From: Zahn, Aaron F. - Managing Director/CEO <zahnaf@jea.com>
Sent: Wednesday, January 16, 2019 6:39 AM
To: (Mgmt - JEA Senior Leadership Team (SLT)
Cc: Bartley, La'Trece M. - Mgr Executive Administration
Subject: Big Ideas of 2019 - ARK
Attachments: Big-Ideas-2019-ARKInvest.pdf; ATT00001.txt

Team -
I look forward to our conversation today as an SLT.

Right now we are focused on building foundations.
1. Align all stakeholders to what matters.
2. Create the right culture for the future.
3. Design incentives to drive desired results and behavior.
4. Define our "Status Quo Baseline" case if we do nothing.
5. Determine the rationale for change - is "Status Quo Baseline" acceptable?
6. Create strategic plan to determine incremental and fundamental shifts necessary to alter baseline case from "Status Quo Baseline" to "Desired Future Baseline"
7. Execute and iteratively adjust as needed based on new data.
8. Always remember to hit the "emergency stop" (figurative) in order to keep logic from 1-7 in line.

This is an interesting read on the possible and the trends in and around our industry. My bet is that this team has a few more really interesting ideas that have exponential impact.

We need to get the foundation right. Please make sure to raise your hand if you feel we skip a step. Future possibilities are exciting but they are not possible without a strong foundation.

Feel free to share.
A

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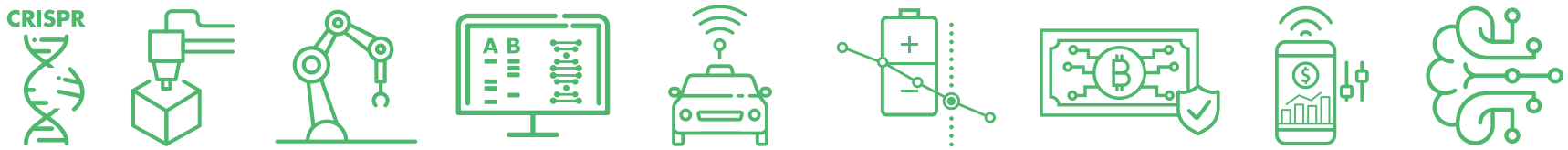
ARK INVEST

BIG IDEAS 2019



Innovation is Key to Growth

January 14, 2019 | For Informational Purposes Only

Why Invest in Disruptive Innovation?

ARK believes that disruptive innovation is key to growth. We aim to identify large-scale investment opportunities by focusing on public companies that are the leaders, enablers, and beneficiaries of disruptive innovation.

Opportunities resulting from disruptive innovation are often undiscovered or misunderstood by traditional investment managers who are focused on sectors, indexes, short-term earnings and price movements.

ARK's research spans across sectors, industries, and markets to gain a deeper understanding of the convergence, market potential, and long-term impact of disruptive innovation.

DISRUPTIVE · INNOVATION

/dIsˈrʌptIv/ • /InəˈveIʃ(ə)n/

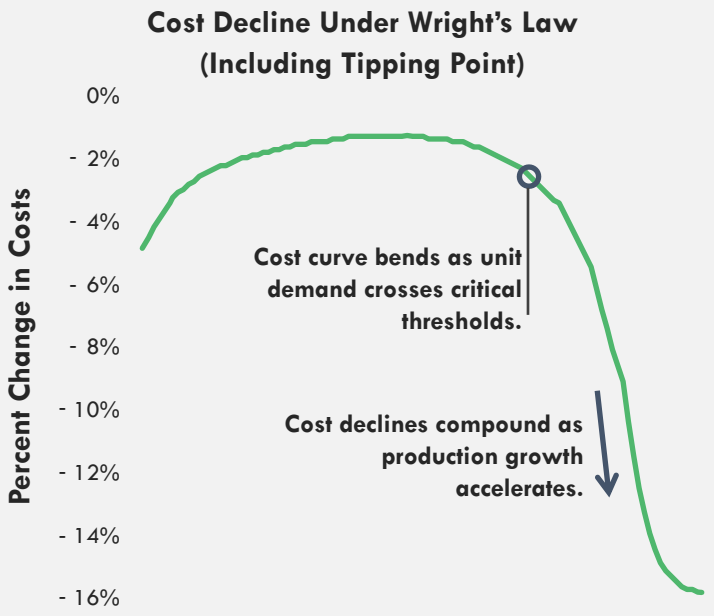
ARK defines "disruptive innovation" as the introduction of a technologically enabled new product or service that should transform economic activity by creating simplicity and accessibility while driving down costs.

Risk of Investing in Disruptive Innovation: *ARK aims to educate investors and to size the potential opportunity of Disruptive Innovation, noting that risks and uncertainties may impact our projections and research models. Investors should use the content presented for informational purposes only, and be aware of market risk, disruptive innovation risk and regulatory risk.*

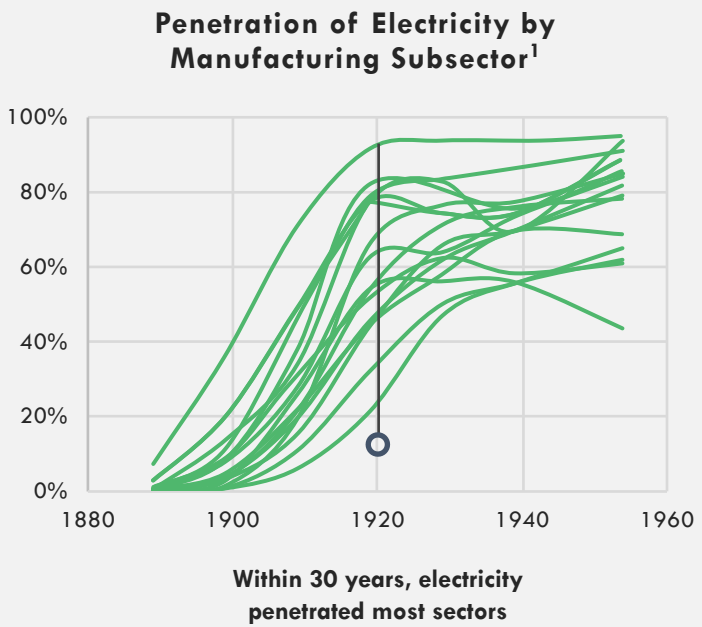
Identifying Investable Innovation Platforms

ARK's investment process recognizes that true disruptive innovation causes rapid cost declines and demand growth, cuts across sectors and geographies, and spawns further innovation, stimulating growth over extended time horizons.

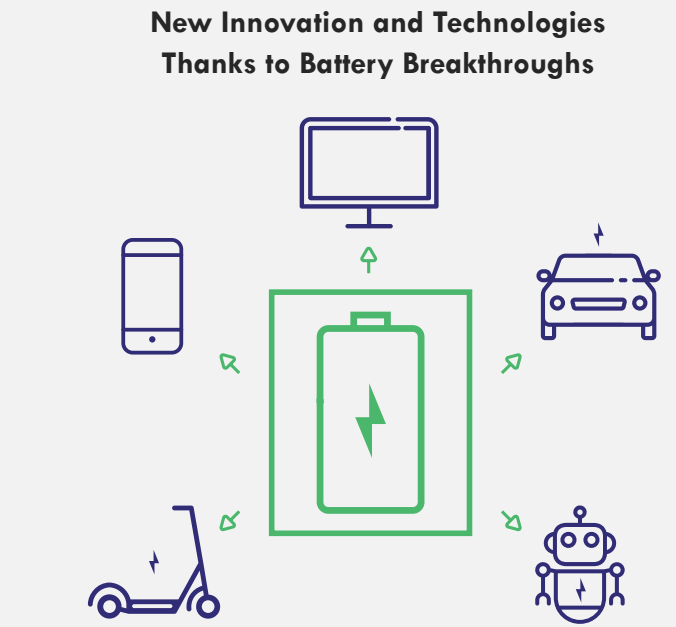
1. Cost Curve Declines



2. Cross Sector Ramifications



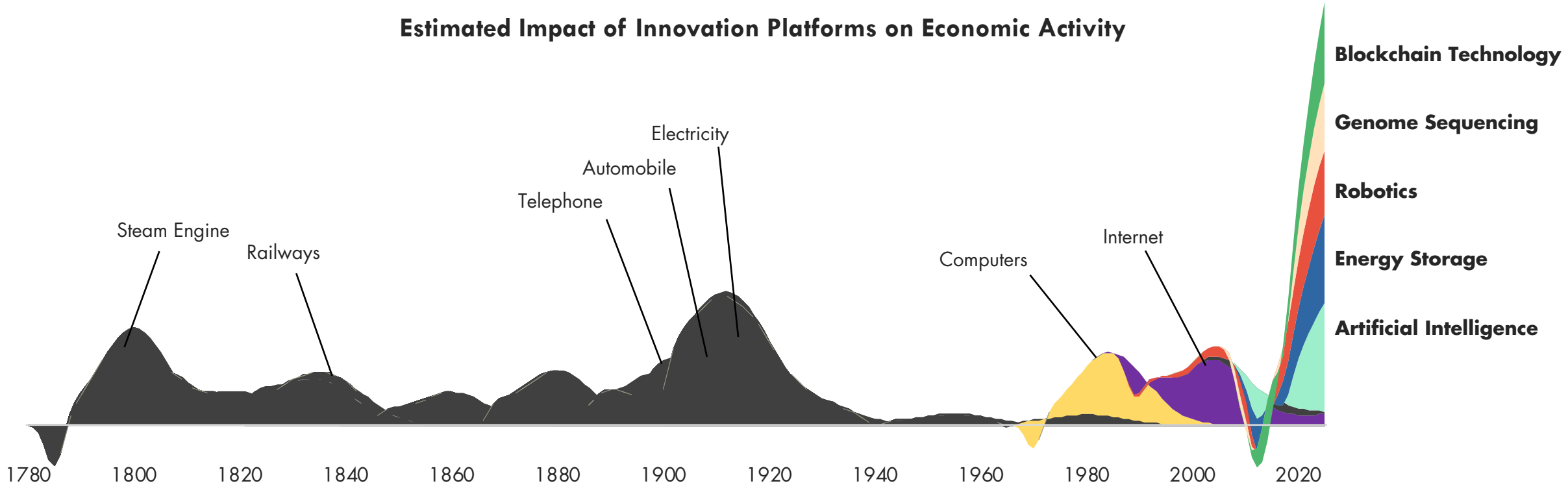
3. More Innovation



[1] Jovanovic, Boyan & Rousseau, Peter L., 2005. "General Purpose Technologies," Chapter 18.
Subsectors include: Printing, Fabricated Metal, Transport Equipment, Stone Clay Glass, Primary Metals, Petrol/Coal, Paper, Electric Machinery, Rubber, Leather, Chemicals, Textiles, and Food.

Why Now?

According to ARK's research, the global economy is undergoing the largest technological transformation in history.



Source: ARK Investment Management LLC, 2018 | Forecasts are inherently limited and cannot be relied upon.

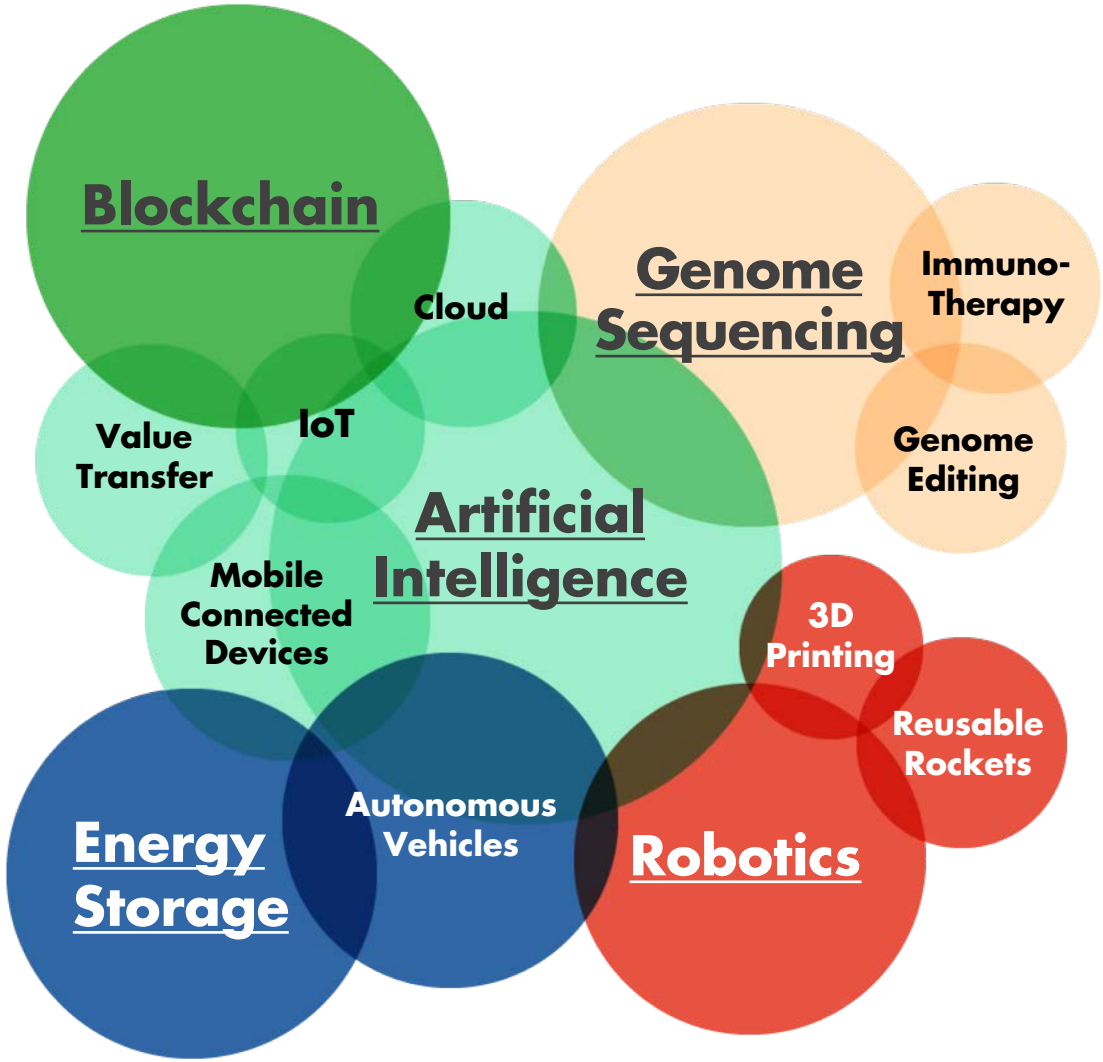
Five Multi-Trillion Dollar Innovation Platforms

As Convergence Accelerates, Innovation Advances

ARK identifies five primary innovation platforms causing what could be the most transformative period in history.

We expect that each of these platforms will create multiple trillions in market capitalization over the next decade, enabling further innovation.

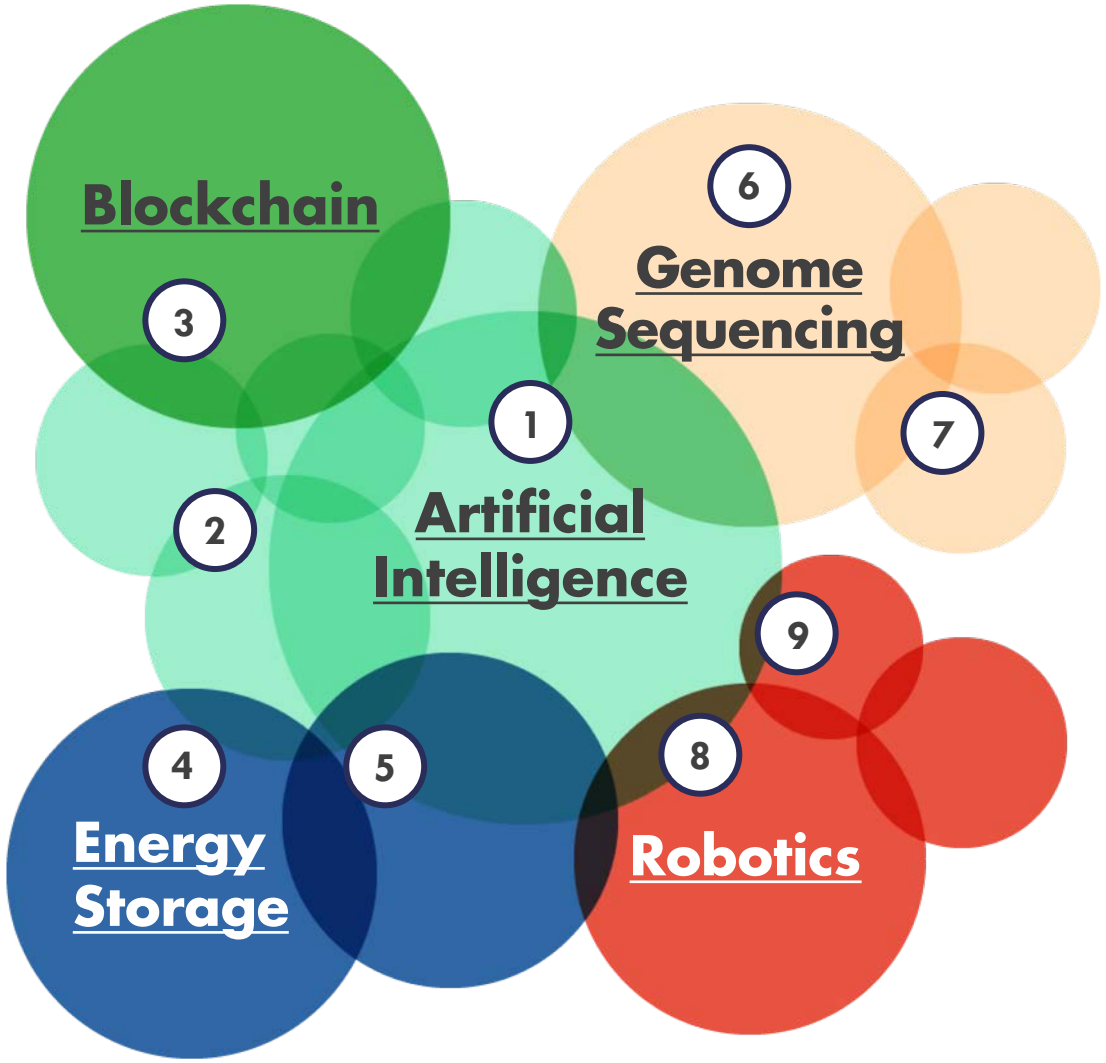
- **Blockchain Technology**
- **Genome Sequencing**
- **Artificial Intelligence**
- **Robotics**
- **Energy Storage**



