data centers marry elements of growth-oriented technology investing and income-oriented real estate. Data centers provide physical space for customized server infrastructure while addressing cooling, power management, and security responsibilities, in exchange for regular fee payments. Data centers also serve a diverse set of clientele, including big tech companies, government agencies, financial services firms, and health care providers.

In 2020, the U.S. accounted for over 80% of new data center construction and expansion projects globally.[12] Investment in this infrastructure totaled more than $700 million.[13] But more is needed, as demands on digital infrastructure will only increase. The vastly improved bandwidth, latency, and speed that 5G networking technologies offer could be required for widespread adoption of advanced IoT-enabled devices like autonomous vehicles. However, current infrastructure is likely to crack under the additional load, making the need for cell towers greater than ever.

ANNUAL U.S. WIRELESS DATA TRAFFIC
Source: CTIA data as of 7/27/21.



"Taking a longer-term view, U.S. mobile data traffic has increased by 108x over the last decade, indicating that much more tower capacity will be needed as data demand continues to expand."

Currently, there are approximately 128,000 macro cell towers in the U.S., but each tower only has so much range and capacity. A typical cellphone only has enough power to reach a tower up to 5–7 miles away, and a single Long Term Evolution (LTE) cell can only manage about 200 active device connections per 5 megahertz (MHz) of spectrum before speeds begin to slow.[14,15] The expansion of IoT means a higher demand for towers and wireless spectrum to ensure adequate coverage.

Tower demand is expected to remain robust with 6.37 billion active smartphone users globally.[16] But construction and permitting hurdles often limit expansion, making existing towers increasingly valuable. In the U.S., suppliers of macro cell towers increased tower capacity by about 8% from 2019 to 2020.[17] But over the same period, mobile data per smartphone increased 29%.[18] Taking a longer-term view, U.S. mobile data traffic has increased by 108x over the last decade, which indicates that much more tower capacity will be needed to meet data demand.[19]

Solutions for capacity constraints coming with 5G, continued investment.

With more data being collected by sensor-enabled devices than ever, transferring information in a timely manner can be a challenge. 5G networks offer a potential solution. Next-generation wireless networks offer more spectrum over more channels, increasing the number of devices able to actively connect to a tower at once, and allocating additional bandwidth to each device. 5G also uses small cell antennas, which have much shorter ranges than their macro counterparts.

The overlapping coverage areas that small cell antennas create raise wireless coverage density, which improves connections while alleviating pressure on any one tower. Coverage remains spotty compared to the more established 4G networks, but 20% of new smartphone sales in the U.S. were expected to contain 5G chips by the end of 2021, so improvement is inevitable.[20]

Wireless network providers are increasing investment in digital infrastructure. Data from wireless communications trade association CTIA shows that the wireless industry invested $30 billion into infrastructure projects in 2020, the third consecutive year capital expenditures increased, and the largest year of investment in the last five. Between 2016 and 2020, the industry's investment in infrastructure totaled $140 billion. Over 417,000 new cell sites were built in 2020, a 35% increase from 2016.[21] Over the last two years, a lighter regulatory touch facilitated more cell site construction than in the previous seven years combined.

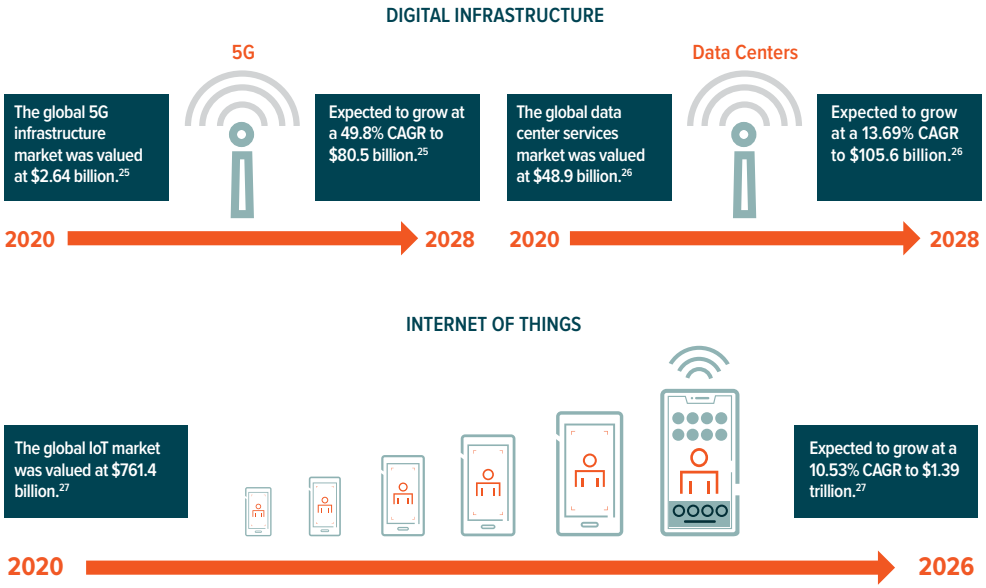
This investment is in addition to the almost $200 billion spent on wireless spectrum auctions over the same period.[22] Spectrum refers to the radio wave frequencies used to transfer wireless signals and is a core component of wireless communications. Auction winners are licensed to transmit on a larger swath of the electromagnetic spectrum, furthering the rollout of 5G technology and increasing the quality of end-user connectivity.

RISKS TO THE CONNECTIVITY THEME

The semiconductor shortage is a headwind for IoT.

Surging demand, including demand from 5G expansion plans, forced foundries to focus on high-margin production, typically the newest and most advanced chips. As a result, the production of lower-tier chips took a backseat. These commodity-type chips are typically used in consumer-focused IoT devices because they generally don't require the fastest networking or processing speeds. An estimated 20 million cellular chipsets will go undelivered due to shortages in 2021, influencing 80% of global manufacturers to report challenges producing digital products and services.[23,24] The result is increased prices and decreased availability of some connected devices, likely negatively affecting sales of consumer goods in the short term.

VISUALIZING THE MARKET OPPORTUNITY



Expanding opportunity that lays the foundation for the digital future.

The chip shortage also affects the 5G rollout because routers, switches, and base stations face longer delivery times. Smaller network providers indicate that equipment delays stalled deployments by 18–24 months.[28] These delays look to be more acute outside of the U.S., given the robust purchasing relationships and financial heft of the large U.S. networks.

IoT devices create more network vulnerabilities.

IoT devices can be easy targets for cybercriminals due to the network integration of many endpoint devices. With more points of failure, network maintenance becomes a larger task, increasing the chances of a missed software update or incorrect device setup. Comcast estimates that U.S. households can be exposed to as many as 104 cybersecurity threats per month, with the most vulnerable devices being smart home gadgets.[29] The general market immaturity of connected devices is the main reason, as cybersecurity issues are often addressed after product creation and through firmware updates. Connected ecosystems such as Google's Nest and Apple's HomeKit could provide solutions, but the risk remains.

THEMATIC INTERSECTION WITH CONNECTIVITY

Robotics & AI and Cloud Computing

The Robotics & AI and Cloud Computing themes intersect with IoT, particularly from an industrial perspective. Industrial IoT can take many forms, but it mainly focuses on increasing operational efficiency via sensor-based monitoring. Future growth in the industrial space could stem from the integration of robotics, cloud computing and connected IoT devices to build smart, automated factories. Artificial intelligence (AI) utilities will rely on data gathered by IoT systems and sensors to present real-time insights about the world around them.

If AI is a system's brain, IoT acts as the digital nervous system. Connectivity will be essential, with private 5G and low power wide area (LPWA) networks playing a critical role in manufacturing automation that enables real-time and remote monitoring of autonomous systems. Juniper Research predicts that the industrial sector will account for over 70% of all IoT connections by 2024.[30]

Health & Wellness

Connected fitness trackers record some of the most intimate data an individual can produce. The health and wellness economy is growing, especially after the pandemic inspired many to be more active and conscious about their wellbeing. The global fitness tracker market grew 19.5% year-over-year in 2020, expanding at a faster rate than the overall IoT space.[31] Fifty-eight percent of U.S. consumers now use smartwatches or fitness trackers to quantify their daily steps, workouts, and sleep.[32]

Additional upside stems from clinical settings, where medical grade sensors can provide lifesaving information. For example, blood sugar tracking and advanced heart monitoring are two key growth areas, as they can take readings in real-time and then share and store patient data with their care team.