Big Ideas 2019

ARK researches the universe of innovation platforms and their underlying technologies. On an annual basis we publish research highlighting the technology breakthroughs that we believe will advance significantly over the coming year. Here are our "Big Ideas" for 2019:

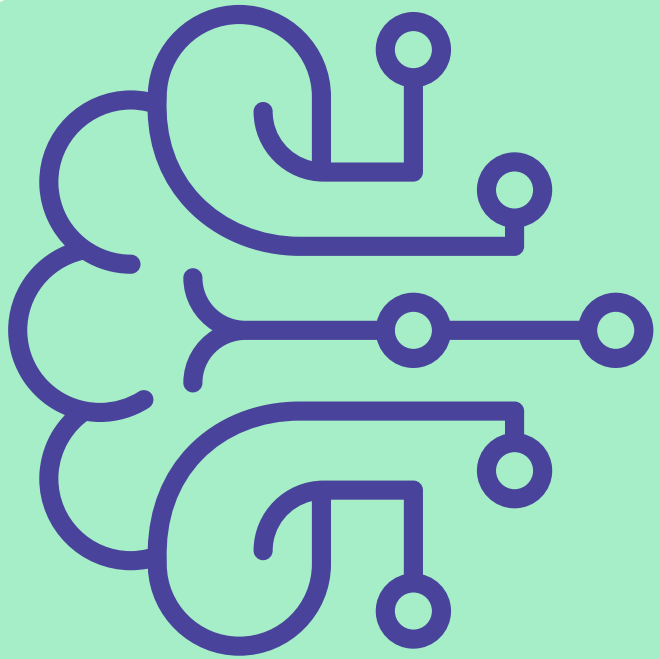
1. **Deep Learning**
2. **Digital Wallets**
3. **Cryptocurrencies**
4. **Battery Cost Tipping Points**
5. **Autonomous Taxi Networks**
6. **Next Gen DNA Sequencing**
7. **CRISPR For Human Therapeutics**
8. **Collaborative Robots**
9. **3D Printing For End-Use Parts**



Deep Learning: Software 2.0

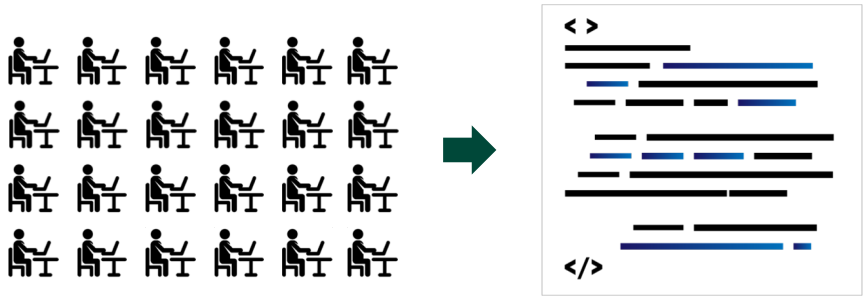
Deep learning is a form of artificial intelligence inspired by the human brain. With deep learning, machines don't need a programmer to tell them what to do. Instead, machines use data to train themselves.

ARK believes every industry will be transformed by deep learning.



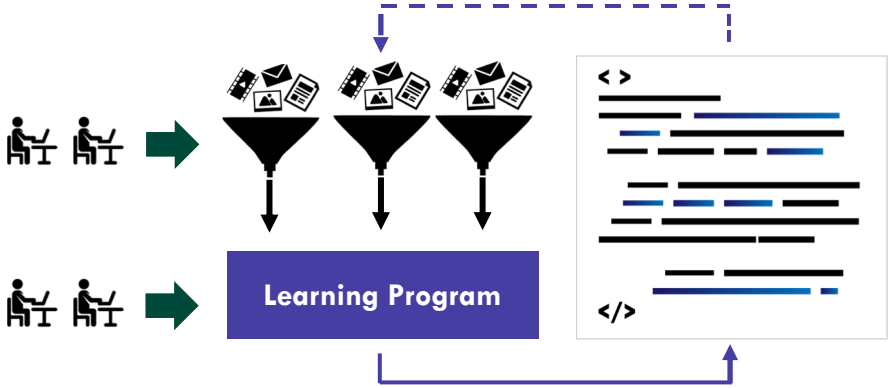
Deep Learning Is Software That Writes Itself

TRADITIONAL SOFTWARE



Traditional software is coded by an army of human programmers. It's expensive, fragile, and difficult to maintain. Programs work as designed but cannot surpass human performance.

DEEP LEARNING



Deep learning is software that's not 'written' but 'trained'. Humans gather data and create a learning framework. The system learns the right behaviors automatically. Deep learning improves with more data and often exceeds human performance.

Deep Learning Is the Magic Behind Consumer and Enterprise Tech

Each story, photo, and video is custom selected for users using deep learning.

Apple Watch can predict atrial fibrillation, diabetes, and sleep apnea.

The Tesla Model 3's Autopilot can overtake other vehicles and drive on highways.

Google Translate translates more than 100 billion words per day.

Salesforce's Einstein makes more than four billion business analytics predictions per day.

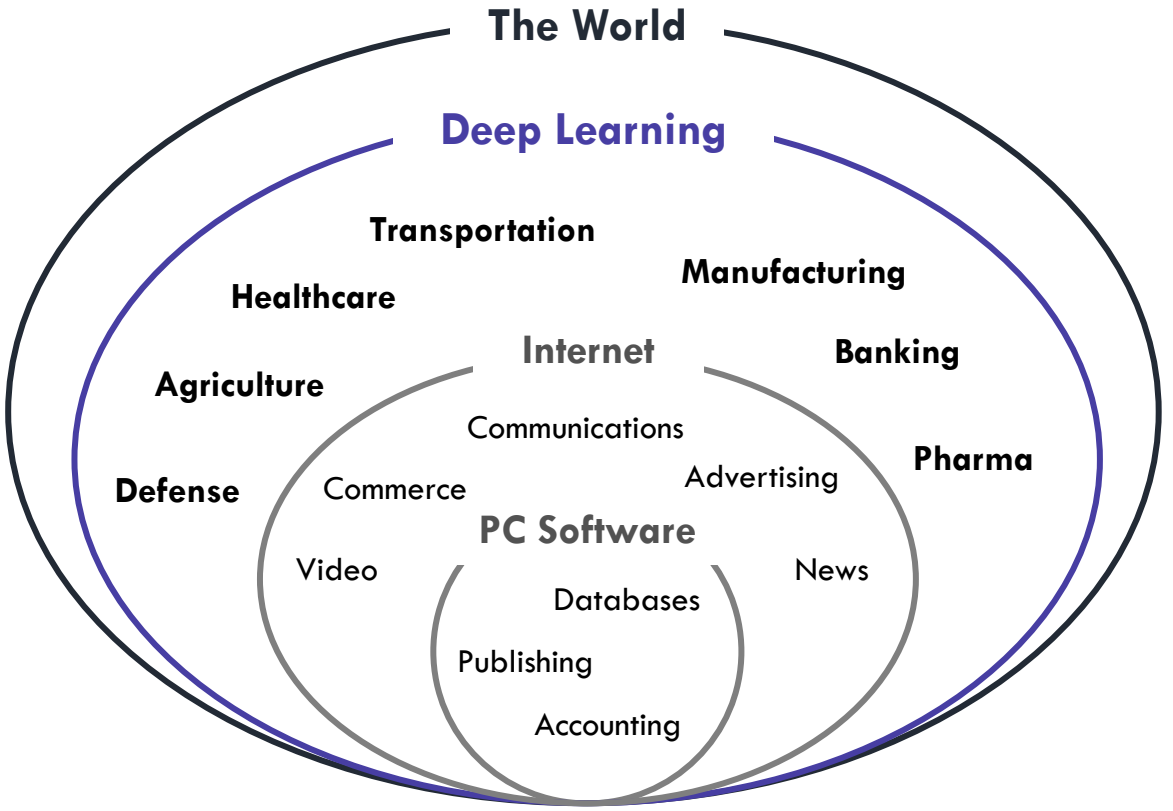
Blue River's smart tractors use computer vision to reduce herbicide use by 90%.

Source: ARK Investment Management LLC, 2018; Information collected from company reports (Facebook, Google, Netflix, Apple, Tesla, Salesforce.com, Blue River Technologies).

Deep Learning Is the Third Wave of "Software Eating the World"

"Software is eating the world"
- *Marc Andreessen*[1]

- The first wave of software on PCs disrupted a handful of industries.
- The Internet wave expanded the reach of software beyond the computer industry, creating new tech giants.
- Deep learning is the third wave of software eating the world. It expands the reach of software into massive industries like healthcare, transportation, and manufacturing.



[1] Andreessen, Marc. "Why Software Is Eating the World." *Andreessen Horowitz*, 20 Aug. 2011, https://arkinv.st/2QuCZ6B.

Example: Deep Learning Eats Retail, a $3 Trillion Market in the US

Old Retail Checkout Experience

Based on ARK's research, Americans wait 300 million hours per year in checkout lines.

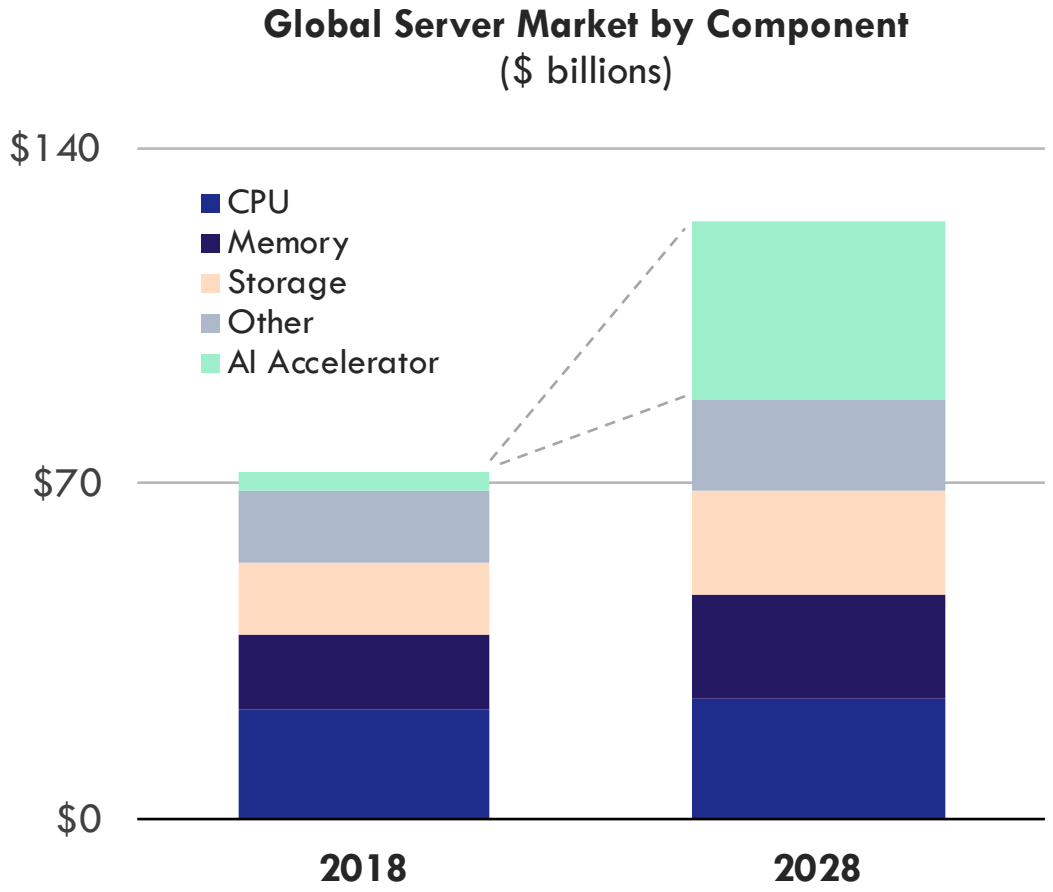
Deep Learning Checkout Experience

Amazon Go uses cameras and sensors which feed into deep learning software to recognize shoppers, to understand when they pick up items or put them back, and to allow them to leave the store without checking out at a cash register. Amazon is planning to open 3,000 stores by 2021.[1]

[1] Soper, Spencer. "Amazon Will Consider Opening Up to 3,000 Cashierless Stores by 2021." *Bloomberg.com*, 19 Sept. 2018, https://arkinv.st/2LXY3lh.

Example: Deep Learning Eats Microprocessors

The slowdown of Moore's Law* could mean the end of 'free' performance upgrades every two years. As a result, server companies will have to increase investment in computing hardware.



The boom in deep learning software is fueling demand for deep learning processors. "AI Accelerators" are used in servers to speed up workloads.

ARK estimates AI Accelerator revenue as a percentage of total server revenue could grow from 5% in 2018 to 30% in 2028, creating another $30+ billion opportunity.

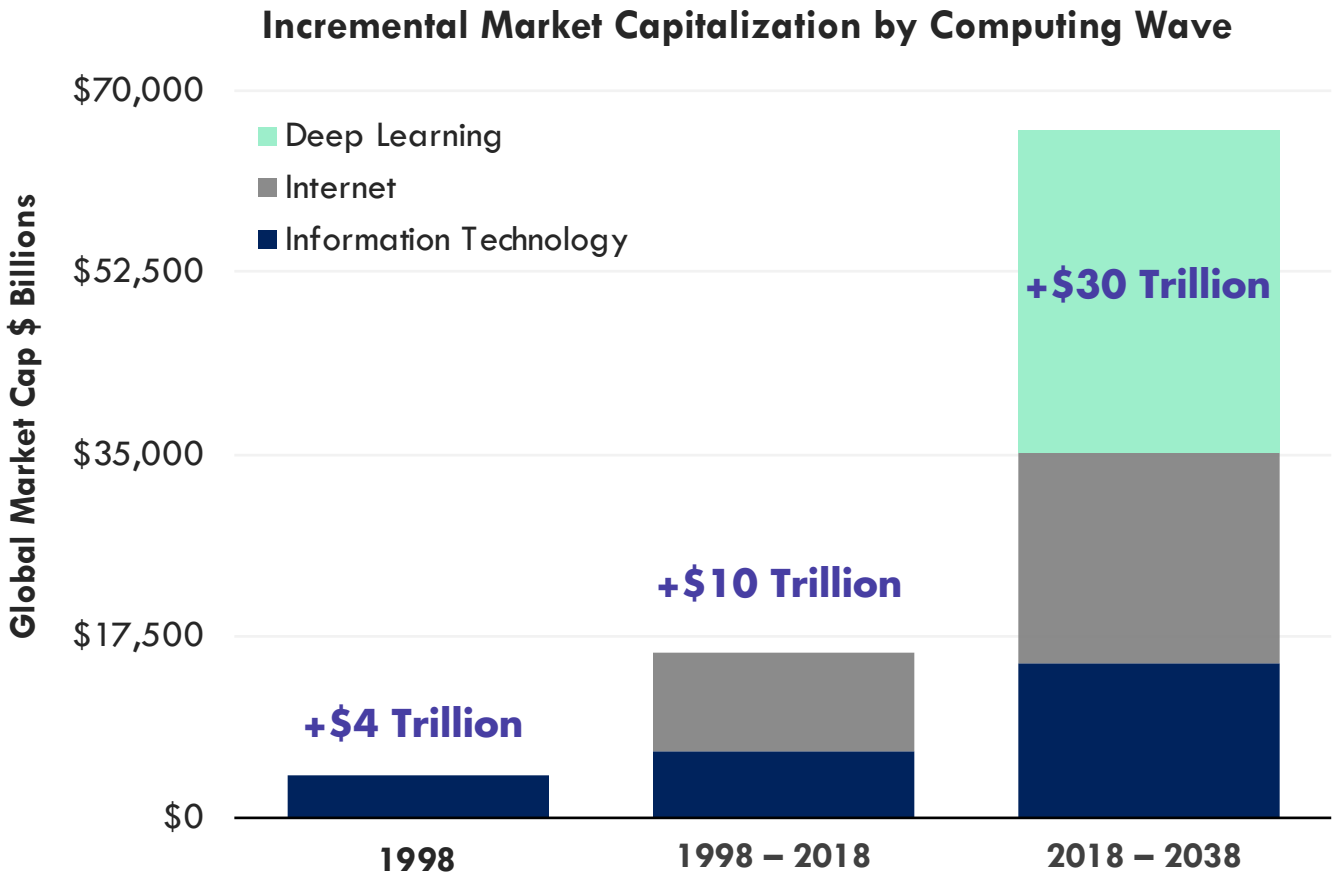
**Gordon Moore's prediction that the number of transistors on a chip would double every two years.*

Forecasts are inherently limited and cannot be relied upon.
Sources: ARK Investment Management LLC, 2018; Data from: "Worldwide Server Market Revenue Grew 43.7% Year Over Year to a Record $22.5 Billion During the Second Quarter of 2018, According to IDC." *IDC*, 5 Sept. 2018, https://arkinv.st/2TBhnaF. Assumes 15% OEM margin.; "1965: 'Moore's Law' Predicts the Future of Integrated Circuits." *What Was The First PC?*, https://arkinv.st/2LXJcHo

Sizing the Opportunity

Deep Learning Could Create 3x the Value of the Internet.

- The internet captured 15% of the globe's equity market capitalization over 20 years.
- If deep learning were to achieve the same rate of adoption, it would add $30 trillion to global equity market capitalizations in the next 20 years.



Forecasts are inherently limited and cannot be relied upon.
Source: ARK Investment Management LLC, 2018; *World Federation of Exchanges*, 2018, https://arkinv.st/2FbJgmp; "ACWI." *MSCI*, 2018 https://arkinv.st/2Rc6y22.

Outlook

While the US Created the Internet Economy, China Could Spearhead the AI Economy.

National Mandate

China has a national mandate to become a leader in AI by 2025.

Internet Population of 800 Million

China has three times as many internet users as the US, enabling large scale data collection and training.

No Privacy Risk

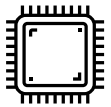
Chinese users are accustomed to censorship and a lack of privacy, which eases AI deployment and minimizes regulatory risk.

AI Applications

The world's most popular AI application is China's social video app, Tik Tok, with more than 500 million users.

AI Chip Design

China is home to a number of leading AI chip design companies such as Cambricon, which powers Huawei smartphones.



Semiconductor Fabrication

China is progressing in chip manufacturing technology. Its domestic 16nm fabs are some of the most advanced in the world.

Source: ARK Investment Management LLC, 2018

Risk and Disclosure

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- Software Industry Risk
- Internet Company Risk
- Semiconductor Company Risk

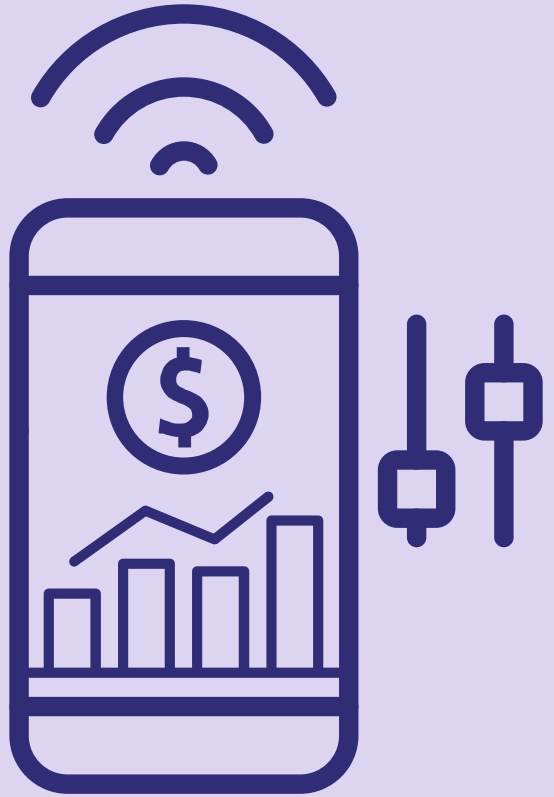
Software Industry Risk. The software industry can be significantly affected by intense competition, aggressive pricing, technological innovations, and product obsolescence. Companies in the software industry are subject to significant competitive pressures, such as aggressive pricing, new market entrants, competition for market share, short product cycles due to an accelerated rate of technological developments and the potential for limited earnings and/or falling profit margins. These companies also face the risks that new services, equipment or technologies will not be accepted by consumers and businesses or will become rapidly obsolete. These factors can affect the profitability of these companies and, as a result, the value of their securities. Also, patent protection is integral to the success of many companies in this industry, and profitability can be affected materially by, among other things, the cost of obtaining (or failing to obtain) patent approvals, the cost of litigating patent infringement and the loss of patent protection for products (which significantly increases pricing pressures and can materially reduce profitability with respect to such products). In addition, many software companies have limited operating histories. Prices of these companies' securities historically have been more volatile than other securities, especially over the short term. **Internet Company Risk.** Many Internet-related companies have incurred large losses since their inception and may continue to incur large losses in the hope of capturing market share and generating future revenues. Accordingly, many such companies expect to incur significant operating losses for the foreseeable future, and may never be profitable. The markets in which many Internet companies compete face rapidly evolving industry standards, frequent new service and product announcements, introductions and enhancements, and changing customer demands. The failure of an Internet company to adapt to such changes could have a material adverse effect on the company's business. **Semiconductor Company Risk.** Competitive pressures may have a significant effect on the financial condition of semiconductor companies and, as product cycles shorten and manufacturing capacity increases, these companies may become increasingly subject to aggressive pricing, which hampers profitability. Reduced demand for end-user products, under-utilization of manufacturing capacity, and other factors could adversely impact the operating results of companies in the semiconductor sector. Semiconductor companies typically face high capital costs and may be heavily dependent on intellectual property rights. The semiconductor sector is highly cyclical, which may cause the operating results of many semiconductor companies to vary significantly. The stock prices of companies in the semiconductor sector have been and likely will continue to be extremely volatile.

Digital Wallets:

Mobile Bank Branches

Digital wallets are transforming more than payments. They are becoming gateways for financial services such as wealth management, insurance, banking, and personal finance.

ARK believes that digital wallets could upend traditional banks within five years.



Digital Wallets Are Becoming Gateways for Financial Services

ARK defines digital wallets as more than applications on a phone with payment capabilities. They are financial ecosystems that enable access to a variety of services including wealth management, insurance, instant payments, and cryptoassets.

Faster peer-to-peer transfers than checks and wires

Instantaneous and more accurate credit assessment

Tailored insurance products

Easy credit card payments

Personal finance management, tax planning and financial education

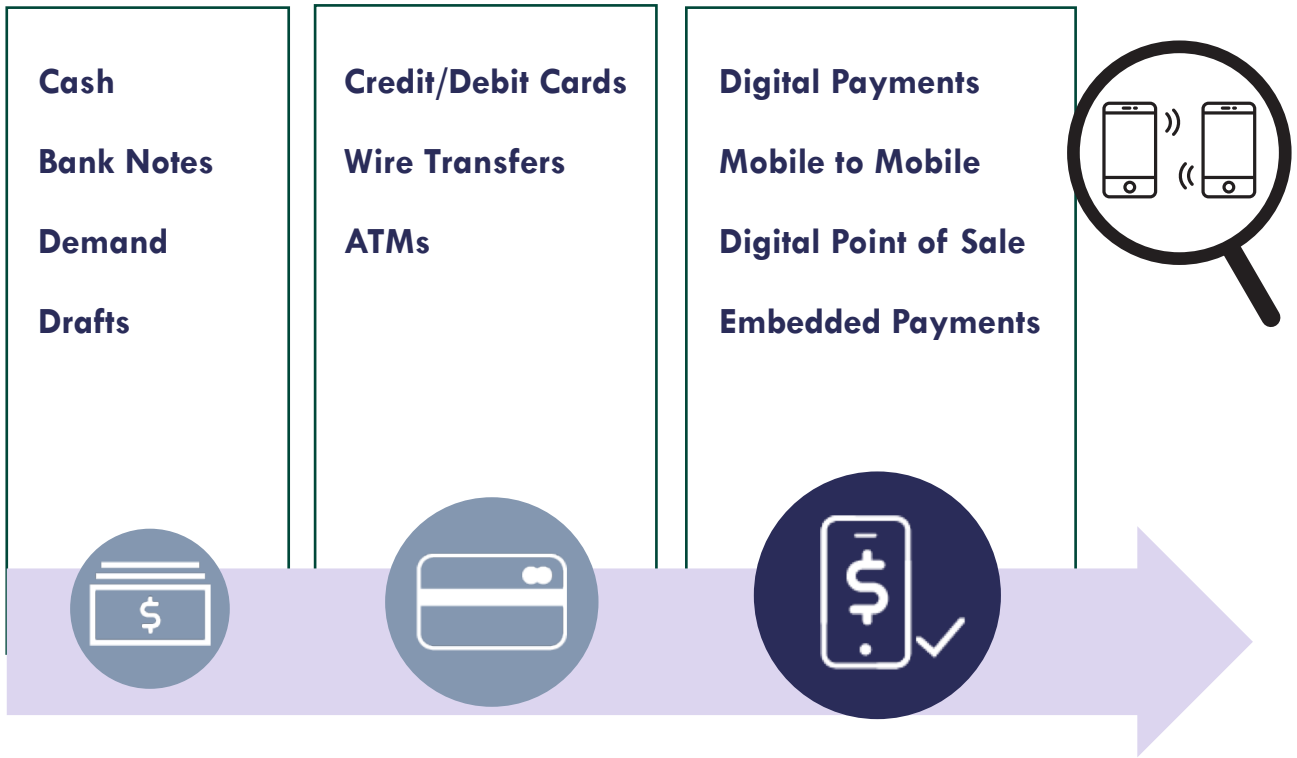
Efficient movement of funds into savings products

Integration with various wealth management platforms

Frictionless access to cryptocurrencies

Digital Wallets Enable Frictionless Value Transfers

Digital wallets are an important step in the evolution of frictionless value transfers, making transactions and exchanges simple and seamless in a user's everyday life.

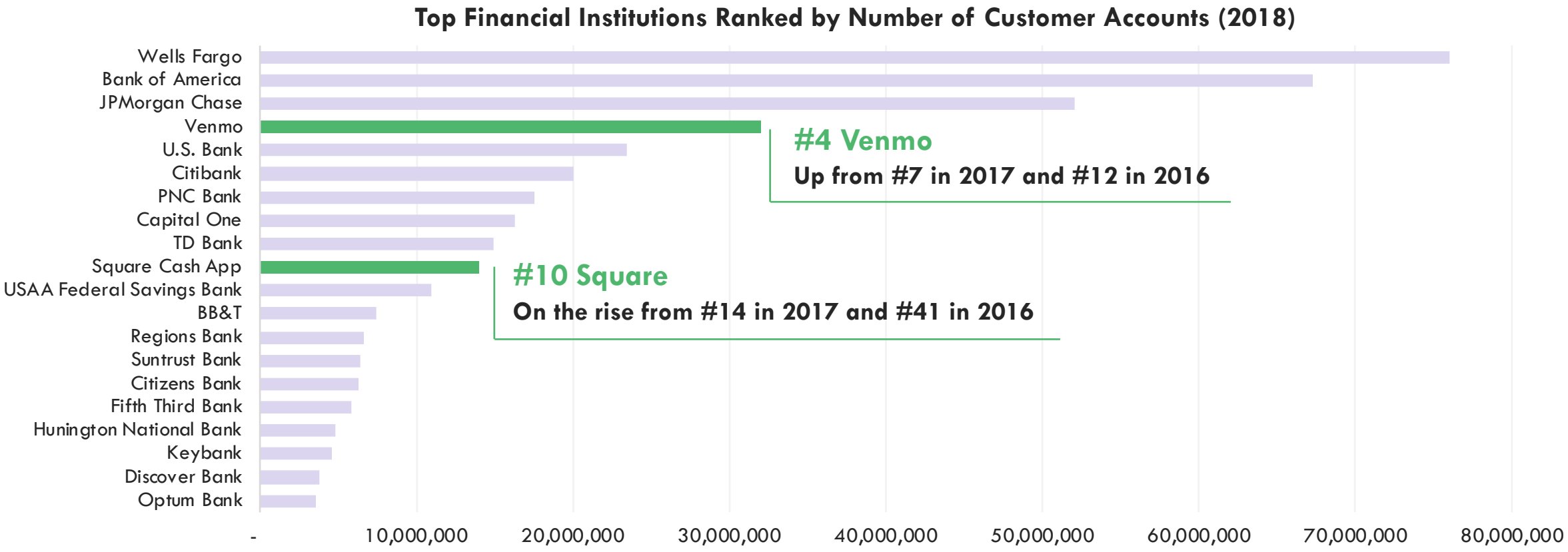


1. By the end of 2018, Venmo became the 4th largest manager of customer accounts, trailing only Bank of America, Chase, and Wells Fargo.[1]
2. In August 2018, China tightened wallet regulations by imposing caps on QR code payments.[2]
3. In March 2018, Square Cash App introduced banking services such as direct deposit of paychecks, rewards programs, and debit cards.[3]

[1] ARK Investment Management LLC, 2018
[2] Wang, Yue. "China Tightens Regulation Over Mobile Payment Apps – What's Next For Tencent and Ant Financial?" *Forbes*, Forbes Magazine, 3 Jan. 2018, https://arkinv.st/2C9cv5y.
[3] Tepper, Fitz. "Square's Cash App Now Supports Direct Deposits for Your Paycheck." *TechCrunch*, TechCrunch, 8 Mar. 2018, https://arkinv.st/2C6HFun.

Digital Wallets Are Encroaching on Big Banks

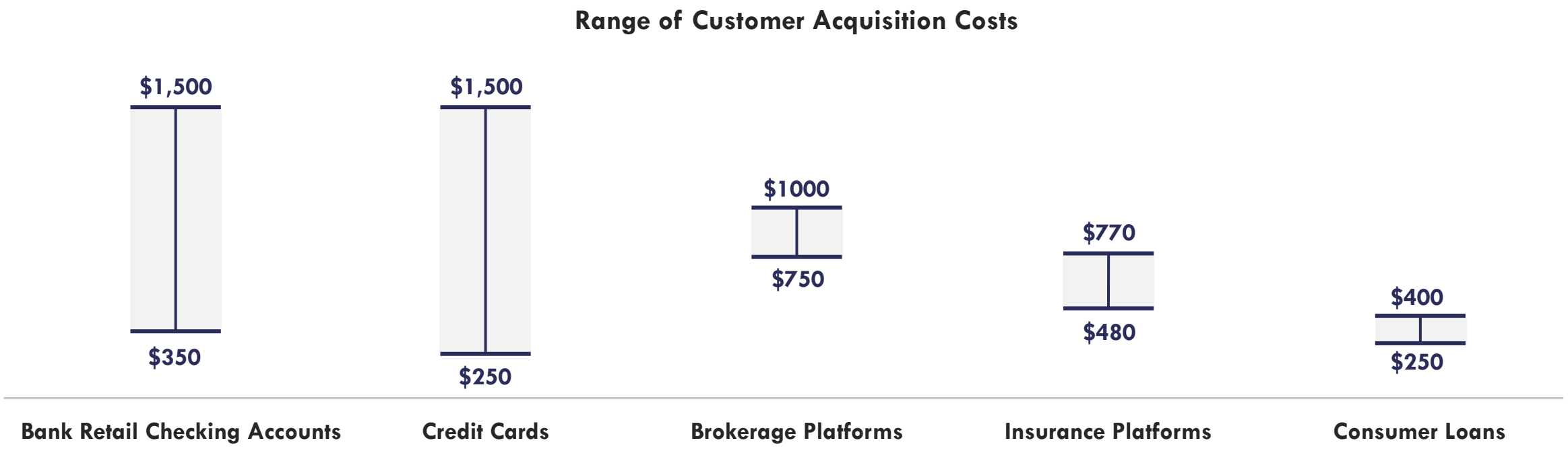
Digital wallets are scaling quickly relative to traditional banks. By the end of 2018, Venmo will have the fourth largest customer base, trailing only Wells Fargo, Bank of America and JP Morgan Chase. Square's Cash App also will be in the top 10.



Source: ARK Investment Management LLC, 2018. Data from: *FDIC: HSOB Commercial Banks*, https://arkinv.st/2CZITcd.

Digital Wallets Should Upend Traditional Bank Branches

- Traditional banks' reliance on physical infrastructure pushes customer acquisition costs (CAC) to **$350-1,500 person.**
- Digital wallets can acquire customers at just **$20 per person,** becoming effective channels for banks to engage and retain customers.



Source: ARK Investment Management LLC, 2018

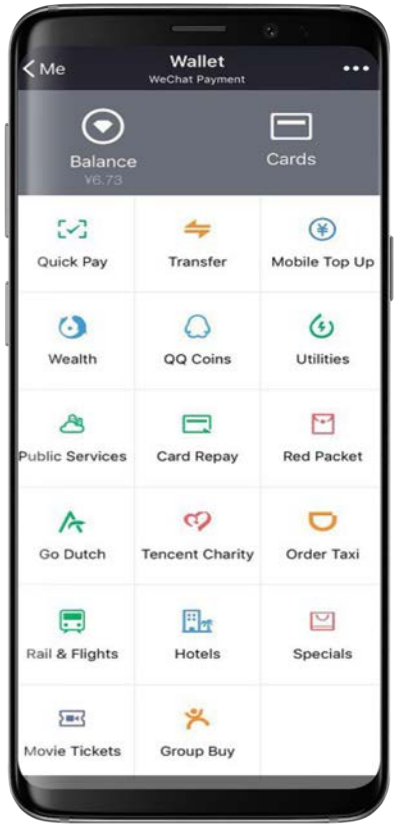
As Seen in China, Digital Wallets Offer Value Beyond Financial Services

WeChat Pay's screen highlights how it drives e-commerce and other activities outside of financial services.

52%

Screen Space Dedicated to E-commerce and Others

For travel, taxi, shopping, specials, games, group buying and gifting.



48%

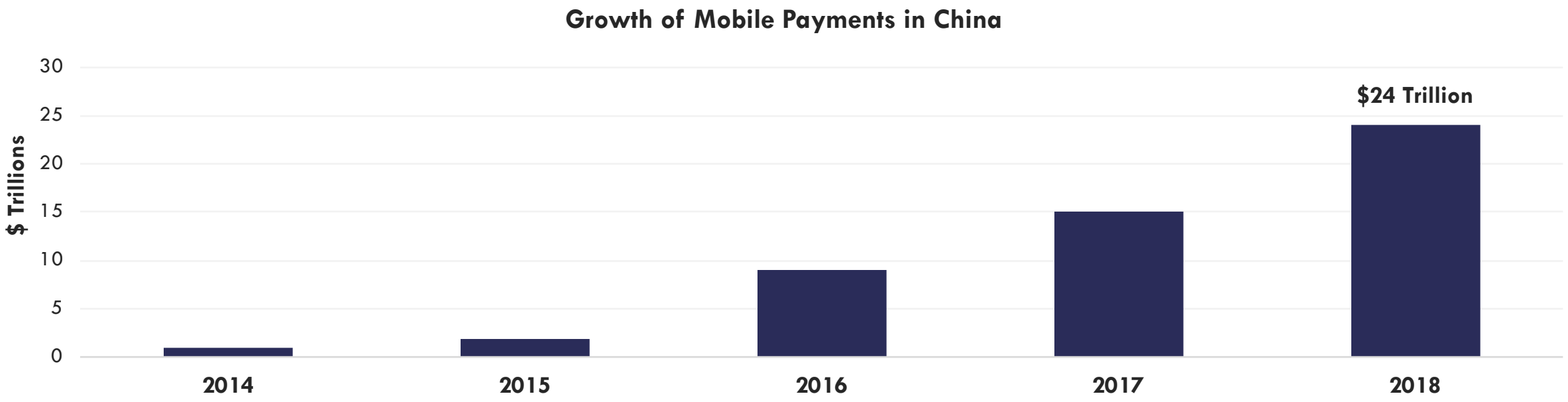
Screen Space Dedicated to Financial Services

For card repayments, peer-to-peer transfers, utility payments, and wealth management.