CONNECTIVITY IN A PORTFOLIO CONTEXT

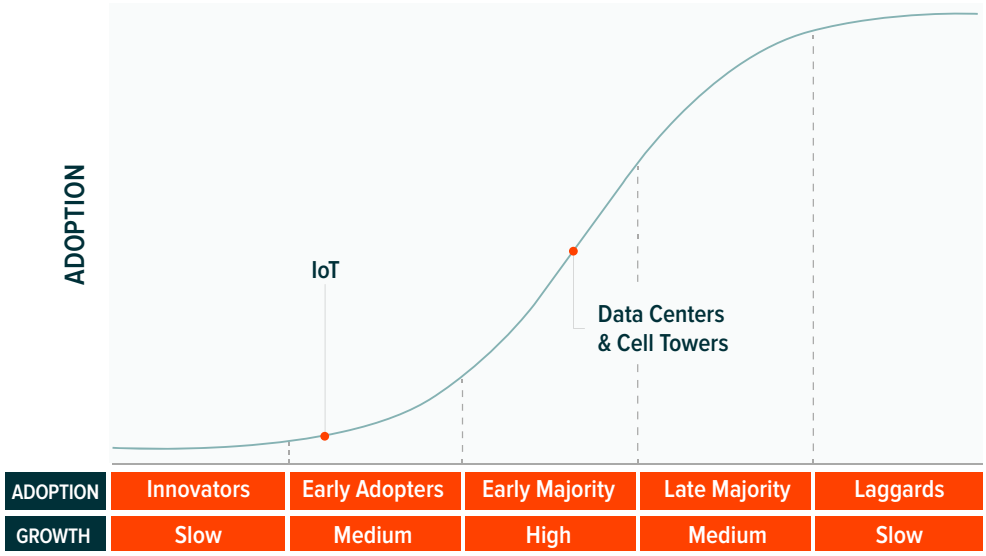
The Connectivity theme lives up to its name by connecting innovative technology and physical infrastructure. We believe this attribute makes the space particularly attractive from a portfolio perspective. Digital infrastructure is further along the adoption curve, falling into the core of the Early Majority phase, and indicating that adoption levels are high and rising. IoT is growing in interest, moving further into the Early Adopters phase, but remaining at a low absolute level.

The companies implementing Connectivity technologies are global and stand to benefit as thematic adoption rises across the world. The pie charts on the next page break down the geographic exposure of the largest Connectivity thematic ETF products. We believe there is ample innovation occurring outside of the states, and that limiting exposure to the U.S. will exclude key players to the detriment of investors over the long term.

In our view, thematic equity should be targeted, using screens to ensure the underlying companies provide the desired exposure. This pure play focus minimizes overlap between themes while also differentiating the exposure provided by the theme relative to broad beta products. We conducted an overlap analysis between Connectivity thematic ETFs, the S&P 500, MSCI ACWI and the most applicable S&P 500 sector ETF for each exposure,

THEMATIC ADOPTION

Source: EM Rogers, "Diffusion of Innovations", 1962, and Global X Research, 2021



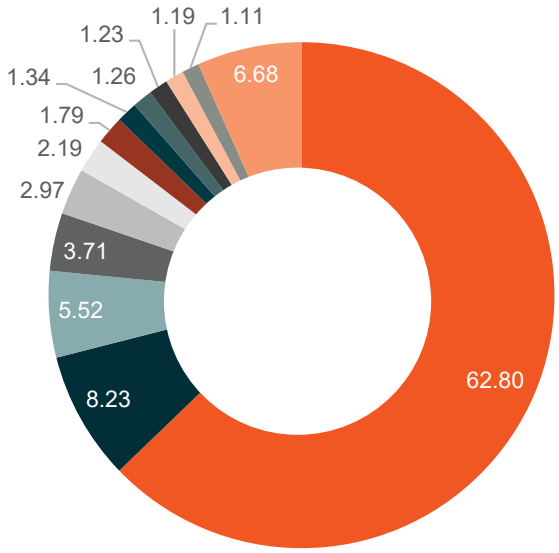
XLK (Technology Select Sector SPDR Fund) for internet of things, and XLRE (Real Estate Select Sector SPDR Fund) for digital infrastructure. We found that average overlap by weight for internet of things was 8.9% when compared to the S&P 500, 7.2% vs. the MSCI ACWI, and 11.7% vs. XLK. Digital Infrastructure scored lower on broad indexes, 2.1% when compared to the S&P 500 and 1.3% vs. the MSCI ACWI, but scored much higher compared to XLRE at 28.0%.[33] These low levels of overlap with broad indexes reflect the benefits of thematic exposure.

The Connectivity theme continues to mature, creating attractive opportunities for long-term investors. The internet of things is now a core technology with connected consumer devices growing in capability and commonality while industrial applications catalyze the Fourth Industrial Revolution. Simultaneously, the digital infrastructure that this connectivity requires continues to advance, including 5G networking technology that provides users with wireless speeds that dwarf those of previous generations.

With data expected to increase exponentially, investment in digital infrastructure has skyrocketed in recent years with wireless providers looking to ensure that their networks can handle the demand. Investment in new and enhanced cell towers and data centers is another sign of the Connectivity theme's maturation, as they can democratize access to the massive processing power of the increasingly connected world.

IOT: AVERAGE GEOGRAPHIC EXPOSURE BY THEME

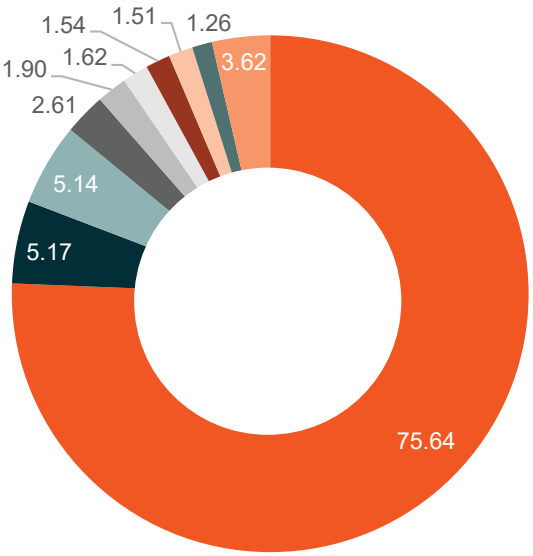
Source: Morningstar data as of 12/31/21.



United States, Taiwan, China, Singapore, Japan, Switzerland, India, France, South Korea, Sweden, Finland, Canada, Other

DIGITAL INFRASTRUCTURE: AVERAGE GEOGRAPHIC EXPOSURE BY THEME

Source: Morningstar data as of 12/31/21.

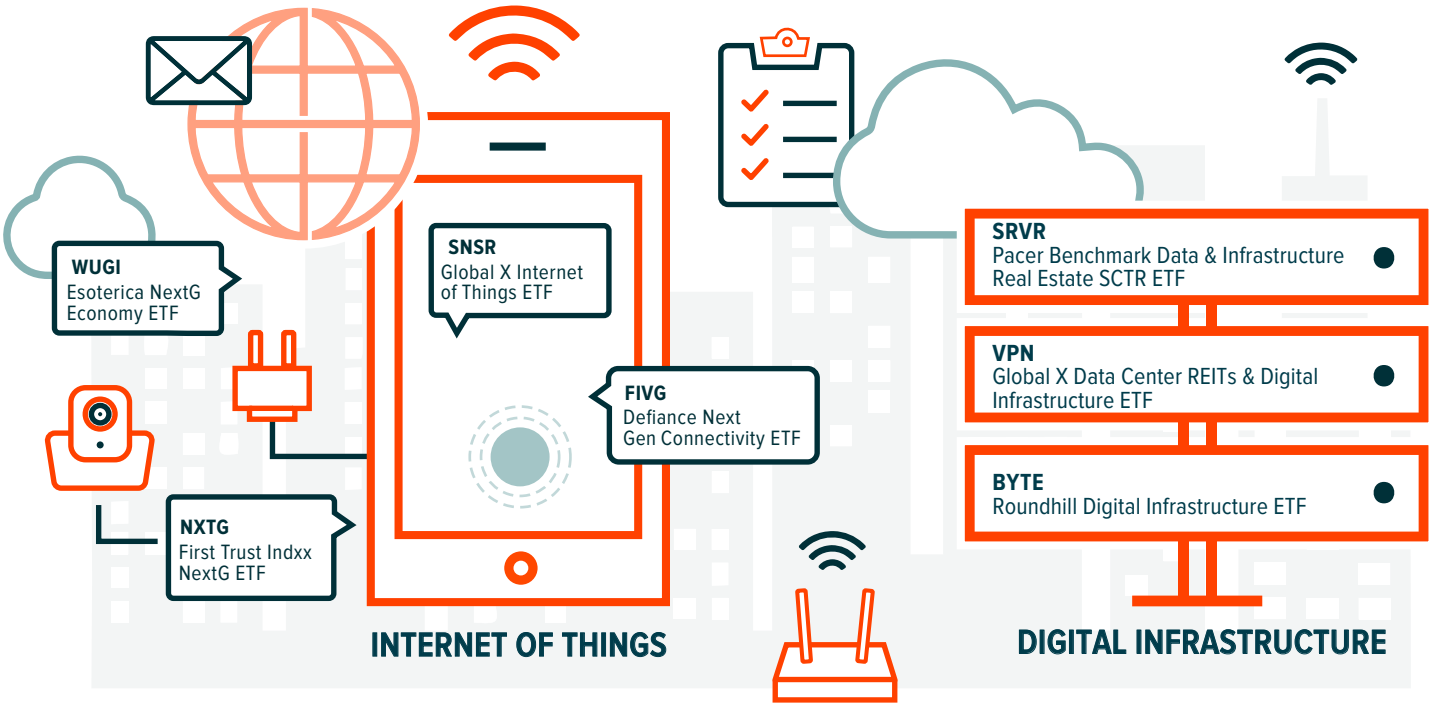


United States, China, Australia, United Kingdom, Indonesia, Spain, Singapore, Mexico, Italy, Other

Note: Pie charts include the largest four internet of things and all three digital infrastructure ETFs according to our thematic classification. All Thematic ETFs weighted the same.

HOW TO ACCESS CONNECTIVITY

The graphic below identifies some U.S. listed ETFs that provide direct exposure to the Digital Infrastructure and Internet of Things themes.



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How Data & Connectivity Relate to the Physical World

In the digital era, everything is becoming more connected and data dependent. Building on the growing pool of data and connections, improved automation systems are changing how processes are run, impacting the future of manufacturing and mobility.

KEY MEGA THEMES:

- Robotics
- Mobility

ROBOTICS & ARTIFICIAL INTELLIGENCE

A constant throughout history is that humans continually look for ways to make work more efficient. With Robotics & AI themes creeping into everyday life, we believe automation is the next step in society's technological evolution. The adoption of robotic and AI tools combined with internet of things (IoT)-based sensors and massive scale cloud computing is sparking the Fourth Industrial Revolution (Industry 4.0), which we expect to increase the efficiency and effectiveness of factory-based production.

KEY TAKEAWAYS

- Robotics solutions look increasingly appealing as their costs fall while wages rise, populations age, and supply chain pressures persist, the result of which is likely a reshoring of manufacturing.
- By leveraging internet of things and cloud computing technologies, automated production systems can gain in efficiency, capability, and performance.
- The Robotics & AI theme is experiencing accelerating adoption, indicating entrance into the Early Majority stage, and signaling an attractive opportunity for portfolio positioning.

WHY ROBOTICS & AI IS SUCH A POWERFUL FORCE

Robotics and AI are the engines behind an impending Fourth Industrial Revolution.

Like previous revolutions, the integration of new technologies could define Industry 4.0, key among them robotics and the internet of things. Together, these technologies are expected to create interconnected manufacturing systems that communicate, analyze, and use data to create positive feedback loops, adapt to changing needs, and increase productivity.

The pinnacle of effective robotic and networking integration is the smart factory — a completely automated production facility that uses data from connected devices to learn and adapt. With this predictive flexibility, smart factories may reduce downtime by auto-scheduling repairs and maintenance when input levels are low or finished product levels are high.

This next-generation production comes as trade wars, supply shocks, and a pandemic reminded the global economy of the fragility and interconnectivity of manufacturing networks. Globalization peaked around 2008, and since then countries have rethought their international trade dependence, reducing the global value of exported goods relative to GDP.[1] COVID-19 only expedited the deglobalization trend. In a 2020 Thomas Industrial survey of 746 manufacturing and industrial companies, 69% of respondents said that they were looking to bring production back to America, and 55% said that they were likely to invest in automation.[2]

Robot economics are becoming more cost-effective.

As manufacturers eye domestic production, the significant cost differential between human and robotic labor grows in stature. Higher wages for humans make automated labor more attractive as firms look for ways to maintain price competitiveness. The average yearly U.S. manufacturing wage neared $50,400 in September 2021, up from $46,600 at the beginning of 2020.[3] So, for example, despite an estimated upfront cost of $250,000 for a sophisticated industrial robotic arm, a company could potentially break even in less than two years compared to what traditional labor costs.[4]

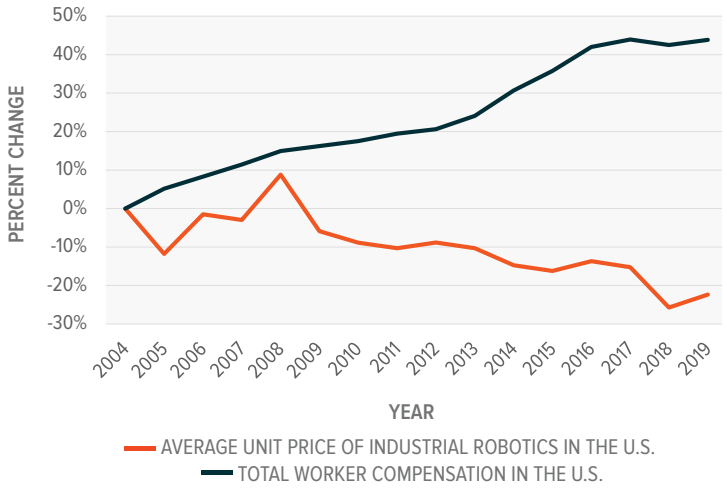
These economics are likely to become more attractive as robotics improve in function and affordability. The average robot price has fallen by more than 50% in real terms over the last 30 years, while labor costs have increased by more than 100%.[5] These cheaper robots are significantly more advanced than older versions. Along with higher dexterity, advanced 3D vision capabilities and swappable end-of-arm tooling create more dynamic robots that are able to perform multiple functions with the capability to improve with software updates.

Robotics can improve human productivity.

Collaborative robots, also known as cobots, work alongside humans, taking on repetitive tasks that are prime sources of boredom and injury. This combination approach plays to the strengths of both labor sources because it decreases the error rate while increasing production efficiency.[6]

PRICE OF INDUSTRIAL ROBOTS VS TOTAL WORKER COMPENSATION IN THE US

Source: International Federation of Robotics, May 2021, Economic Policy Institute, February 2020.

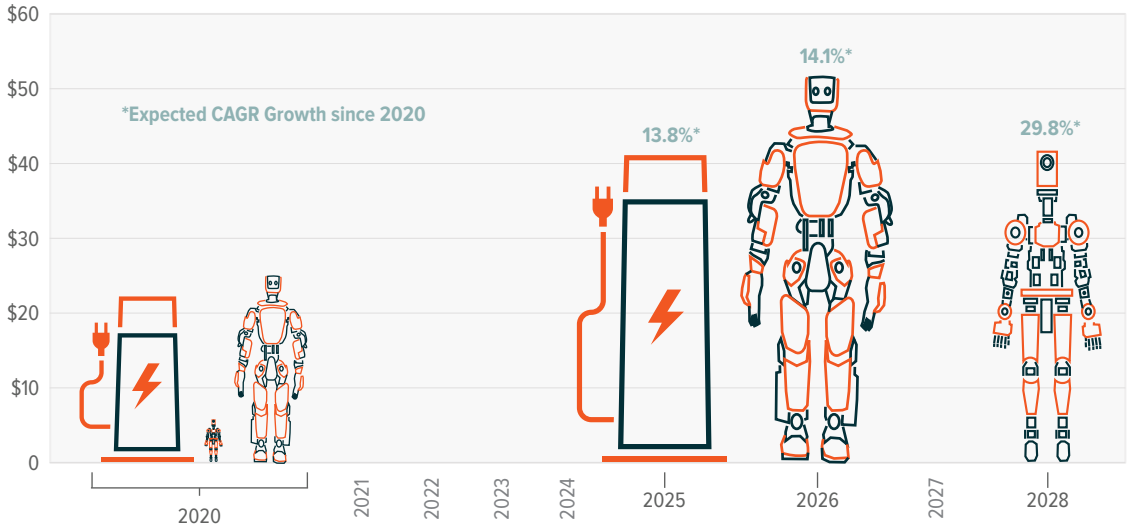


An increasingly automated future may be necessary given the world's rapidly aging workforce. The World Health Organization (WHO) predicts that between 2015 and 2030 the proportion of the global population aged over 60 will nearly double from 12% to 22%.[7] Domestically, 65+ age bracket comprises an even larger percentage of the population at 16.3% as of the 2020 census, and it's expected to grow to 20%+ by 2030, surpassing the under 18 age group.[8,9]