Source: Chan, Connie. "When One App Rules Them All: The Case of WeChat and Mobile in China." Edited by Sonal Chokshi, *Andreessen Horowitz*, Aug. 2015, http://arkinv.st/1Tgm2g0.

China Points the Way to Digital Wallets and Mobile Payments

ARK believes that digital wallets like Alipay and WeChat Pay have revolutionized the delivery of banking products at scale in both rural and urban areas throughout China. Their ease of use and accessibility have caused mobile payments to soar 12-fold to $24 trillion in the three years ended 2018.



Sources: ARK Investment Management LLC, 2018 and Meeker, Mary. "Internet Trends Report 2018." *Kleiner Perkins*, 30 May 2018, https://arkinv.st/2QzTTAS.

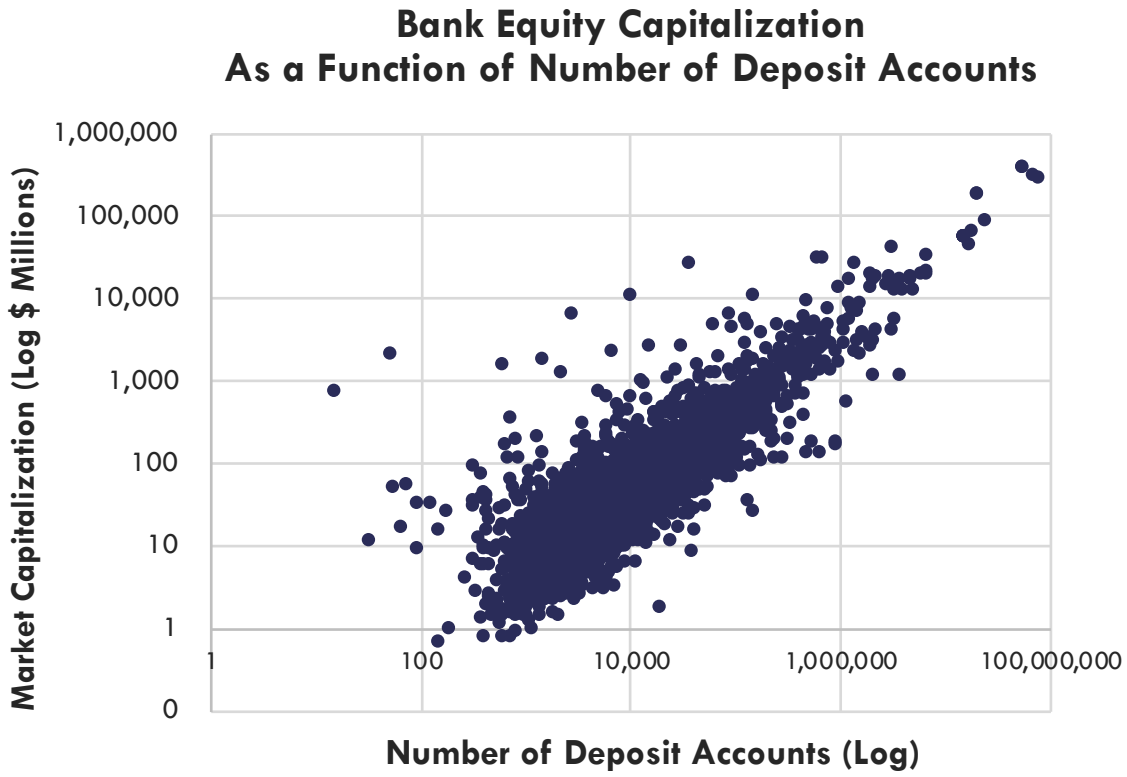
Sizing the Opportunity

Digital Wallet Providers Could Be Valued at $200 Billion by 2023.

Investors value banks for their core deposits and loan relationships. As shown in the chart, they pay a median market cap of $3,400* per US demand deposit for traditional banks today.

Based on lower customer acquisition costs and more cross-selling opportunities, investors could value digital wallets at a significant premium to traditional banks.

Even if the value of a digital wallet customer were just one third that of a bank customer, digital wallet providers could be worth approximately $1,000 per user, or $200 billion, in 2023, leading to seismic changes in the valuations of digital wallet companies such as Square, PayPal, Amazon, and Apple.

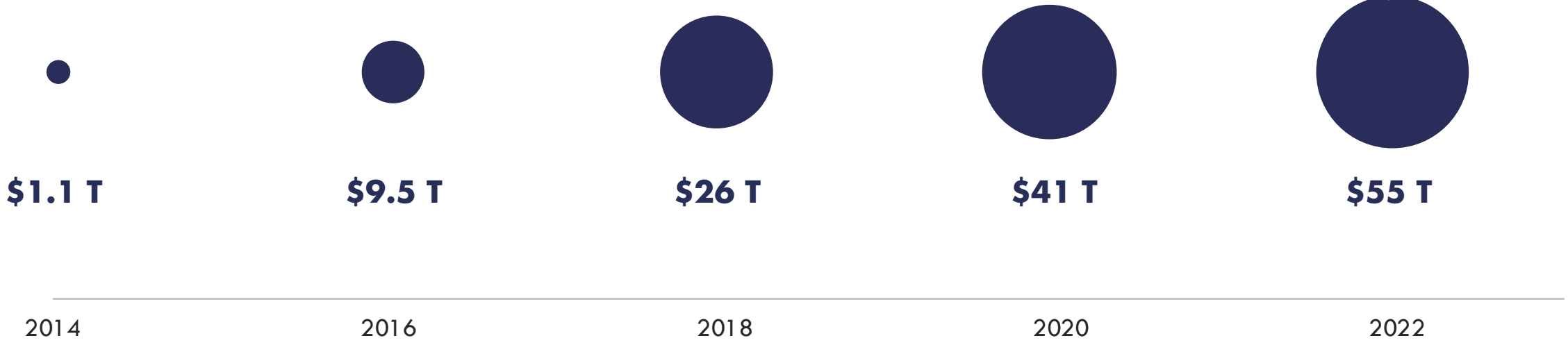


Forecasts are inherently limited and cannot be relied upon.
*The individual median data point was calculated from the market cap of more than 3000 data points.
Sources: ARK Investment Management LLC, 2018, Data from: *FDIC: HSOB Commercial Banks*, https://arkinv.st/2CZITcd.

Sizing the Opportunity

Mobile Value Transfers Could Reach $55 Trillion by 2022.

Global Mobile Transactions
($ trillions)



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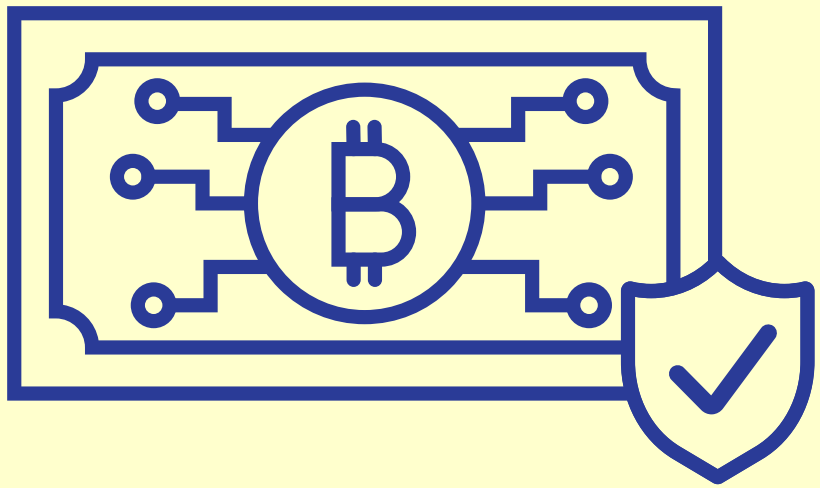
Cryptocurrencies:

Storing and Transferring Value

Throughout history, we have had to rely on trusted intermediaries to store and transfer value. With the launch of Bitcoin, Satoshi Nakamoto proposed an alternative financial system, one decentralized and free from top-down control.

ARK believes that cryptocurrencies have the potential to shift the course of monetary history and eliminate inefficiencies.



We Are Witnessing the Rise of an Alternative Financial System

BARTER

In early civilization, trade occurred in the form of barter.

Subject to the coincidence of wants, barter limited trade's scale and efficiency.

GOLD

Over time, collectibles emerged as widespread stores of value.

In the 19th century, a single store of value – gold – emerged.

FIAT

Given gold's intrinsic limitations as a means of exchange, the state monopolized the issuance of money, undermining its function as a store of value.

BITCOIN

In 2008, Satoshi Nakamoto proposed an alternative financial system governed by decentralized agents such as developers, miners, and users.

With the launch of Bitcoin, value can be stored and transferred in a permissionless and decentralized manner.

Sources: ARK Investment Management LLC, 2018 | Burniske, Chris, and Jack Tatar. *Cryptoassets the Innovative Investor's Guide to Bitcoin and Beyond.* McGraw-Hill, 2018.
Boyapati, Vijay. "The Bullish Case for Bitcoin". *Medium,* Mar 2, 2018, https://arkinv.st/2RFICU4.
Szabo, Nick, *Shelling Out: The Origins of Money.* 2002.

Bitcoin Launched the "Blockchain" Movement

- **Bitcoin** – with an uppercase B – refers to the software that facilitates the transfer and custody of **bitcoin** – with a lowercase b – the cryptocurrency.
- Bitcoin's blockchain is a distributed digital ledger and database that records the flow of its native currency, bitcoin, and provides the foundation for **cryptonetworks**, the networks powering cryptocurrencies.

Bitcoin's Blockchain

Distributed

Any computer can access Bitcoin's blockchain, including the records of every transaction.

Cryptographic

Every transaction recorded must be verified cryptographically. Cryptography allows computers building Bitcoin's blockchain to collaborate in an automated system of mathematical trust.

Immutable

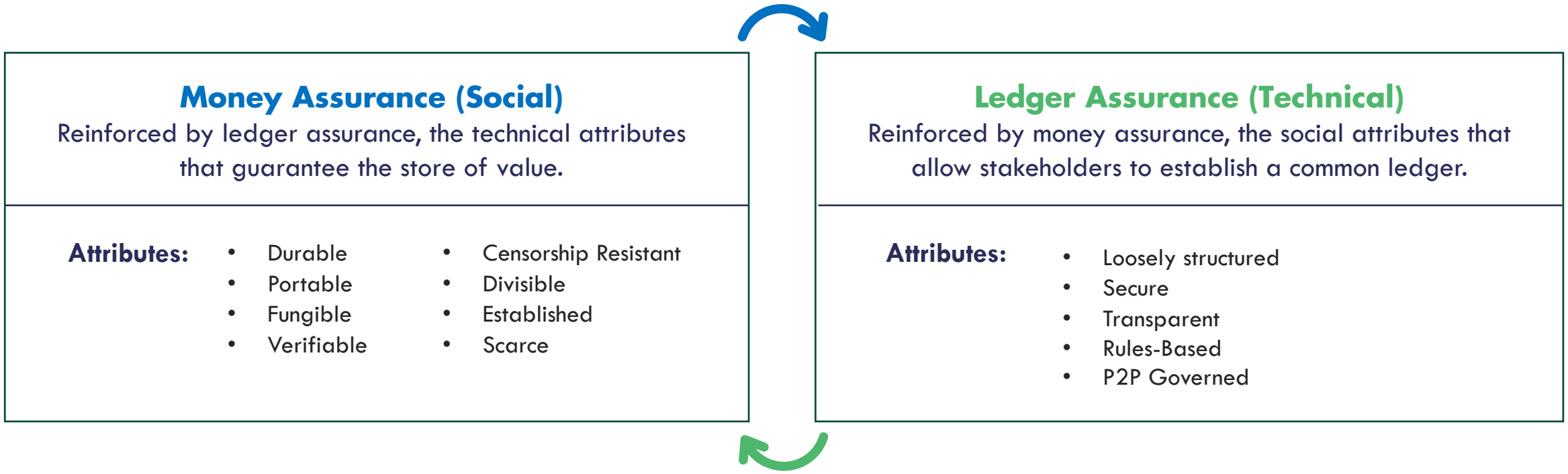
An immutable database means Bitcoin's blockchain is append-only. That is, information can be added but not deleted over time. Once confirmed, the information in Bitcoin's blockchain cannot be erased.

Secure

Computers (aka miners) compete to solve cryptographic puzzles allowing them to add a block of transactions to the blockchain. Miners are rewarded for creating a new block either with newly minted bitcoin or fees from verifying transactions. This competition ensures Bitcoin blockchain's security.

Assurance Is Key to Money

- Fiat currencies and the assurance they provide depend on the jurisdictions that issue them.
- Cryptonetworks such as Bitcoin provide assurance without relying on intermediaries.



Source: ARK Investment Management LLC, 2018

How Does Bitcoin Rank on "Money Assurance"?

The table below lists attributes that characterize money, and a qualitative grading system that ranks various instruments.

"Money" Characteristics	Bitcoin	Gold	Fiat
Durable	B	A+	C
Portable	A+	D	B
Fungible	B	A	B
Verifiable	A+	B	B
Censorship Resistant	A	C	D
Divisible	A+	C	B
Scarce	A+	A	F
Established	D	A+	C

Source: Boyapati, Vijay. "The Bullish Case for Bitcoin". *Medium*, Mar 2, 2018, https://arkinv.st/2RFICU4.

How Does Bitcoin Rank on "Ledger Assurance"?

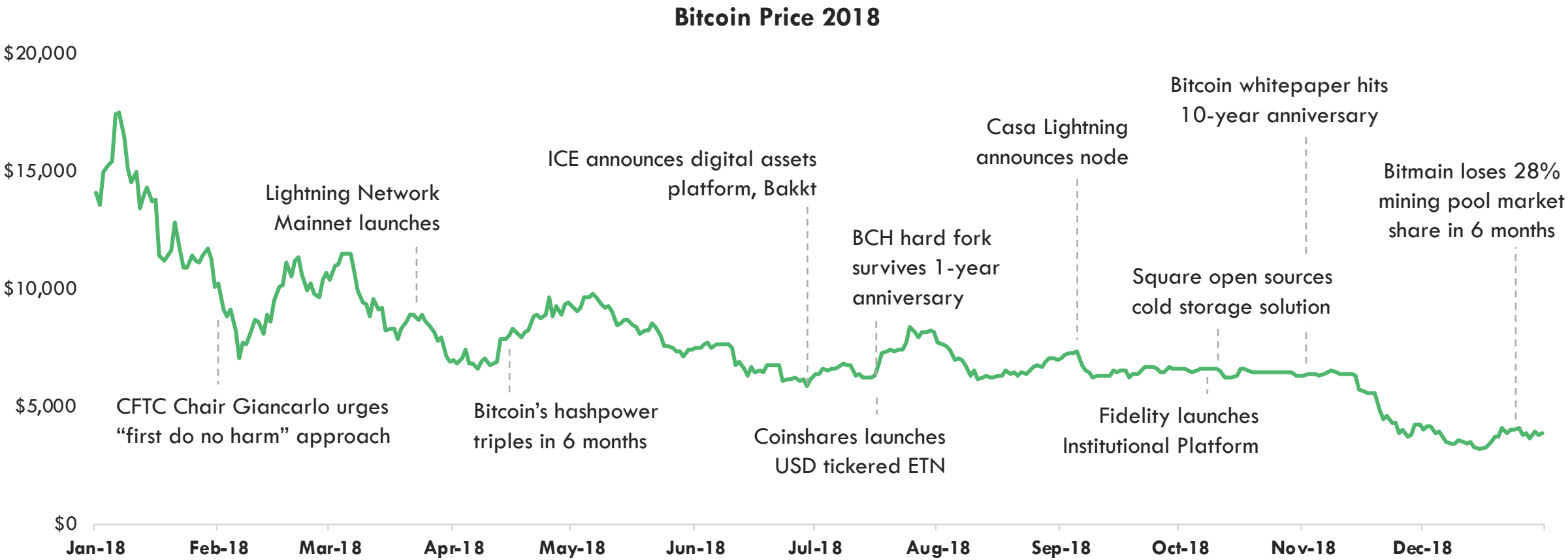
An instrument's money assurance depends on its ledger assurance. Unlike any other model, Bitcoin enables absolute ledger assurance without a trusted intermediary.

"Ledger" Characteristics	Bitcoin	Gold	Fiat
Structure	Loose	Fixed	Arbitrary
Security: Cost to Attack	Expensive	Expensive	Variable
Transparency: Accounting Entry Mechanics	Transparent	Opaque	Opaque
Rules-Based	Yes	Yes	No*
Governance	Distributed	Distributed	Centralized

*While central banks follow general guidelines in determining monetary policy, Bitcoin's rules are mathematically metered and gold is constrained by natural limitations.

Source: Decentralized Credit (DR/CR). "#1: Assurances in Crypto edit". *Good Audience*, Oct 3, 2018, https://arkinv.st/2RjoQyd.