This trend is positive overall because it suggests that people are living longer and healthier lives due to advancements in healthcare. However, with age comes metabolic and cellular decline that can compromise physical and mental capacity, which the workplace can expose. This lower productivity at the individual worker level translates into lower GDP growth nationally. A 10% increase in the fraction of the population aged 60+ decreases the growth rate of GDP per capita by 5.5%.[10] Robotics adoption can help offset these declines. A 1-unit increase in robotic density, or the number of robots per 10,000 manufacturing workers, increases labor productivity by 0.04% while potentially freeing up labor for use elsewhere in the economy.[11]

VISUALIZING THE MARKET OPPORTUNITY

ROBOTICS: EXPECTED GROWTH IN BILLIONS[12,13,14]



Non-industrial Robotics

Robots and AI used for non-industrial applications, such as health care, hospitality, and consumer uses.

Industrial Robots and Automation

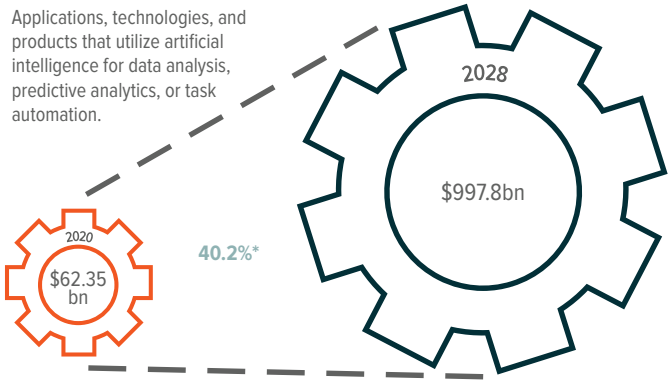
Robots and robotic automation products and services with a focus on industrial applications, such as smart factories.

Unmanned Vehicles and Drones

Self-driving or autonomous vehicles and drones for military, consumer, and commercial uses.

ARTIFICIAL INTELLIGENCE: EXPECTED GROWTH IN BILLIONS[15]

Applications, technologies, and products that utilize artificial intelligence for data analysis, predictive analytics, or task automation.



The global market for Artificial Intelligence applications is expected to expand at an impressive 40.2% CAGR to reach almost a trillion dollars in total value by 2028.

RISKS TO THE ROBOTICS & AI THEME

A China slowdown could have an outsized impact.

China is the largest and fastest-growing global market for robotics, having installed more industrial robots than the next four countries combined.[16] In Q1 2020, when Chinese factories were shuddered due to COVID-19, industrial robotic sales there fell by 20% year-over-year, and international suppliers felt the decline.[17] Then, as the rest of the world shut down and China returned to life, it installed more industrial robotics than the next 15 largest markets combined.[18] This surge resulted in the five largest industrial robotics suppliers by revenue deriving roughly 20% of their income on average from Chinese purchases during 2020.[19]

Regulatory risks could dampen U.S. adoption.

The U.S. could catch up to China as reshoring of manufacturing continues. However, a risk to large increases in domestic robot density is that it can result in public backlash. We see the potential for robotics adoption to rise alongside income inequality, and we see the potential for policy makers to respond by enacting new taxes and regulations. So-called robot taxes would serve two purposes: To disincentivize firms from replacing workers with robots and to supplement lost payroll tax revenue. By design, these policies would be destructive for the Robotics & AI theme. While not a near-term issue, if such policies were to have any chance of passing in the future, the stock price reaction would likely be dramatic.

Manufacturing is particularly exposed to cyber threats.

Like any technology, robotics manufacturers can be hijacked by malicious actors, whether cybercriminals, competing companies, or foreign states. Verizon data shows that the manufacturing industry had the third-highest level of large-scale data breaches in 2020, with system intrusions due to hacking and malware especially common.[20] Unauthorized access is a particular concern because most robotic systems are designed to interact with and manipulate objects in the real world.

However, cybersecurity programs remain underfunded. Manufacturers typically operate on thin margins, leaving cybersecurity a lower priority than capex spending that can increase productivity or output. According to information technology solutions company CDW, just 22% of manufacturing firms who experienced an attack in recent years increased their cybersecurity budgets, while about half did nothing at all.[21] As production continues to automate, securing connected devices will require additional investment.

THEMATIC INTERSECTION WITH ROBOTICS & AI

Internet of Things and Cloud Computing.

The Robotics & AI, IoT, and Cloud Computing themes fit together perfectly. The IoT theme likely represents the biggest integration opportunity because IoT sensors are core to Industry 4.0 and smart factory trends. As sensor costs continue to fall, the accuracy and availability of data captured from robotic systems may increase. These developments should create a positive feedback loop spurring robotic purchases as updated sensor packages increase the effectiveness of machines young and old.

Cheaper processing power due to further maturation of the Cloud Computing theme allows AI tools to make quicker and more accurate judgements from sensor data. We expect such insights to drive efficiency gains, and increased factory performance could promote expansion via further robotics spending.

Cybersecurity

The downside of all this connectivity is that manufacturers are regular targets for digital intrusions. We expect their responses to this growing threat to improve significantly due to the increasing cost of malicious activity and the growing integration of technology in production. To this end, increased spending on robotics necessitates increased spending on cybersecurity initiatives. Co-positioning with the Cybersecurity theme may help to lessen cybersecurity risks from the roboticized manufacturing space.

ROBOTICS & AI IN A PORTFOLIO CONTEXT

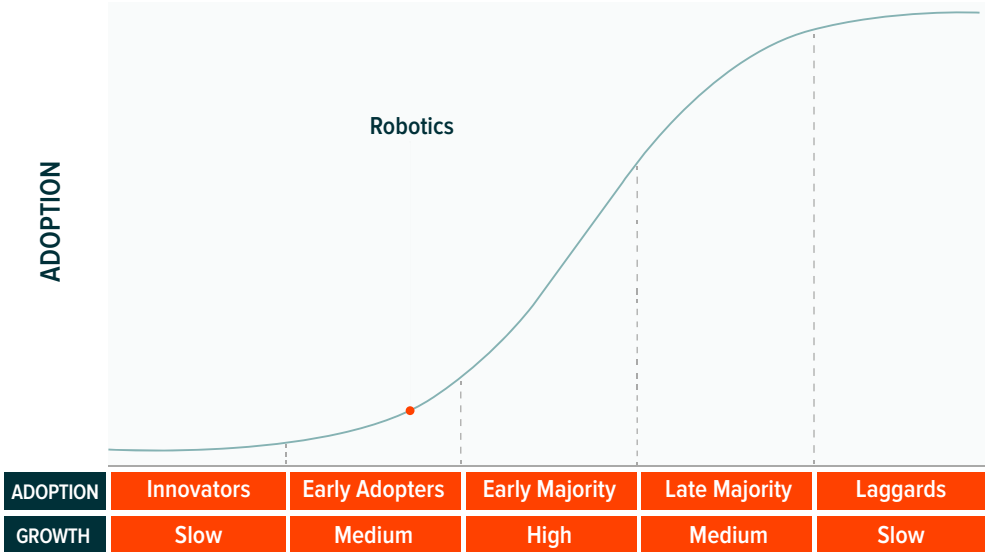
The Robotics & AI theme is quietly humming along, integrating itself into the global economy. Falling squarely into the Early Adopters phase, robotic penetration levels are moderate today, but are accelerating quickly, as technological advancements enable Robotics & AI to play increasingly impactful roles. We believe that adoption levels are set to expand rapidly in the coming years, as firms and individuals leverage robot and AI tech in new and exciting ways.

The companies implementing Robotics and AI technologies are global and stand to benefit as thematic adoption rises across the world. The pie chart breaks down the geographic exposure of the largest Robotics and AI thematic ETF products. We believe there is ample innovation occurring outside of the states, and that limiting exposure to the U.S. will exclude key players to the detriment of investors over the long term.

In our view, thematic equity should be targeted, using screens to ensure the underlying companies provide the desired exposure. This pure play focus minimizes overlap between themes, while also differentiating the exposure provided by the theme relative to broad beta products. We conducted an overlap analysis between Robotics and AI thematic ETFs, the S&P 500, MSCI ACWI and the most applicable S&P 500 sector ETF, XLI (Industrial Select Sector SPDR Fund). We found that average overlap by weight for Robotics and AI focused ETFs was 5.7% when compared to the S&P 500, 5.2% vs. the MSCI ACWI, and 2.4% vs. XLI.[22] Common holdings included medically focused robotics producers, semiconductor firms that produce AI chips, and heavy machinery manufacturers, collectively totaling just a handful of individual companies. These low levels of overlap with broad indexes reflect the benefits of thematic exposure.

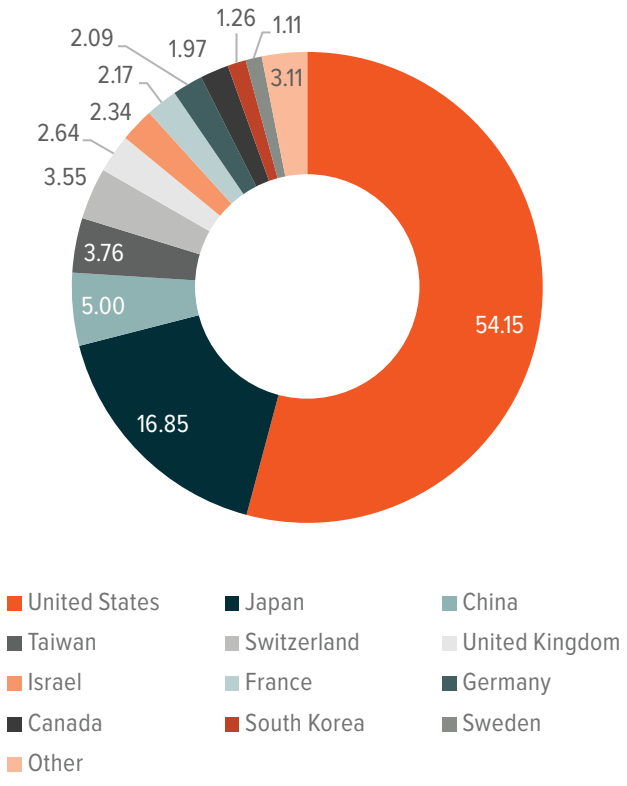
THEMATIC ADOPTION

Source: EM Rogers, "Diffusion of Innovations", 1962, and Global X Research, 2021.



ROBOTICS AND AI: AVERAGE GEOGRAPHIC EXPOSURE BY THEME

Source: Morningstar data as of 12/31/21.



Note: Pie chart includes the largest five robotics and AI ETFs according to our thematic classification. All Thematic ETFs weighted the same.

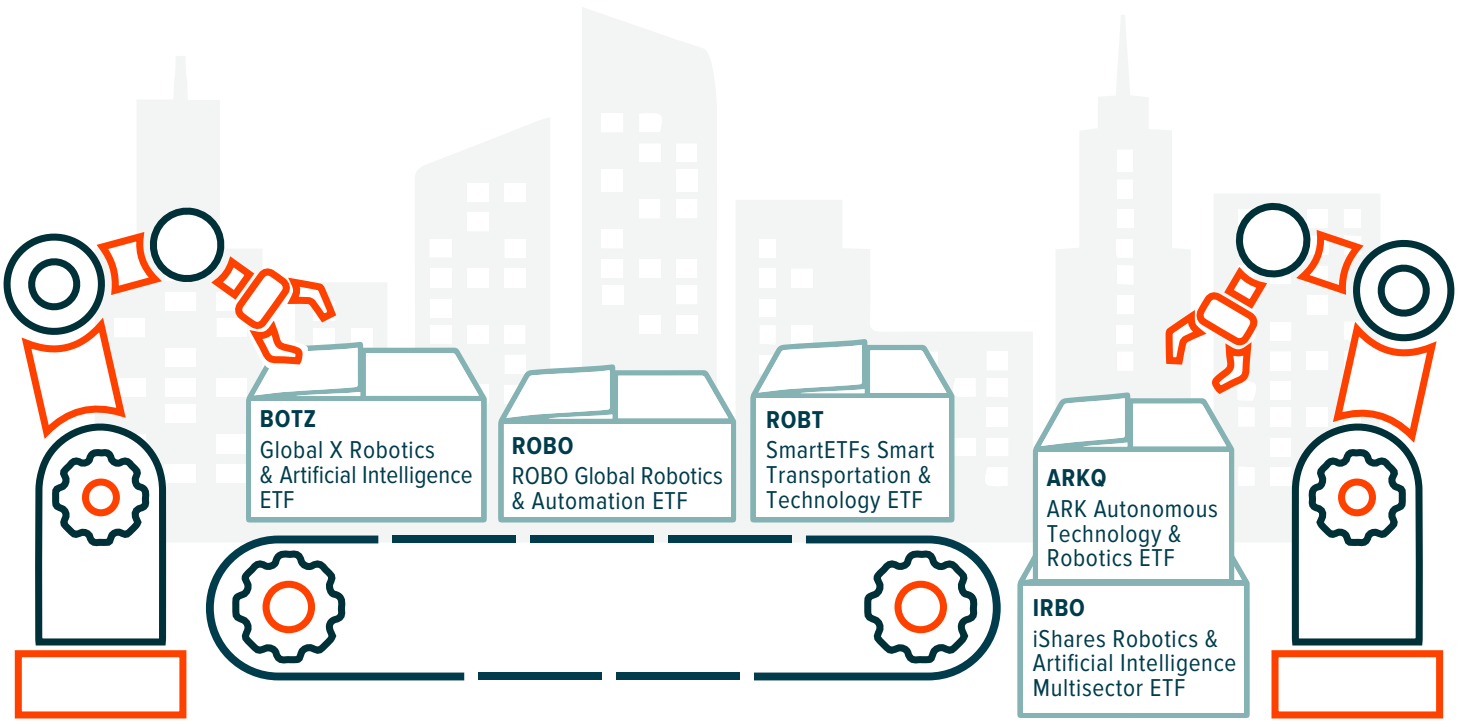
HOW DATA AND CONNECTIVITY RELATE TO THE PHYSICAL WORLD

The Robotics & AI theme sits at the crossroads of multiple structural trends that are expected to increase adoption in the coming years. Rising inflation, supply chain disruptions, deglobalization, and aging populations have firms exploring solutions to enhance manufacturing efficiency and reduce costs. As automation becomes increasingly capable, cheaper, and easier to implement, reshoring will likely accelerate as firms see that the benefits of more localized manufacturing outweigh the risks of producing goods far abroad.

From this perspective, the space looks primed for investment as catalysts drive Robotics and AI adoption into the Early Majority stage. The global average robotic density is at just 126 per 10,000 employees, illustrating the scale of the opportunity as automation begins to answer the problems of today with the machines of tomorrow.[23]

HOW TO ACCESS ROBOTICS & AI

Eleven U.S. listed ETFs provide direct exposure to the Robotics & AI theme, the graphic below identifies the five largest.



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MOBILITY (EV/AVs & LITHIUM/ BATTERY TECHNOLOGY)

Electronic and autonomous vehicles (EV/AVs) highlight the Mobility theme's potential, as they represent an entirely new class of everyday consumer goods and services that use artificial intelligence (AI) for their core functionality. The EV/AV revolution runs parallel to electrification via lithium-based batteries, a similarly influential component of Mobility. As disruption in the transportation sector takes hold, we expect the benefits of EVs, AVs, and lithium battery technologies to proliferate across the global economy.

KEY TAKEAWAYS

- Consumer appetite for EVs is high. A recent survey revealed that 7 out of 10 U.S. drivers would be interested in buying when EV charging infrastructure expand, and EV costs drop.[1]
- Better lithium-ion technology will increase the amount of lithium used in each EV battery. Lithium demand is expected to more than double from 300,000 mt in 2020 to 1 million mt by 2025 and reach 2 million mt by 2030.[2]
- We expect the integration of robotics, AI, and internet of things (IoT) technologies to propel the Mobility theme and eventually the adoption of fully autonomous EVs.

WHY AV AND EVS ARE SUCH POWERFUL FORCES

Mobility is becoming cleaner, smarter, and more autonomous.