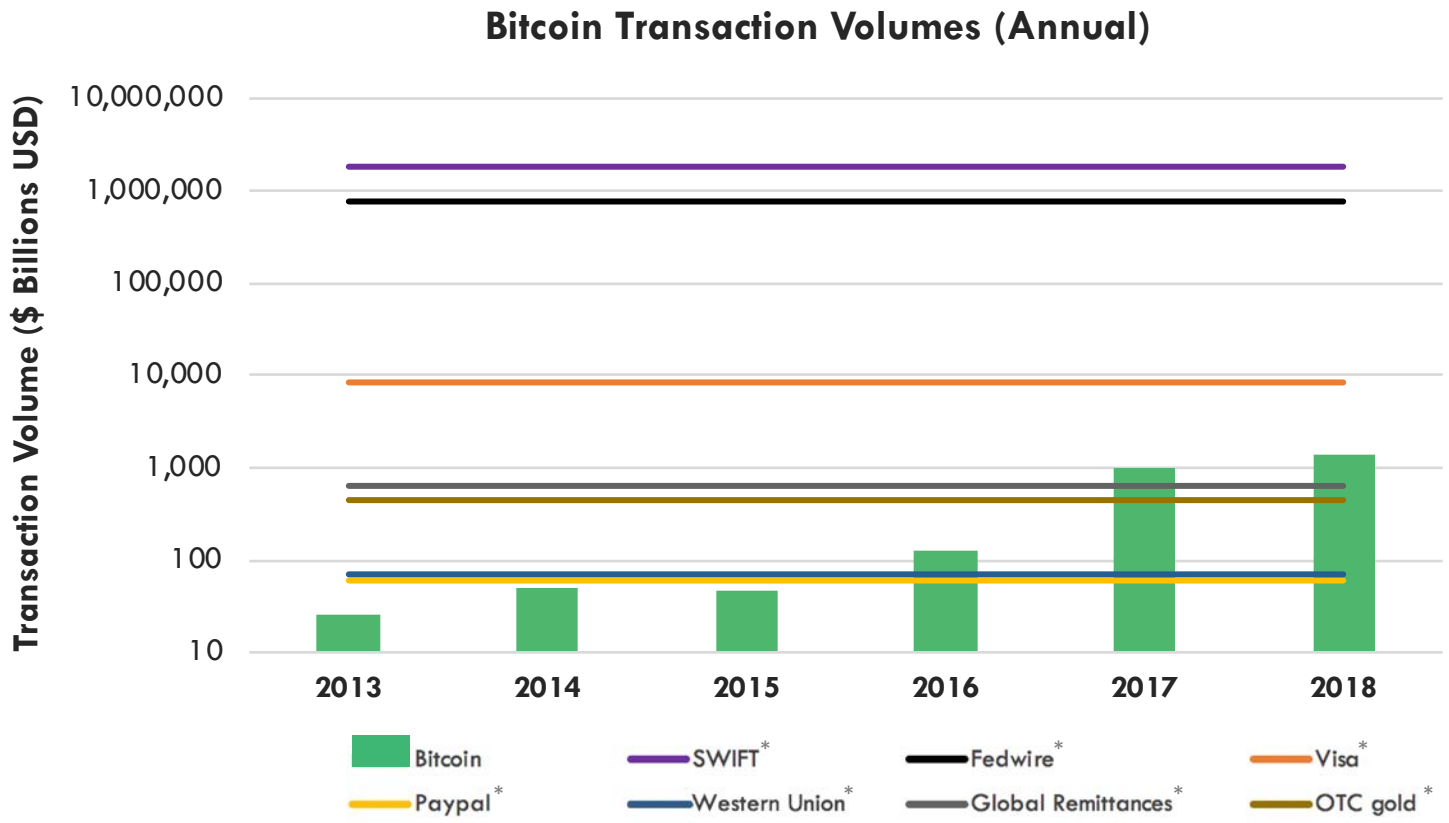
Despite a Prolonged Bear Market, Support for Bitcoin's Network Seems to Be Increasing



Source: ARK Investment Management LLC, 2018

Bitcoin Transactions Are Scaling

Bitcoin's base layer provides instant settlement for large value transactions.



Bitcoin Metrics	2017	2018
Median Price	$2,527	$6,905
Daily Transaction Volume	$2.8 B	$3.1 B
Average Transaction Value	$9,700	$15,300
Median Transaction Value	$351	$450
Active Addresses (Average)	750,000	675,000

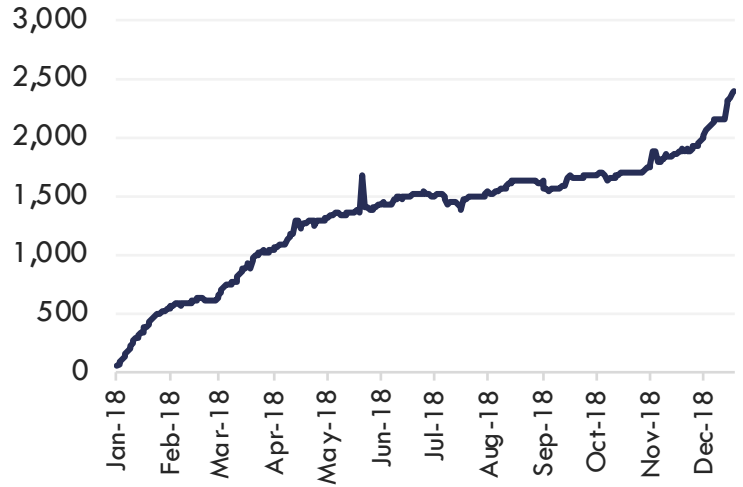
Dec. 31, 2018

*Note: Lines show 2018 data for comparison.
Sources: ARK Investment Management LLC, 2018, Carter Nic. "Bitcoin as a novel economic institution". *Castle Island Ventures. https://arkinv.st/2QwChFL* | Data from: coinmetrics.io

Bitcoin Should Continue to Scale Thanks to Technological Breakthroughs

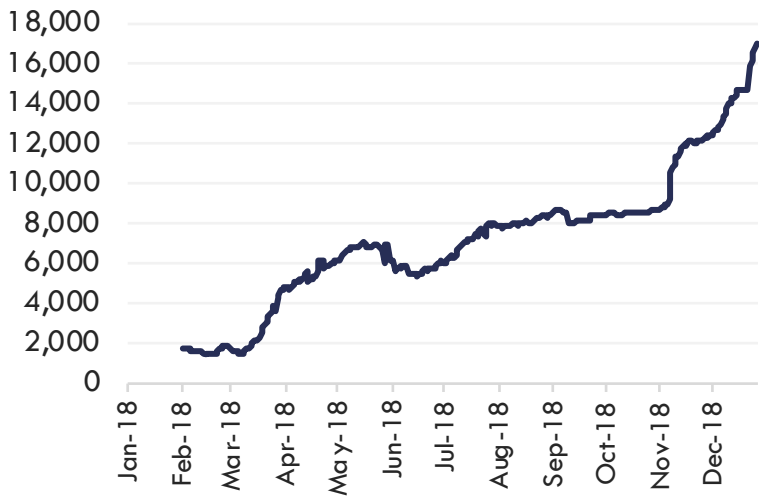
The Lightning Network is a second layer payment protocol with multi-directional channels, enabling fast and 'fee-less' transactions.

Number of Nodes With Channels



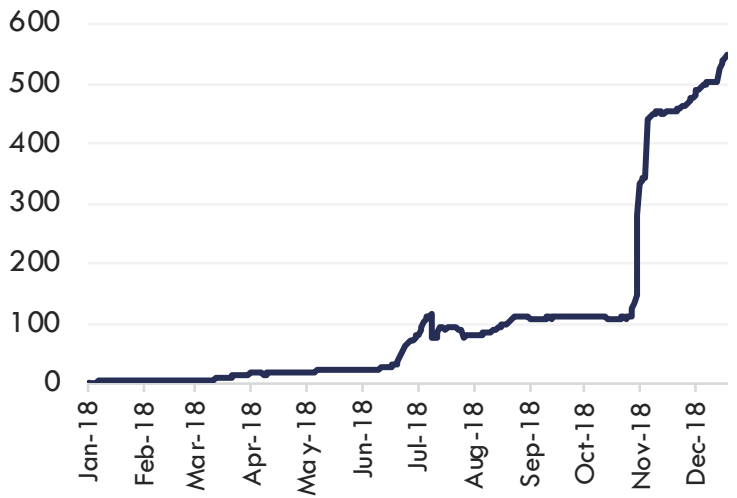
Nodes: A network participant with one or more open Lightning channels.

Number of Lightning Network Channels



Channels: A communication channel that allows two parties to exchange payments rapidly on the Lightning Network.

BTC Network Capacity (Thousands)



BTC Capacity: Cumulative amount of bitcoin across all Lightning Network channels.

Sources: ARK Investment Management LLC, 2018 | Data from: bitcoinvisuals.com/lightning

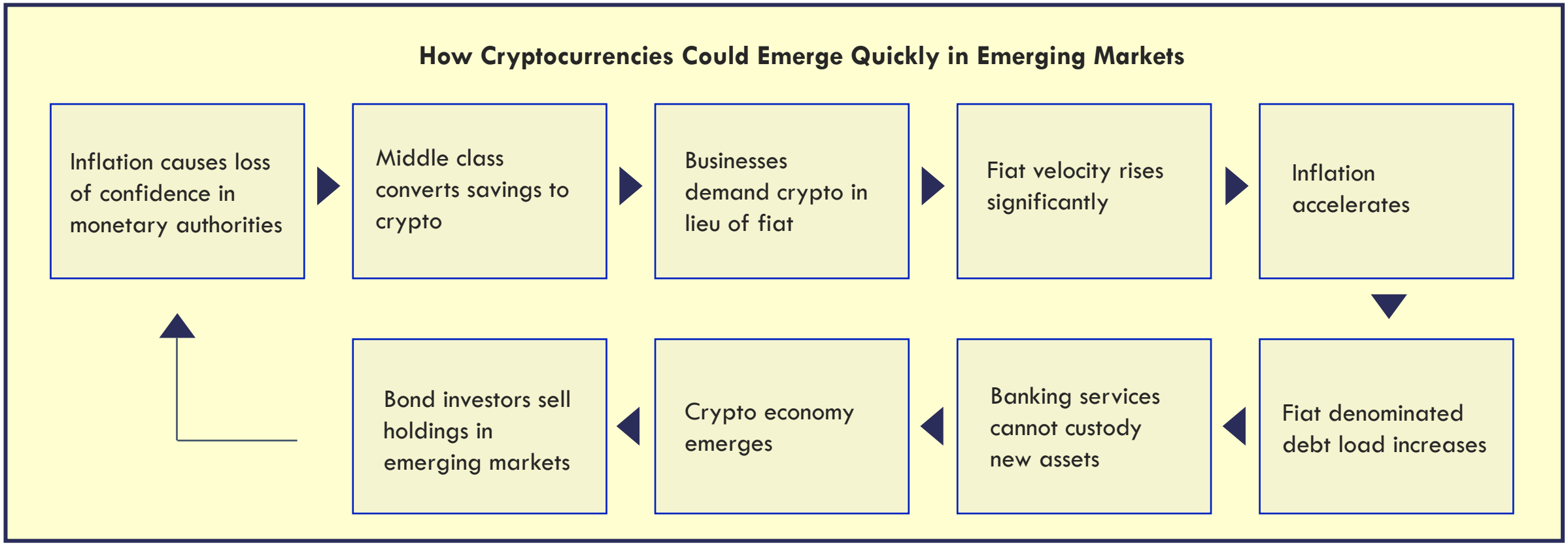
Infrastructure Will Reinforce Bitcoin's Layered Architecture

1. **Casa:** personal key security system for Bitcoin, Ethereum, Litecoin, and more. Multi-signature key service with hardware wallets.
2. **Bakkt:** an open, seamless global network to enable purchases, sales, storage, and ecommerce simply, safely, and efficiently.
3. **Lightning Labs:** an open protocol layer that leverages the power of blockchains and smart contracts to make cheap, fast, private transactions.
4. **TxTenna:** an app that enables off-grid broadcasts of Bitcoin transactions from Samourai Wallet.
5. **CoinJoin:** a decentralized method of combining multiple bitcoin payments from multiple spenders into a single transaction, making it difficult for outside parties to determine which spender paid which recipient or recipients.
6. **Bitrefill:** an ecosystem that refills prepaid phones & buys gift cards online using cryptocurrencies.

Source: ARK Investment Management LLC, 2018

"Bitcoinization" is Impacting Economies

"Bitcoinization" is defined as a Bitcoin-induced currency demonetization. With hyperinflation in emerging markets like Venezuela, Iran, and Zimbabwe, the demand for cryptocurrencies could increase suddenly and significantly.



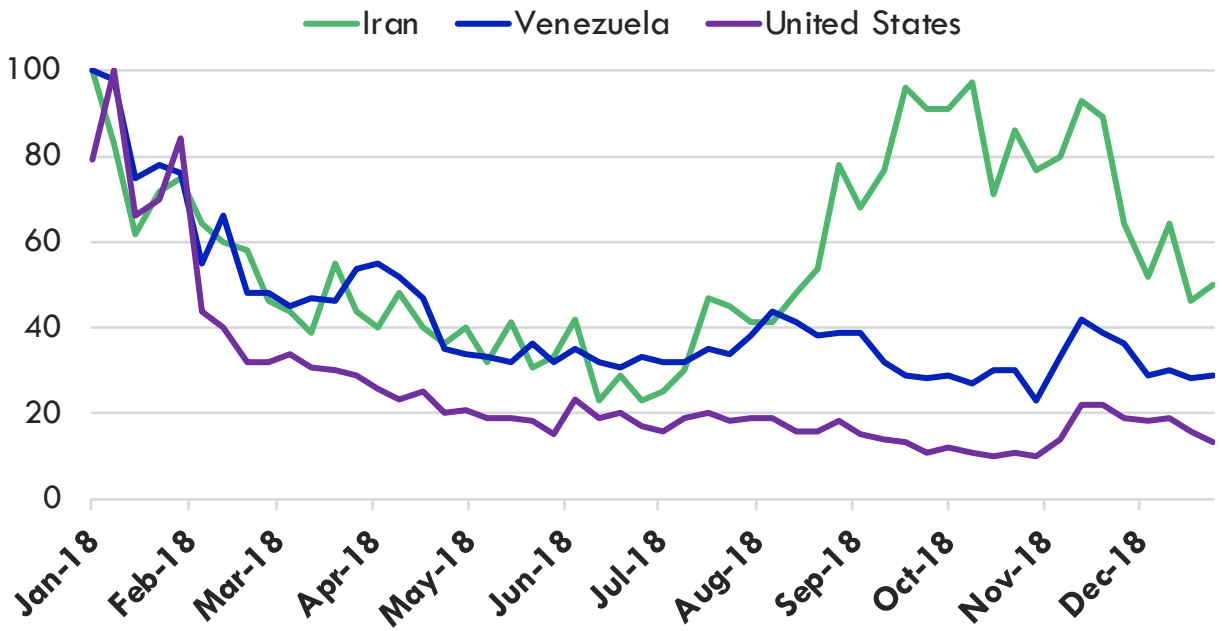
Source: ARK Investment Management LLC, 2018

Sizing the Opportunity

Emerging Markets Prone to Inflation Are Adopting Bitcoin.

As indicated by Google search trends and exchange volume statistics, demand for bitcoin in emerging markets is high and growing.

Google Search Trends of "Bitcoin" by Country



Local Bitcoin Volume in Venezuela

Source: ARK Investment Management LLC, 2018

Risk and Disclosure

Please note, companies that ARK believes are capitalizing on disruptive innovation and developing technologies to displace older technologies or create new markets may not in fact do so and/or may face political or legal attacks from competitors, industry groups, or local and national governments.

ARK aims to educate investors and to size the potential opportunity of **Cryptoassets,** noting that risks and uncertainties may impact our projections and research models. Investors should use the content presented for informational purposes only, and be aware of market risk, disruptive innovation risk, regulatory risk, and risks related to **Cryptoassets,** such as:

- Cryptocurrency Risk
- Cryptocurrency Tax Risk

Cryptocurrency Risk. Cryptocurrency (notably, bitcoin), often referred to as "virtual currency" or "digital currency," operates as a decentralized, peer-to-peer financial exchange and value storage that is used like money. ARK's investment products may have exposure to bitcoin, a cryptocurrency, indirectly through an investment in the Bitcoin Investment Trust ("GBTC"), a privately offered, open-end investment vehicle. Cryptocurrency operates without central authority or banks and is not back by any government. Even indirectly, cryptocurrencies (i.e., bitcoin) may experience very high volatility and related investment vehicles like GBTC may be affected by such volatility. As a result of holding cryptocurrency, regulated investment companies such as Exchange Traded Funds ("ETFs") may also trade at a significant premium to NAV. Cryptocurrency is also not legal tender. Federal, state or foreign governments may restrict the use and exchange of cryptocurrency, and regulation in the U.S. is still developing. Cryptocurrency exchanges may stop operating or permanently shut down due to fraud, technical glitches, hackers or malware. **Cryptocurrency Tax Risk.** Many significant aspects of the U.S. federal income tax treatment of investments in bitcoin are uncertain and an investment in bitcoin may produce income that is not treated as qualifying income for purposes of the income test applicable to regulated investment companies, such as ETFs. GBTC is expected to be treated as a grantor trust for U.S. federal income tax purposes, and therefore an investment by ETFs in GBTC will generally be treated as a direct investment in bitcoin for such purposes. Additional information may be found in the "Taxes" section of an ETF's disclosure documents such as the prospectus and/or SAI.

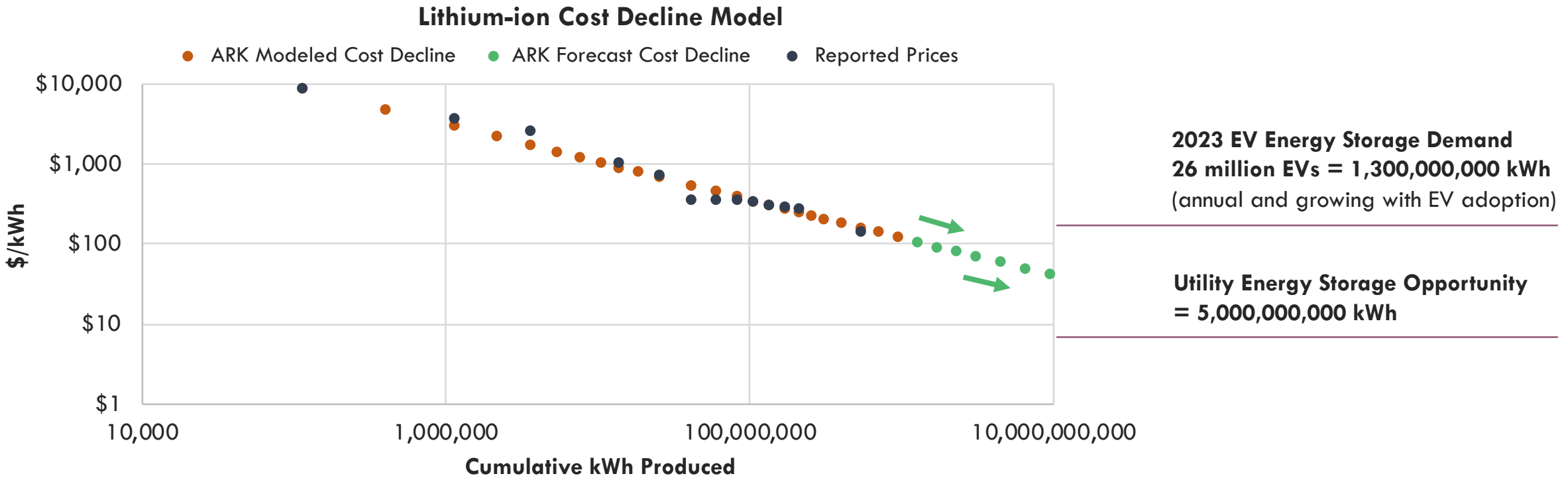
Battery Cost Tipping Points

Batteries have entered a virtuous cycle: cost of goods is falling, stimulating unit demand growth which, in turn, is pushing batteries further down the cost curve.

ARK is forecasting that electric vehicle sales will rise from roughly 1.3 million in 2018 to more than 26 million in 2023. As a result, battery costs should drop to a point where utility-scale energy storage becomes attractive, enabling a multitude of new applications.

Lithium-ion Battery Costs Are Dropping Relentlessly

- Commercialized and assumed to have reached maturity in the early 1990's, batteries are experiencing faster cost declines than most analysts anticipated.
- As batteries decline in cost, they are passing critical unit economic tipping points, unleashing further demand.
- Electric Vehicles (EVs) will drive battery prices down to a point where they will become economic for utility-scale energy storage.



Forecasts are inherently limited and cannot be relied upon.
Sources: ARK Investment Management, 2018; Avicenne Energy, Crabtree, George, et al. "The Energy-Storage Frontier: Lithium-Ion Batteries and Beyond." *UChicago.edu*, Dec. 2015, https://arkinv.st/2VAmn0S.

Battery Cost Declines Are Enabling New Applications

- Low cost energy storage is enabling electric vehicles, stationary energy storage, and form factor diversification.
- ARK's research focuses on Electric Vehicles and Utility Energy Storage as the main drivers of battery demand.

Electric Vehicles

In August Tesla's Model 3 became the top revenue grossing sedan in the U.S.[1]

Utility Energy Storage

California's Public Utilities Commission approved more than 2 GWh of energy storage to replace natural gas plants.[2]

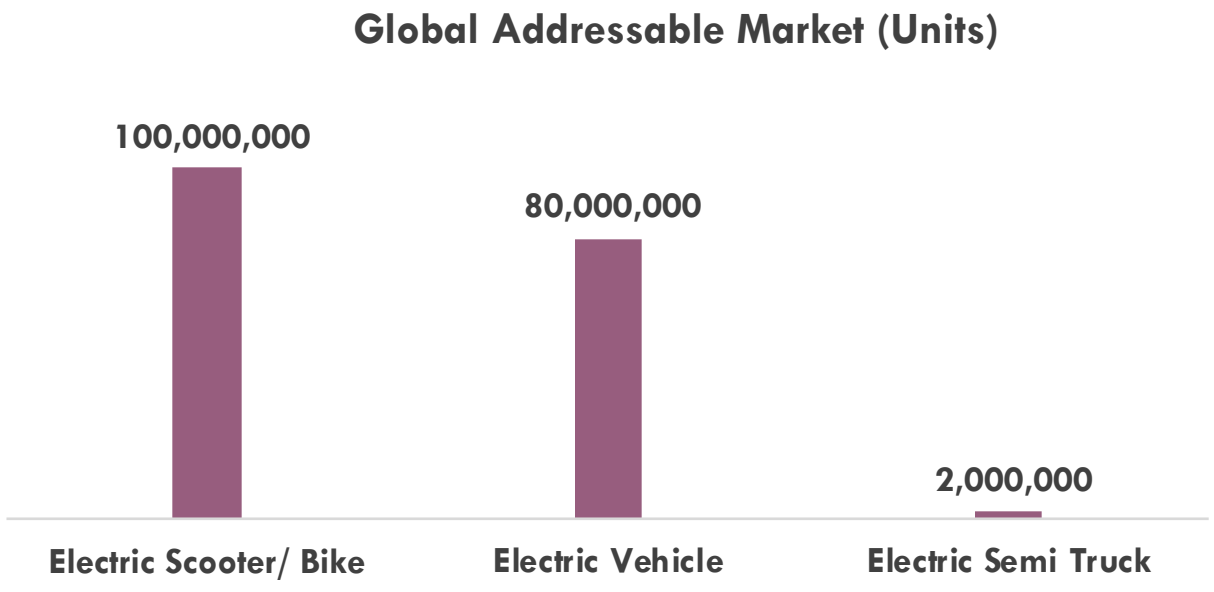
Micromobility

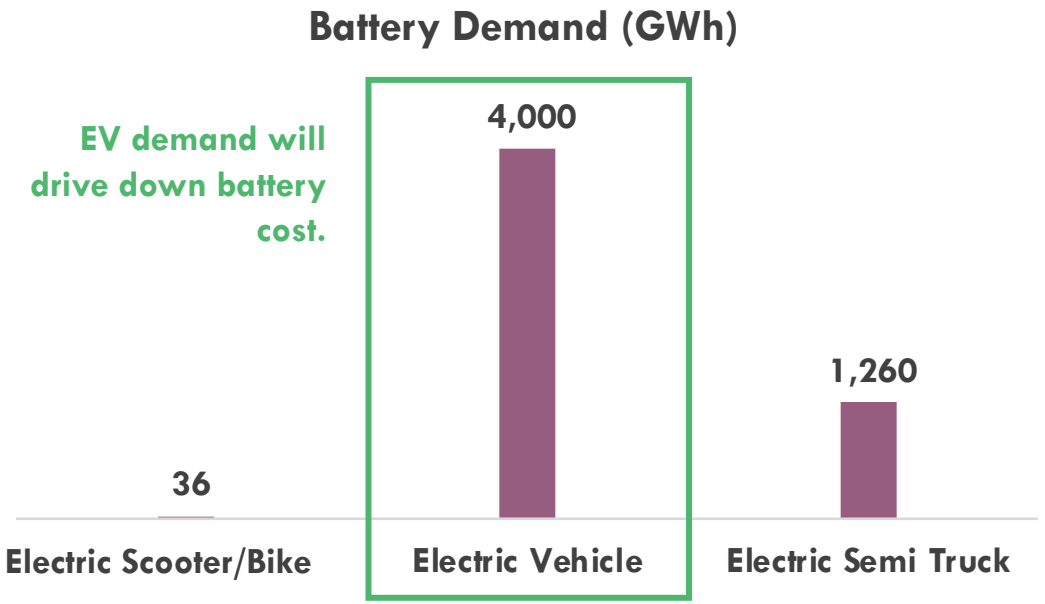
30% of vehicle trips in the US are fewer than two miles in distance.[3]

Sources: [1] Grinshpun, Michael. "Tesla Model 3 = #1 Best Selling Car In The US (In Revenue)." *CleanTechnica*, 9 Sept. 2018, https://arkinv.st/2Fenuhf.
[2] Lambert, Fred. "Tesla and Others to Deliver over 2 GWh of Energy Storage in California Project to Replace 3 Gas Plants." *Electrek*, 9 Nov. 2018, https://arkinv.st/2CVPQLD.
[3] ARK Investment Management LLC, 2018 Data from: NHTS

All Vehicles Are Likely to Run on Electric Drivetrains

- If all vehicles go electric, the annual demand for batteries should top 4,000 GWh, more than 20 times current production levels.
- EVs probably will be the most important determinant of battery demand, though their unit sales may not top those of electric scooters/bikes, and their battery packs will be smaller than those of electric semi trucks.

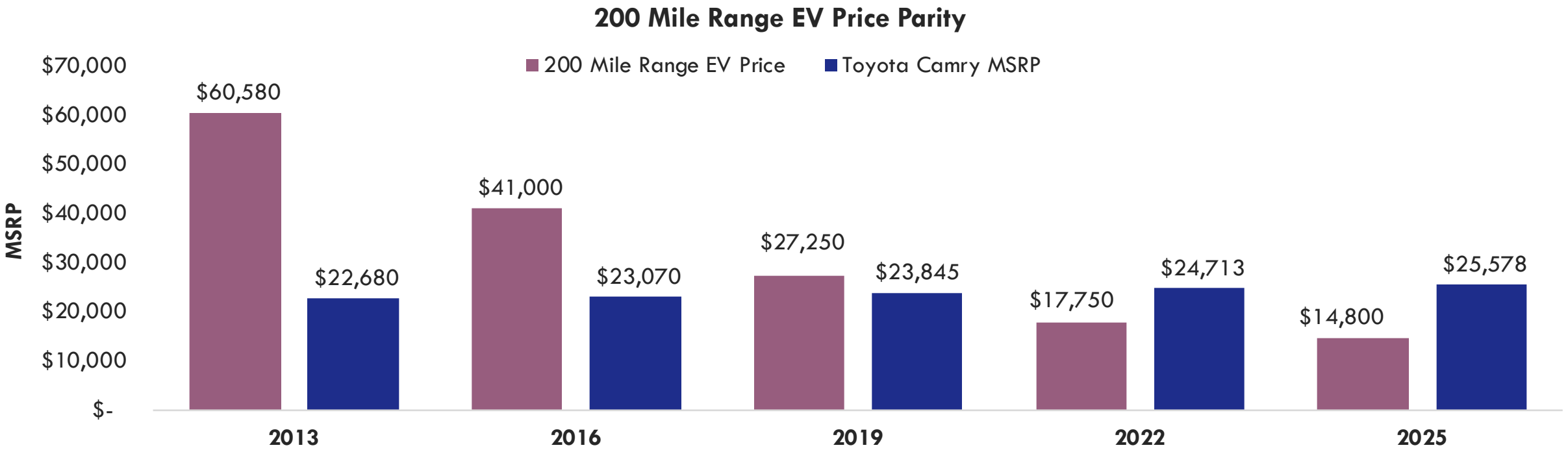




Forecasts are inherently limited and cannot be relied upon.
Sources: ARK Investment Management, 2018

Thanks to Battery Cost Declines, EVs Should be Cheaper Than Comparable Gas-Powered Cars by 2022

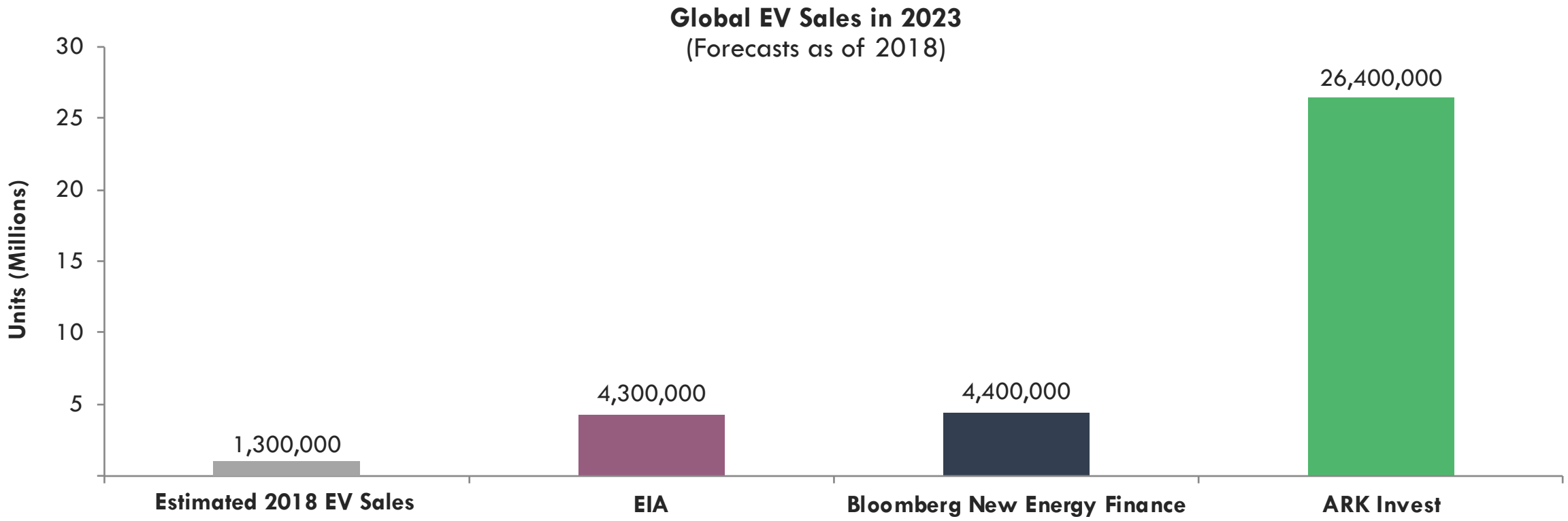
- Battery costs should continue to drop, pushing EV prices below gas-powered vehicles in the early 2020s.
- In 2025 EVs should be competitive with gas powered cars at every price point, unleashing tremendous demand.



Forecasts are inherently limited and cannot be relied upon.
Source: ARK Investment Management LLC, 2018 | ARK's expectation for EV MSRP (Manufacturer's Suggested Retail Price) parity is largely based on decreasing lithium-ion battery costs. Other factors could influence MSRP. The MSRP prices shown do not include any government subsidies.

Sizing the Opportunity

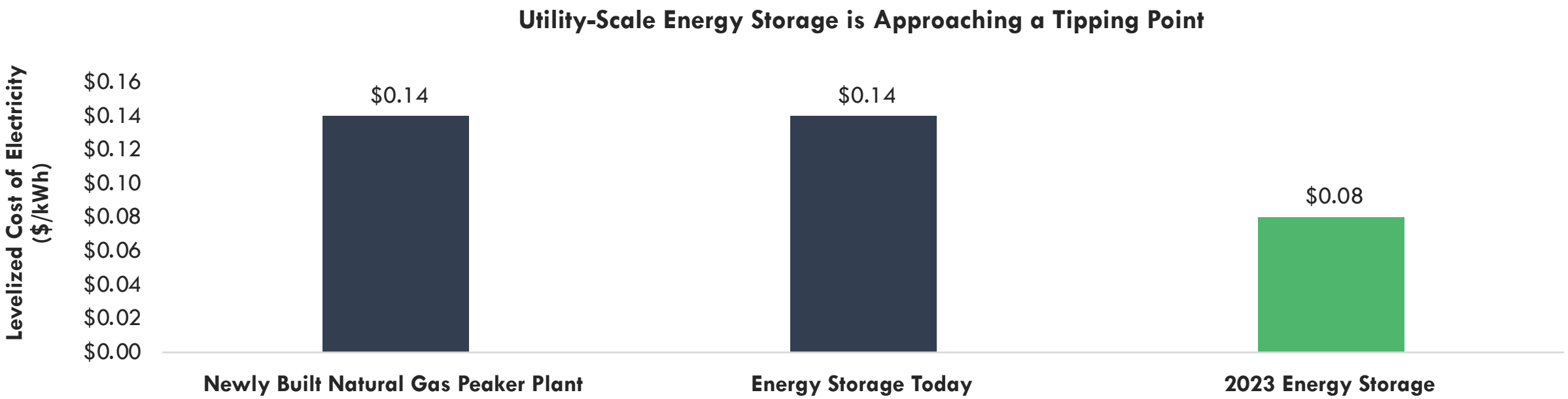
ARK Forecasts That EV Sales Will Top 26 Million Globally in 2023.



Forecasts are inherently limited and cannot be relied upon.
Source: ARK Investment Management LLC, 2018; Data from: Bloomberg New Energy Finance, U.S. Energy Information Administration, EV-volumes.com.

Utility-Scale Energy Storage Should Become Competitive

- Energy storage already is competitive with newly built natural gas plants.
- As battery costs decline, energy storage will become competitive with "peaker" plants and other underutilized generators.
- Building and operating new utility-scale energy storage will be more cost-effective than operating underutilized plants.

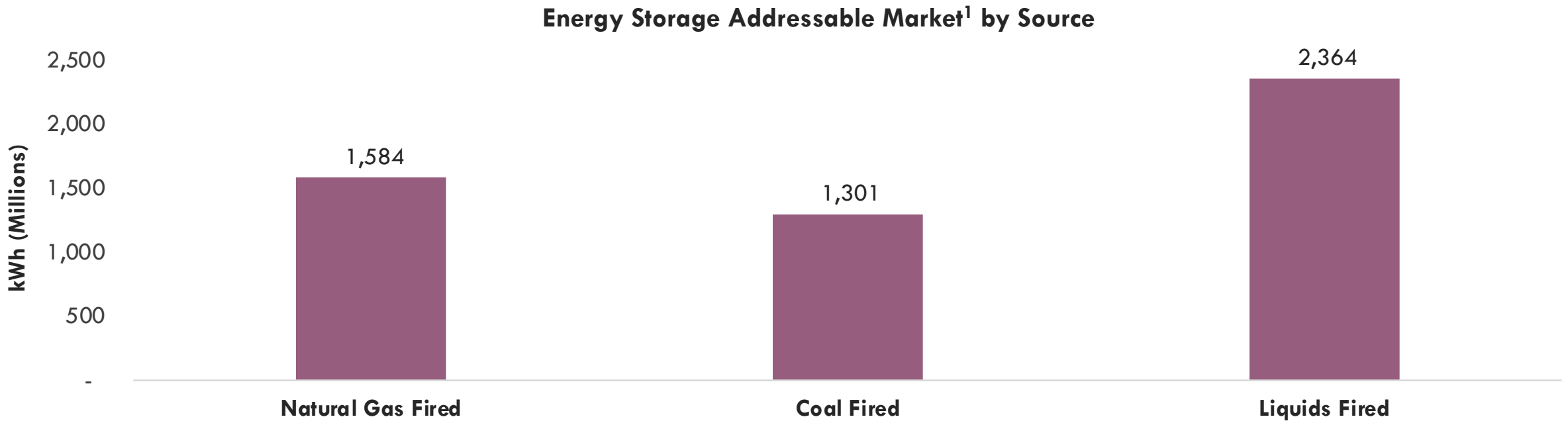


Sources: ARK Investment Management LLC, 2018; Energy Information Administration; "Lazard's Levelized Cost of Energy Analysis — Version 12.0." *Lazard*, 2018, https://arkinv.st/2H5kUfT.