Using AI to compute billions of data points per second supplied from an array of sensors, cameras, and radar systems, AVs can effectively see the road and respond accordingly to changing conditions. By communicating with and integrating data from neighboring vehicles and even the roadways at large, AVs are expected to reduce accident rates, increase throughput and decrease travel time.

Fully autonomous vehicles remain years away, but it's not too early to project the economic efficiencies they could bring. Trucking company Ryder estimates a fully autonomous truck and transfer hub network could reduce costs by 29–40%, decreasing empty trailer time while increasing flexibility.[3] Such efficiency gains would revolutionize domestic supply chains, increasing the availability of lower-priced goods. Effective AV technology will also allow non-commercial drivers to reclaim hours each day spent commuting, which currently total 70 billion hours per year in the U.S.[4] This found personal time represents a massive opportunity because it creates a distinct space for rest, relaxation, content consumption and productivity.

Regulation remains a key consideration for the development of autonomous vehicles. Recently, the U.S. National Highway Traffic Safety Administration (NHTSA) issued new rules for future fully autonomous vehicles, providing some regulatory clarity to AV OEMs. The new rules eliminate the requirement for driverless vehicles to include manual controls, such as pedals and steering wheels. This change could accelerate the path-to-market for AVs by bringing regulatory policy more in line with the AV development cycle, while ensuring safety standards.

EVs are nearing broad market adoption.

With over 1.8 million EVs registered in the U.S. as of the end of 2020, many Americans are already zooming around in emission-free vehicles.[5] U.S. adoption of electric vehicles slowed in 2021 despite increasing in other regions of the globe. Given polls showing that 7 out of 10 U.S. drivers are interested in buying an EV should charging infrastructure proliferate and costs drop, we believe that a confluence of policy changes and technological advancement will spark higher adoption rates.[6]

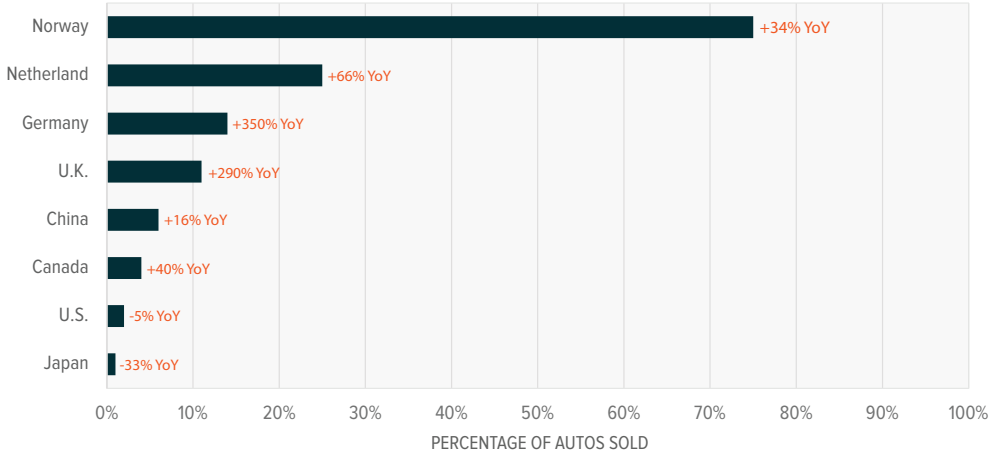
Norway, the global leader in EV adoption, offers a roadmap. In 2020, 75% of cars sold in Norway were electric.[7] The country plans to sell its last internal combustion engine (ICE) vehicle in 2025, a rapid transition sped up by aggressive policy changes. Polices include an exemption of EVs from a value added tax (VAT) and vehicle purchase taxes, which in some cases can lower the purchase cost by nearly 50% compared to an equivalent ICE vehicle. Another perk is EV access to bus lanes, which can shorten travel times.[8] The World Economic Forum believes these polices closed the price gap between EVs and ICE vehicles in Norway.[9]

U.S. to ramp up investment in charging infrastructure.

The U.S. lags many European nations due in part to limited EV incentive structures. Forty-five states and D.C. offer some form of incentive, but the federal government hasn't passed any new subsidies since 2009, and many popular EV models are no longer eligible.[10] President Biden's Build Back Better bill may be able to address this relative shortfall by restructuring incentive programs and offering expanded tax credits should vehicles meet a wider set of conditions. The bill's passage remains uncertain, but it indicates that policy makers recognize that an enhanced incentive program is key to spur domestic EV adoption.

EV'S SHARE OF AUTOS SOLD IN 2020

Source: IEA data as of April 2021.



Note: Above reflects select markets. Other markets may have +/- EV share, though Norway leads.

"Over **1.8 million** EVs registered in the U.S. as of 2020. In the same year, **75%** of cars sold in Norway were electric."

In the geographically expansive U.S., the build-out of charging infrastructure will take time. The number of public charging stations has more than tripled since 2015, but the U.S. has a long way to go. EV charging stations total roughly 48,400, with just 5,398 classed as DC Fast Chargers, compared to more than 150,000 gas stations.[11,12] More DC Fast Chargers are essential, as less powerful options can take substantial time to recharge, increasing the perceived inconvenience of EVs. The $7.5 billion in grant funding for a national network of charging stations contained in the Infrastructure Investment and Jobs Act will not solve the charger shortage. However, it is the first federally lead investment in charging infrastructure, and it could portend the strategic direction of future funding.

Private investment is following suit with original equipment auto manufacturers and independent charging companies expanding their networks. Tesla and Electrify America, a subsidiary of Volkswagen, pledged to triple and double the size of their charging networks, respectively, over the next two years. Sizable private investment alongside public support will likely be able to address infrastructure shortfalls in the coming years.

Another factor working against large-scale adoption of EVs thus far in the U.S. and elsewhere is their premium cost. Incentives such as tax breaks and rebates may help close this gap, based on the success of such programs in Europe and China. But even without subsidies, EVs are expected to be cheaper than ICE vehicles in only about five years as battery costs continue to fall.[13]

Cheaper batteries are expected to lower EV prices.

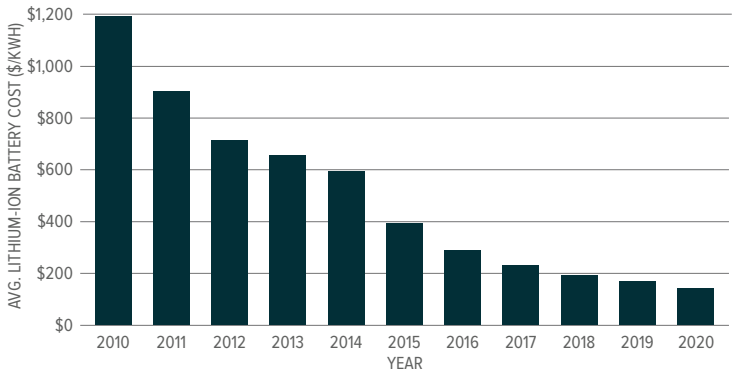
Global X Research estimates that battery costs could be cut in half by 2030.[14] Worldwide, the lithium battery market is expected to grow by a factor of 5–10x over the next decade.[15] As of this writing, supply restrictions and rising demand increased lithium prices by 225% in 2021.[16] Lithium demand is expected to more than double from 300,000 mt in 2020 to 1 million mt by 2025, and then reach 2 million mt by 2030.[17]

At the core of each battery is lithium metal. As demand grows, EVs could use up to 75% of all newly mined lithium by 2025.[18] As the 33rd most common element in the Earth's crust, there is no shortage.[19] But it takes time to bring additional supply online. Improvements to lithium-ion technology will increase per battery lithium utilization. Currently, most batteries use lithium in the cathode component, while next-generation batteries will likely place lithium in the anode as well.

Transitioning to a green energy economy will also require massive capacity of long-duration, grid-scale storage. Lithium-ion batteries are the most common battery storage option today, accounting for more than 90% of global grid battery storage.[20] Lightweight and energy dense, lithium-ion batteries discharge quickly and can be assembled into modular and flexible energy storage systems.

DECLINING BATTERY COSTS SHOULD DRIVE EV & LITHIUM DEMAND

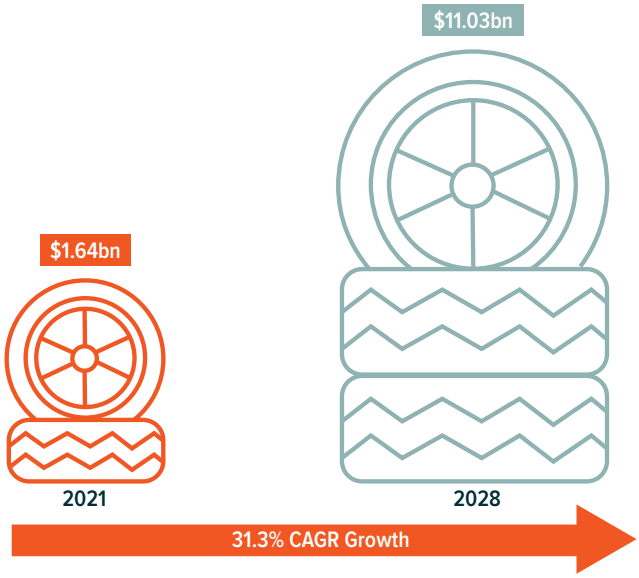
Source: Bloomberg New Energy Finance data as of December 2020.



The Hornsdale Power Reserve in Australia, the largest lithium-ion battery installation in the world when built, prevented a cascading blackout in 2017 when a large coal power plant fell offline. The storage system supplied several megawatts of power within milliseconds and supported the grid until another plant came online. This capability demonstrates the benefits of battery storage, even outside of a renewables context.

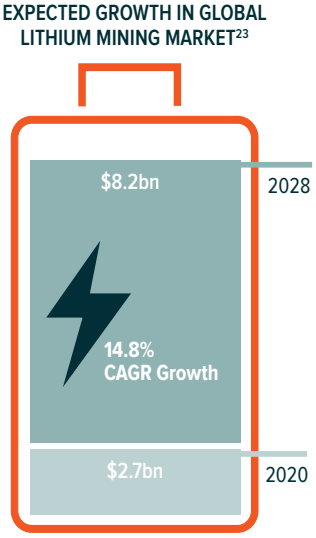
VISUALIZING THE MARKET OPPORTUNITY

EXPECTED GROWTH IN GLOBAL AUTONOMOUS CARS MARKET[21]

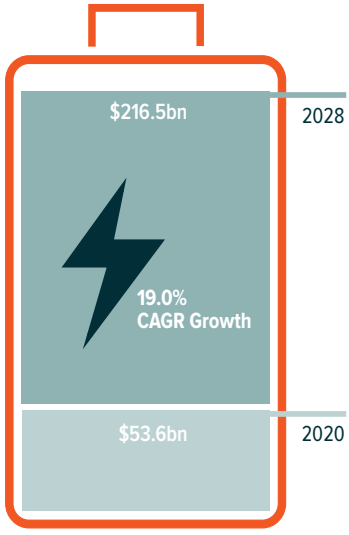


EXPECTED GROWTH IN GLOBAL EV MARKET[22]

EXPECTED GROWTH IN GLOBAL LITHIUM MINING MARKET[23]



EXPECTED GROWTH IN GLOBAL LITHIUM-ION BATTERY MARKET[24]



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RISKS TO THE MOBILITY THEME

Restrictive regulations could stunt adoption.

We believe the main risk to the adoption of fully autonomous vehicles is a mismatch between their technological advancement and consumer expectations. According to the National Highway Traffic Safety Administration (NHTSA), the highest level of autonomous systems currently available in the U.S. is Level 3, where the automated driving system can perform all aspects of driving under some conditions. However, a human driver must be ready to take back control at any time.[25]

Object detection and classification failures by autonomous systems have led to driver and pedestrian fatalities due to driver negligence. Such events are rare but well-publicized, and they can result in state governments restricting autonomous vehicle testing on their roads. For example, California banned a leading ride share company's self-driving cars for nearly two years following a 2018 crash that resulted in the first documented death of a pedestrian.[26]

Environmental costs can be high.

EVs and battery technology represent green tech, but another risk to the Mobility theme is that they have their environmental problems, too. Extraction and processing of any raw material creates externalities, and lithium is no different. The two most common extraction methods source the metal from underground brine reservoirs or mined lithium containing rocks.

Both methods create carbon emissions while using water and land resources. On average, producing a ton of lithium from hard rock sources yields 9 tons of CO2, reducing emissions savings of end-use applications.[27] Newer methods such as brine recovery limit emissions to a third of traditional methods, but they can cause other issues such as watershed contamination.[28] With focus shifting to more holistic supply chains, these issues may grow in stature.

Connected vehicles create opportunities for cybercriminals.

Like other themes that rely on connectivity, cybersecurity is a risk for Mobility. In a now-famous story from 2015, Wired magazine worked with a hacker group to demonstrate the vulnerabilities in connected vehicles.[29] Remotely accessing a Jeep while it was traveling 70 mph on a highway, the hackers cut engine power, engaged and then removed access to breaks, and changed radio and climate settings. This specific vulnerability was patched, but it illustrates the potential risks consumers face as vehicles become increasingly computerized and connected. To identify and mitigate similar risks, we expect cybersecurity investments from automobile OEMs to increase.

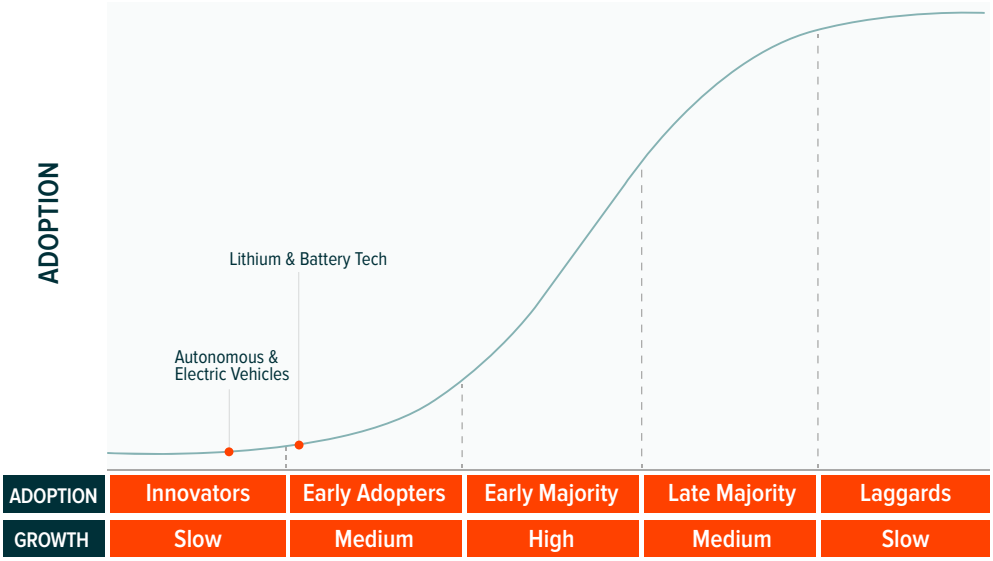
THEMATIC INTERSECTION WITH MOBILITY

Robotics & AI

At the heart of modern-day vehicles is a digital brain powered by a specifically trained AI, the most advanced of which currently enables driver-assist features such as lane departure monitoring. Eventually, this technology could enable full self-driving capabilities. Improvements in these deep learning-based image recognition systems and EV-specific semiconductors could dramatically increase operations per second performance, boosting the speed and ability with which autos model the road environment. This software layer can be improved more rapidly than hardware, and it can be updated and enhanced after a car rolls off of the lot.

THEMATIC ADOPTION

Source: EM Rogers, "Diffusion of Innovations", 1962, and Global X Research, 2021.



Internet of Things

The Internet of Things theme is central to autonomous driving systems, particularly the use of sensor technology. Aggregating real-time traffic data could allow vehicles to more accurately model the world, planning out routes to increase traffic flow and improve safety. Connected sensor-based EV charging stations could monitor the number of EVs in route for a recharge, reducing downtime by automatically scheduling charger maintenance when expected vehicle demand is low. Sensors could also help route incoming vehicles to ideal charging locations with current availability.

MOBILITY IN A PORTFOLIO CONTEXT

The Mobility theme is earlier on in its life cycle than others within our coverage. While adoption of electric vehicles is gaining steam, the theme remains in the Innovators phase, held back by today's self-driving limitations. There are few pure-play EV/AV companies and even fewer are publicly traded. The space is dominated by a large pioneer, while more classical auto OEMs play catchup. Lithium and battery technology is slightly farther along, entering the Early Adopters phase as commercial uses grow and begin to scale. Over the coming years we expect both Mobility themes to progress further into the Early Adopters stage where growth accelerates while remaining at a low absolute level.