Sizing the Opportunity

The Addressable Market for Utility-Scale Energy Storage Is $800 Billion.

- ARK's research shows that, at $150/kWh, utility energy storage should become competitive with underutilized plants.
- Assuming batteries cycle daily, roughly 5 billion kWh of energy storage could replace electricity generated from underutilized plants.



Sources: ARK Investment Management LLC, 2018; Energy Information Administration | [1] Addressable market is electricity generated from underutilized plants.

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- Industrials Sector Risk
- Information Technology Sector Risk

Industrials Sector Risk. The industrials sector includes companies engaged in the aerospace and defense industry, electrical engineering, machinery, and professional services. Companies in the industrials sector may be adversely affected by changes in government regulation, world events and economic conditions. In addition, companies in the industrials sector may be adversely affected by environmental damages, product liability claims and exchange rates. *Aerospace and Defense Company Risk*. Companies in the aerospace and defense industry rely to a large extent on U.S. (and other) Government demand for their products and services and may be significantly affected by changes in government regulations and spending, as well as economic conditions and industry consolidation. *Professional Services Company Risk*. Professional services companies may be materially impacted by economic conditions and related fluctuations in client demand for marketing, business, technology and other consulting services. Professional services companies' success depends in large part on attracting and retaining key employees and a failure to do so could adversely affect a company's business. There are relatively few barriers to entry into the professional services market, and new competitors could readily seek to compete in one or more market segments, which could adversely affect a professional services company's operating results through pricing pressure and loss of market share. **Information Technology Sector Risk.** The information technology sector includes companies engaged in internet software and services, technology hardware and storage peripherals, electronic equipment instruments and components, and semiconductors and semiconductor equipment. Information technology companies face intense competition, both domestically and internationally, which may have an adverse effect on profit margins. These companies may have limited product lines, markets, financial resources or personnel. The products of information technology companies may face rapid product obsolescence due to technological developments and frequent new product introduction, unpredictable changes in growth rates and competition for the services of qualified personnel. Failure to introduce new products, develop and maintain a loyal customer base, or achieve general market acceptance for their products could have a material adverse effect on a company's business. Companies in the information technology sector are heavily dependent on intellectual property and the loss of patent, copyright and trademark protections may adversely affect the profitability of these companies.

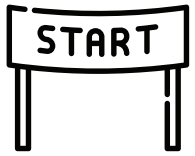
Autonomous Taxi Networks

ARK expects fully autonomous vehicles to be available commercially before 2020, enabling the rise and rapid growth of autonomous taxi networks. These networks should decrease the cost and inconvenience of point-to-point travel.

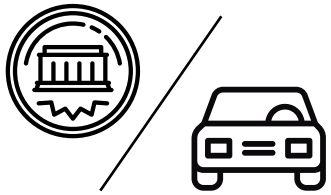
ARK believes that autonomous taxi networks represent one of the most important investment opportunities in public equity markets.

The Future of Driving Is Autonomous

ARK identifies four milestones in autonomous travel:



Autonomous driving technology is ready today and should reach consumers in the next 1-2 years.



Autonomous travel should be inexpensive, driving widespread adoption.

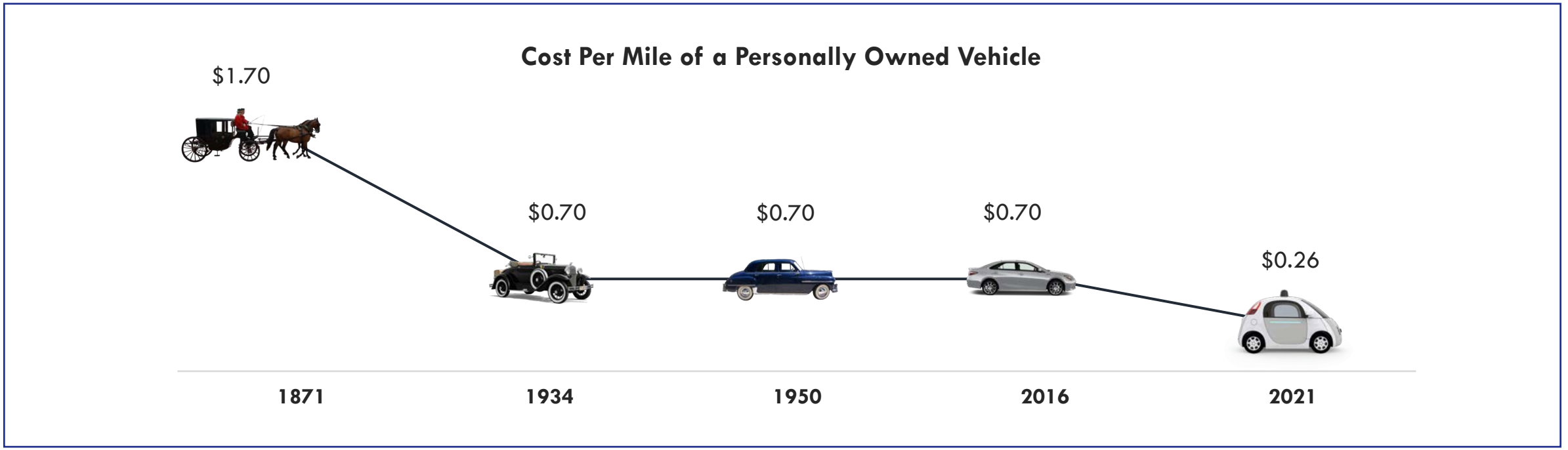
Autonomous travel should supercharge app-based ride hailing.

Autonomous taxis will not involve human drivers but, in rare instances, probably will be assisted by remote human operators.

Source: ARK Investment Management LLC, 2018

Transportation Should Become More Affordable

- The cost to own and operate a personal car has not changed since the Model T rolled off the first assembly line.
- ARK estimates that, at scale, autonomous taxis will cost consumers $0.26 cents per mile, spurring widespread adoption.

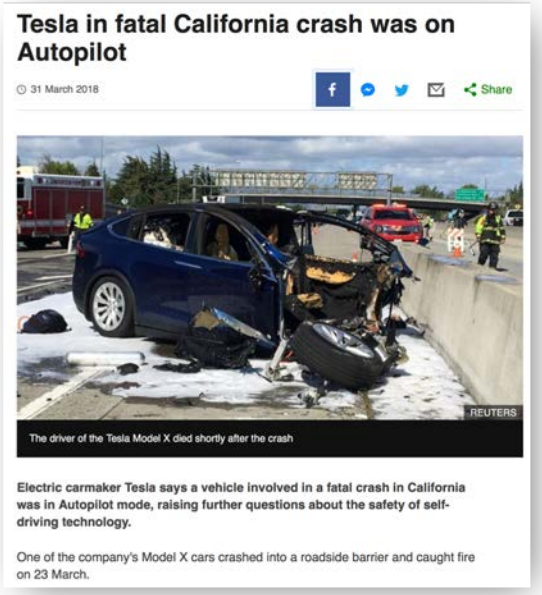


Note that ARK had estimated previously that an autonomous taxi could price at $0.35 per mile. We have refined our estimates and believe that autonomous taxis could be even cheaper, at only $0.26 per mile due to remote operator costs and discount rates.

Forecasts are inherently limited and cannot be relied upon.
Sources: ARK Investment Management LLC, 2018; Morton Salt Company Records, American Automobile Association (AAA)

Autonomous Driving Is An Extremely Challenging Problem to Solve

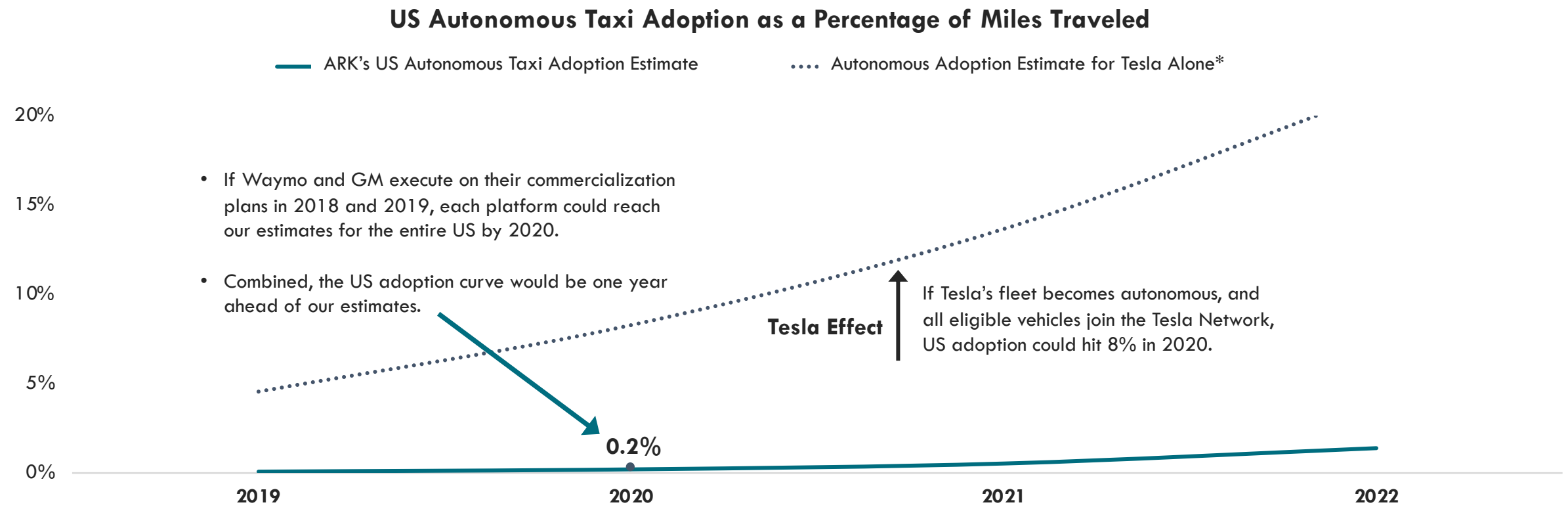
Fully autonomous driving (Level 5) is not ready for prime time yet, but ARK believes that Level 4 – in which a car drives itself most of the time with the exception of rare circumstances or in severe weather conditions – is ready for prime time.



Source: Variety of news sources in order:
[1] "Tesla in Fatal California Crash Was on Autopilot." *BBC News*, 31 Mar. 2018, https://arkinv.st/2GYmy31.
[2] Boland, Hannah. "Waymo's Self-Driving Cars 'Struggle to Turn Left and Don't Understand Basic Road Features'." *The Telegraph*, 29 Aug. 2018, https://arkinv.st/2LVE32L.
[3] Stock, Kyle. "Self-Driving Cars Can Handle Neither Rain nor Sleet nor Snow." *Bloomberg*, 17 Sept. 2018, https://arkinv.st/2RzoXVX.
[4] Efrati, Amir. "Uber Finds Deadly Accident Likely Caused By Software Set to Ignore Objects On Road." *The Information*, 7 May 2018, https://arkinv.st/2AvyLGE.

Travel Could Go Autonomous Sooner Than Most Expect

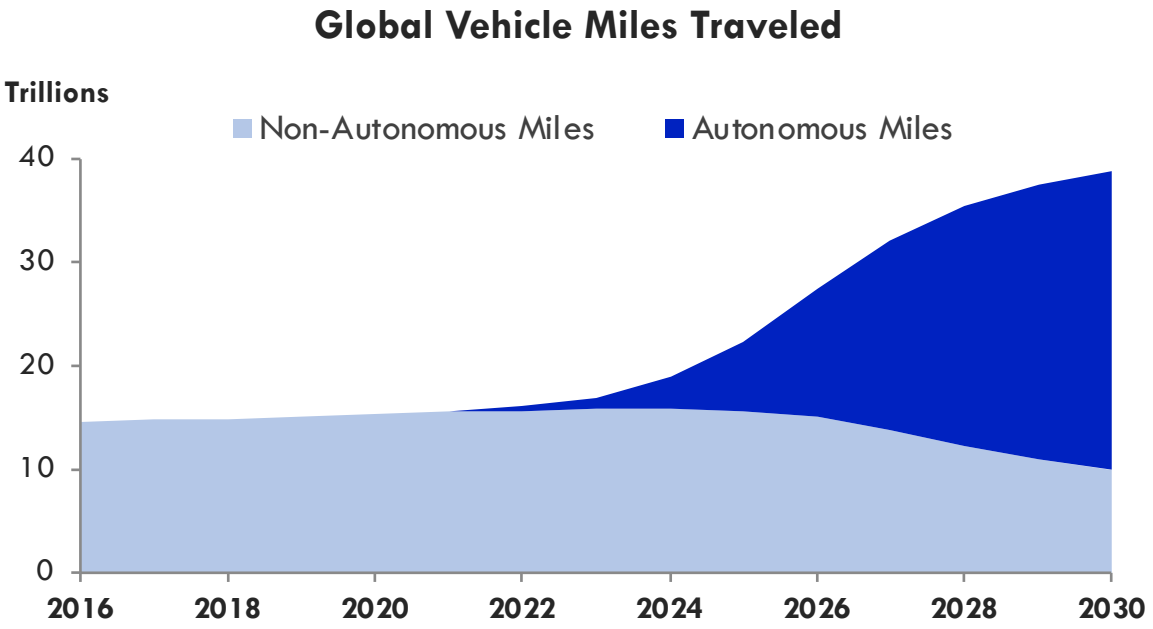
ARK's autonomous taxi adoption forecast is conservative, given the rollout plans of Waymo, GM, and Tesla.

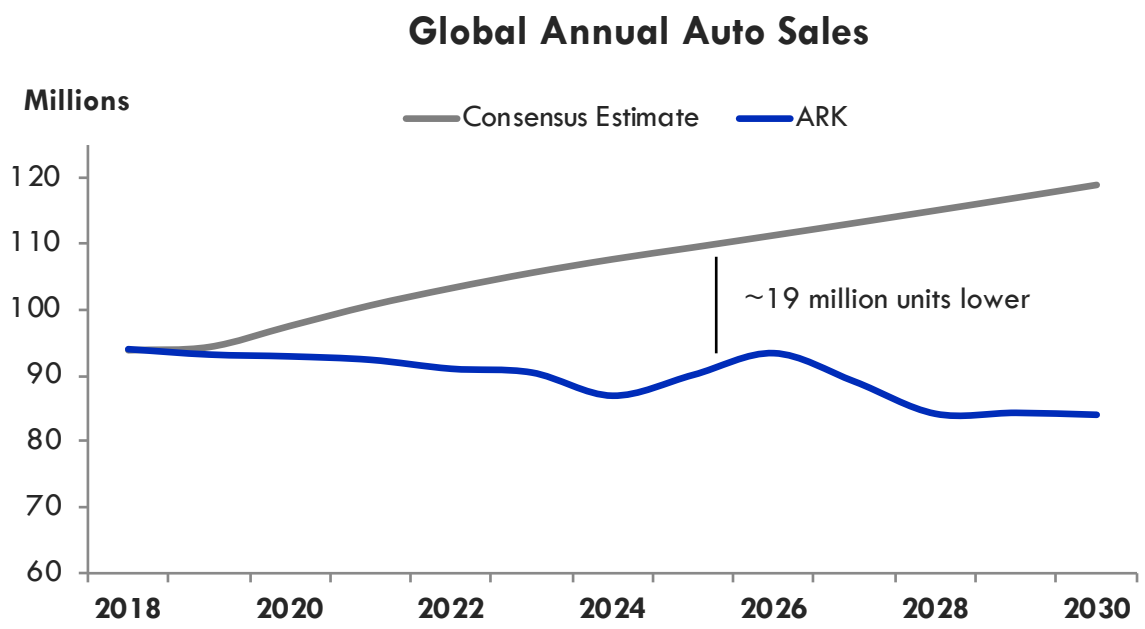


Source: ARK Investment Management LLC, 2018 | *Assumes all eligible vehicles join the network.

Autonomous Taxis Will Cause More Congestion, But Will Lower Car Sales

- ARK expects global vehicle miles traveled to increase two- to three-fold during the next 15 years, as autonomous costs drop.
- At the same time, auto sales should be flat to down, thanks to the higher utilization of autonomous taxis.