Mobility technologies are global and stand to benefit as thematic adoption rises across the world. The pie charts, on the next page, break down the geographic exposure of the largest Mobility thematic ETF products. We believe there is ample innovation occurring outside of the states, and that limiting exposure to the U.S. will exclude key players to the detriment of investors over the long term.

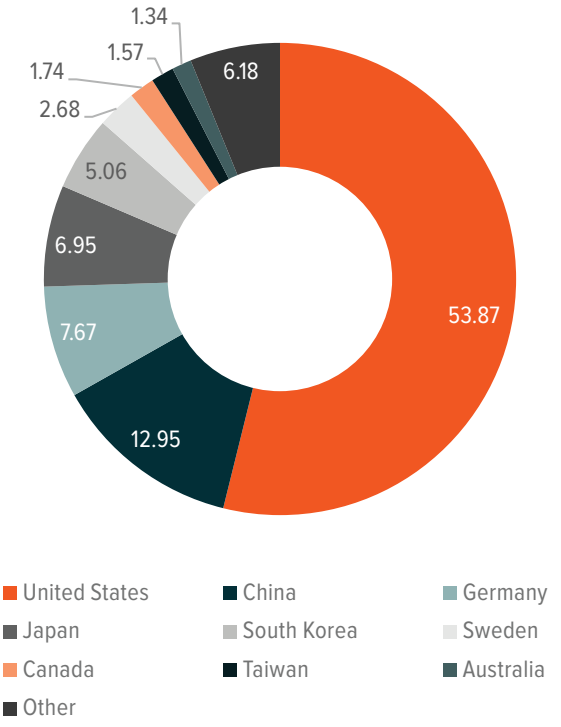
In our view, thematic equity should be targeted, using screens to ensure the underlying companies provide the desired exposure. This pure play focus minimizes overlap between themes while also differentiating the exposure provided by the theme relative to broad beta products. We conducted an overlap analysis between Mobility thematic ETFs, the S&P 500, MSCI ACWI and the most applicable S&P 500 sector ETFs for each exposure, XLY & XLK (Consumer Discretionary and Technology Select Sector SPDR Funds) for electric and autonomous vehicles, and XLB (Materials Select Sector SPDR Fund) for lithium and battery technology. We found that average overlap

by weight for EV/AVs was 8.3% when compared to the S&P 500, 6.7% vs. the MSCI ACWI, 7.4% vs. XLY and 8.3% vs XLK. Much of this overlap stems from traditional vehicle OEMs and large technology companies innovating in the space. Lithium and battery technology scored lower across the board, 2.0% when compared to the S&P 500, 1.6% vs. the MSCI ACWI and 1.9% compared to XLB.[30] These low levels of overlap with broad indexes reflect the benefits of thematic exposure, as sector indexes have yet to include substantial exposures towards Mobility themes.

Mobility innovation represents one of the most tangible areas of technological advancement for the average consumer. Battery costs are falling, while technology and performance are improving dramatically. Soon, EVs won't be a luxury choice, but an economical one. Over the next decade, electrification and automation technologies may merge to forever alter nearly all forms of transportation. The ways we commute, travel and trade could receive an upgrade, powered by a new generation of lithium-based batteries and artificial intelligence. Electric vehicles are at the precipice of transforming the automobile market, and look to be an attractive investment opportunity for years to come.

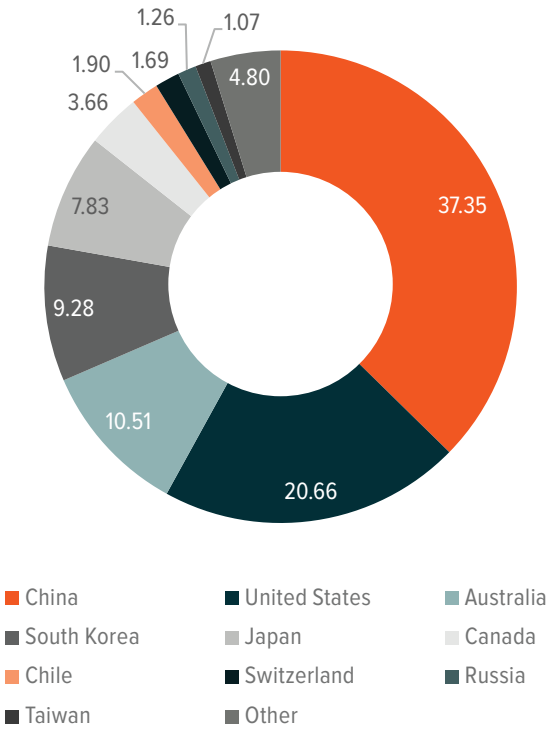
ELECTRIC & AUTONOMOUS VEHICLES: AVERAGE GEOGRAPHIC EXPOSURE BY THEME

Source: Morningstar data as of 12/31/21.



LITHIUM & BATTERY TECHNOLOGY: AVERAGE GEOGRAPHIC EXPOSURE BY THEME

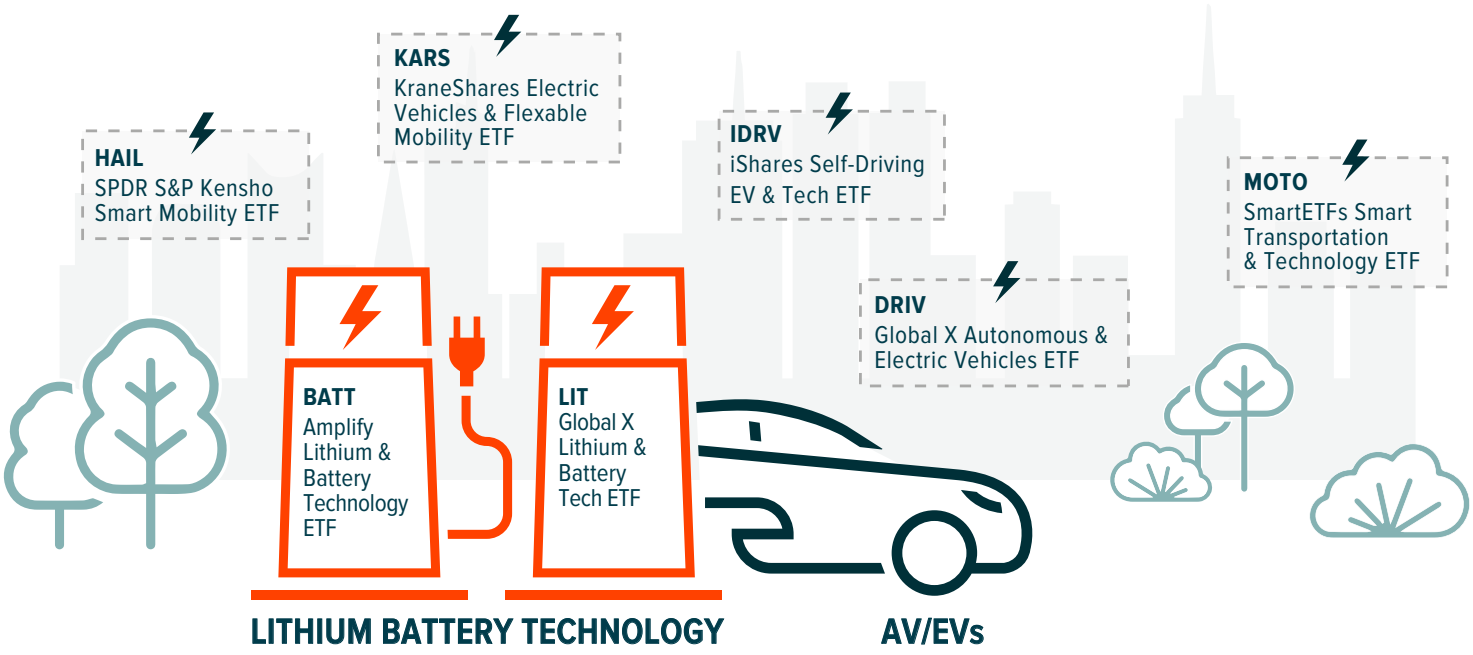
Source: Morningstar data as of 12/31/21.



Note: Pie charts include the largest five electric and autonomous vehicles and all two lithium and battery technology ETFs according to our thematic classification. All Thematic ETFs weighted the same.

HOW TO ACCESS MOBILITY

The graphic below identifies some U.S. listed ETFs that provide direct exposure to the Mobility theme through AV/EVs & lithium/battery technology.



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