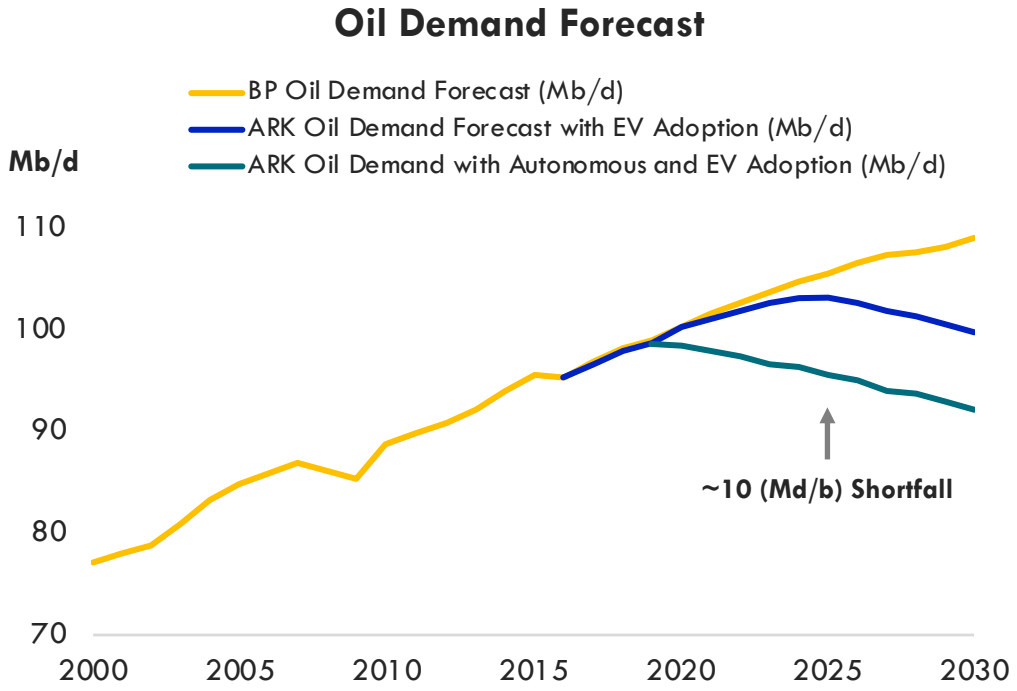


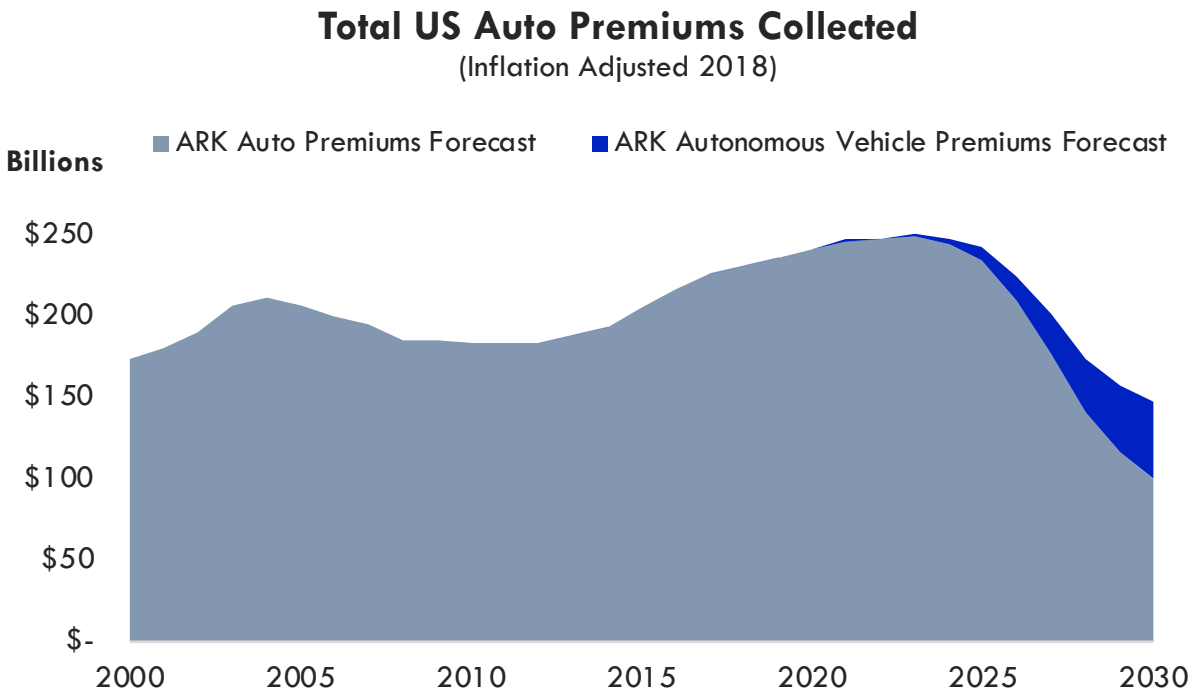
Forecasts are inherently limited and cannot be relied upon.
Sources: ARK Investment Management LLC, 2018
"Global Light Vehicle Sales Summary." *IHS Markit*, Oct. 2018, https://arkinv.st/2VBxAhW | "Learn About BTS and Our Work." *Bureau of Transportation Statistics*, 2018, https://arkinv.st/2VBrn5q. | "Travel Monitoring - Traffic Volume Trends." *U.S. Department of Transportation - Federal Highway Administration*, 2018, https://arkinv.st/2H5utLP | "Global Autos Outlook 2019: Waiting for the Final Cut." *Evercore ISI*, 2018, https://arkinv.st/2M23csu.

Autonomous Taxis Should Curtail Both Oil Demand and Insurance Premiums

Because of electric vehicle and autonomous taxi adoption, oil demand could peak next year and, within five years, could drop by roughly 10%, or 10 Mb/d, relative to expectations.

By 2030, annual insurance premiums could fall by 50-60% to $100 billion, thanks to the increased safety of autonomous technology and early adoption by young drivers who pay the highest rates today.



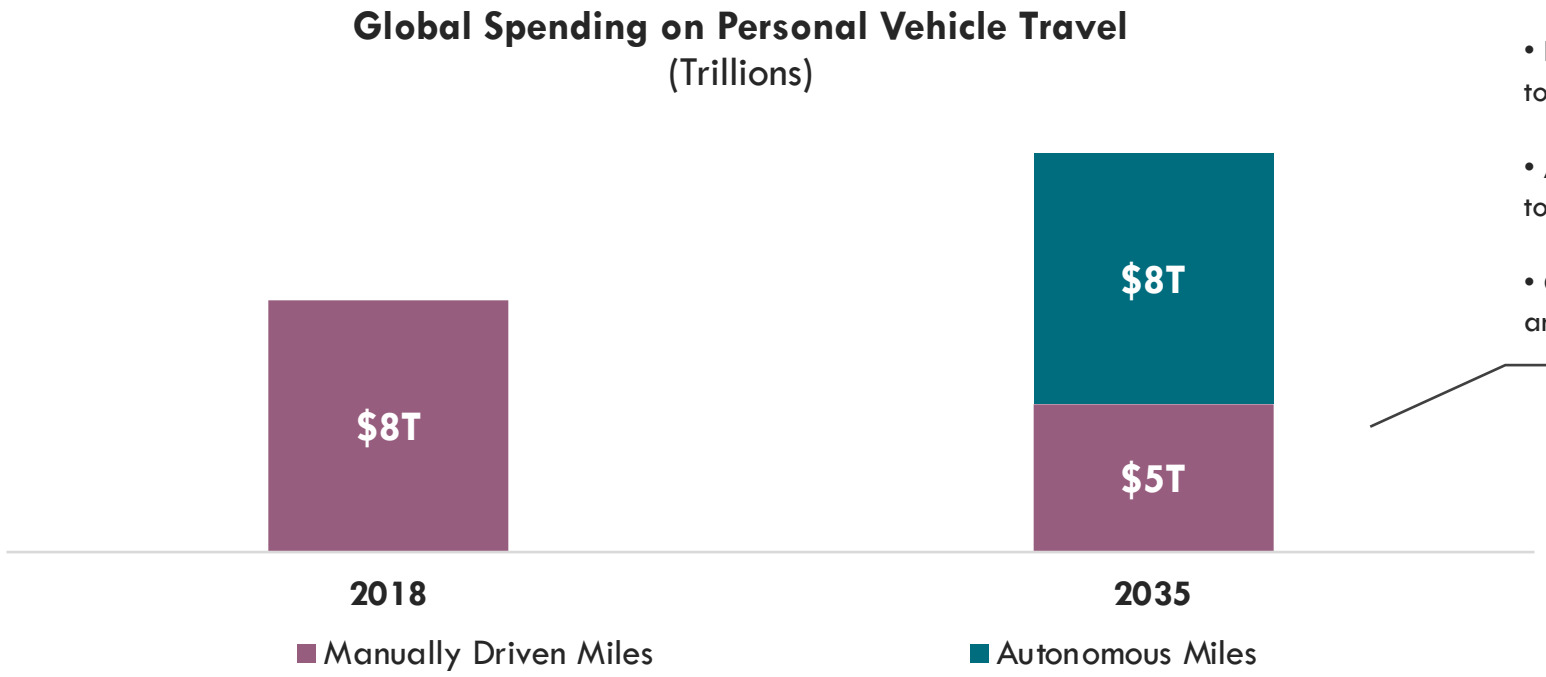


Forecasts are inherently limited and cannot be relied upon.
Sources: ARK Investment Management LLC, 2018; "BP Energy Outlook 2017 Edition." *BP.com*, 2017, https://arkinv.st/2AvQtcX.

Sizing the Opportunity

Autonomous Taxi Revenues Could Reach $8 Trillion in 2035.

Autonomous taxis should expand the market for personal point-to-point travel.



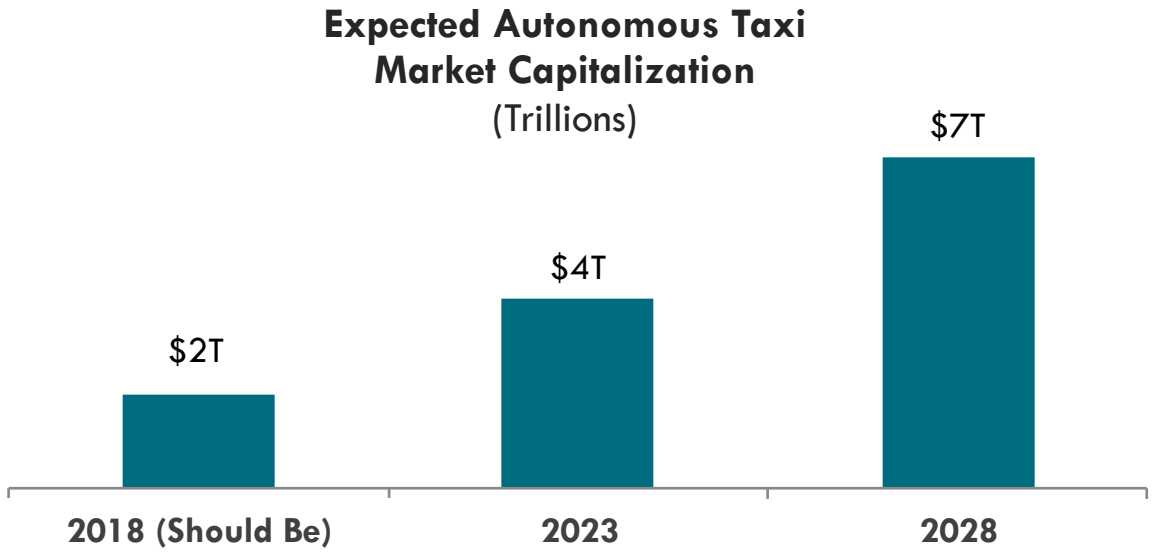
- In urban areas, manually driven miles should convert to autonomous miles.
- Average cost per mile traveled should drop, while total miles driven increase.
- Consequently, the market for vehicle manufacturers and suppliers will consolidate.

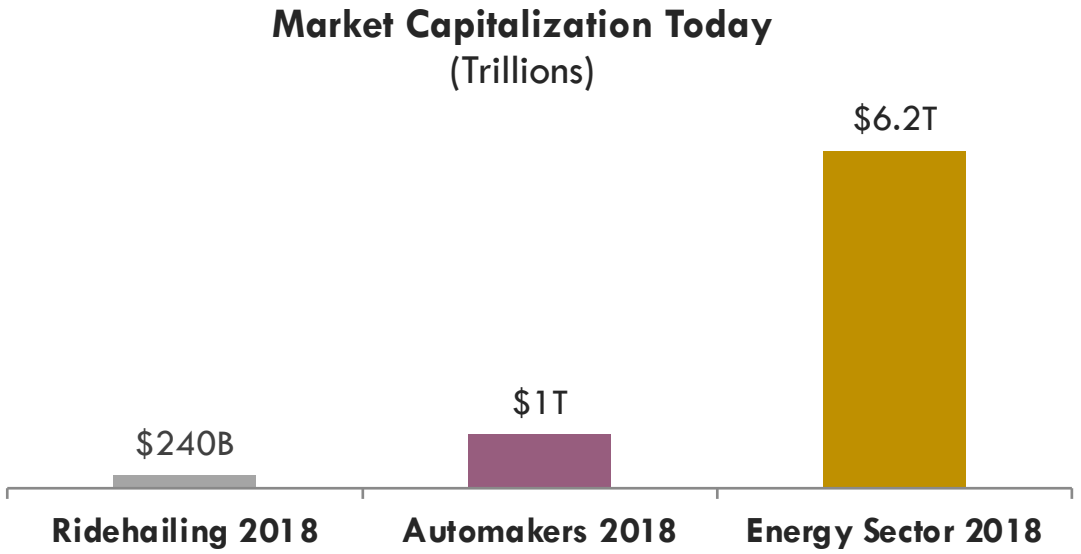
Forecasts are inherently limited and cannot be relied upon.
Source: ARK Investment Management LLC, 2018

Sizing the Opportunity

ARK Believes That the Autonomous Taxi Opportunity Should Be Valued at $2 Trillion Dollars Today and $7 Trillion by 2028.

By 2028, the market cap of autonomous taxi platforms could exceed that of today's energy sector.



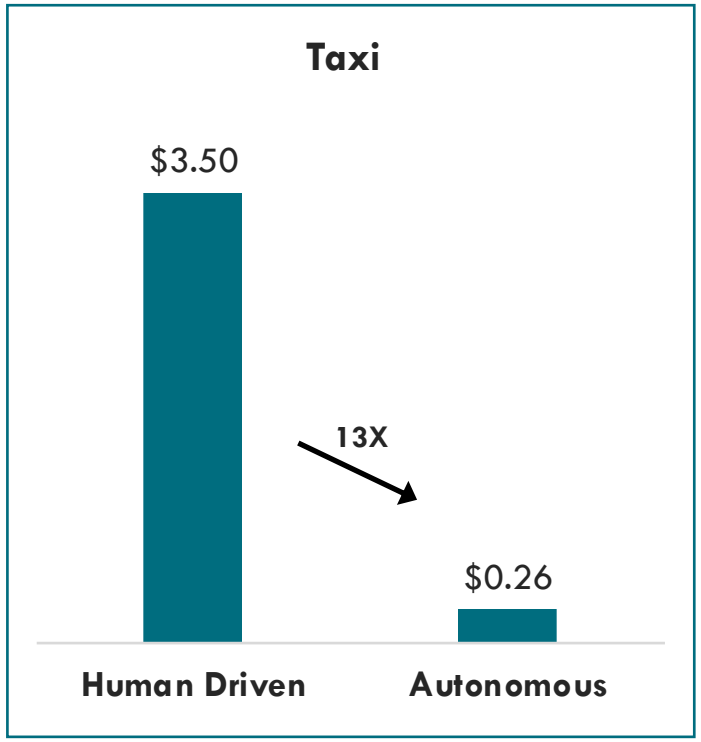


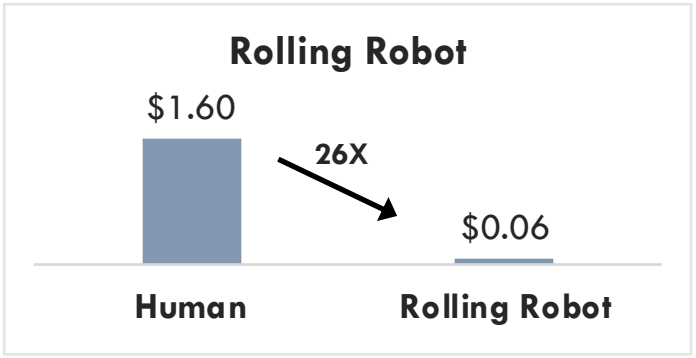
Forecasts are inherently limited and cannot be relied upon.
Source: ARK Investment Management LLC, 2018
Note: ARK's estimate for market capitalization is using our global adoption curve and revenue estimates, assuming software like margins and cash flow for platform operators, and discounting cash flows from 15 years forward.

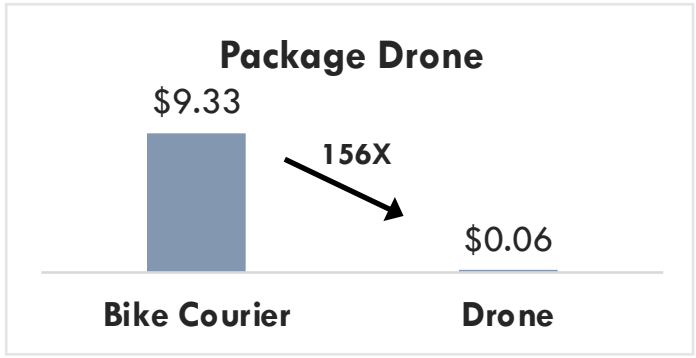
Outlook

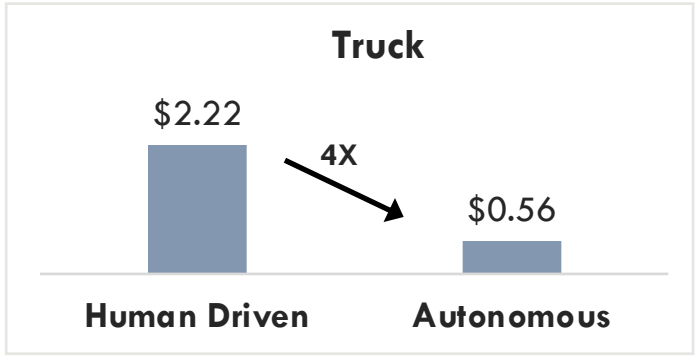
The Cost of Moving People and Goods Is Declining Dramatically Across All Forms of Transportation.

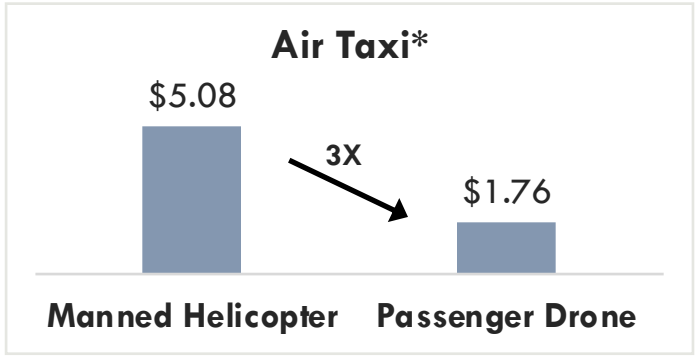
Price-Per-Mile Comparisons Across Transportation Modes











Forecasts are inherently limited and cannot be relied upon.
Source: ARK Investment Management LLC, 2018 | *Note: excludes landing costs

Risk and Disclosure

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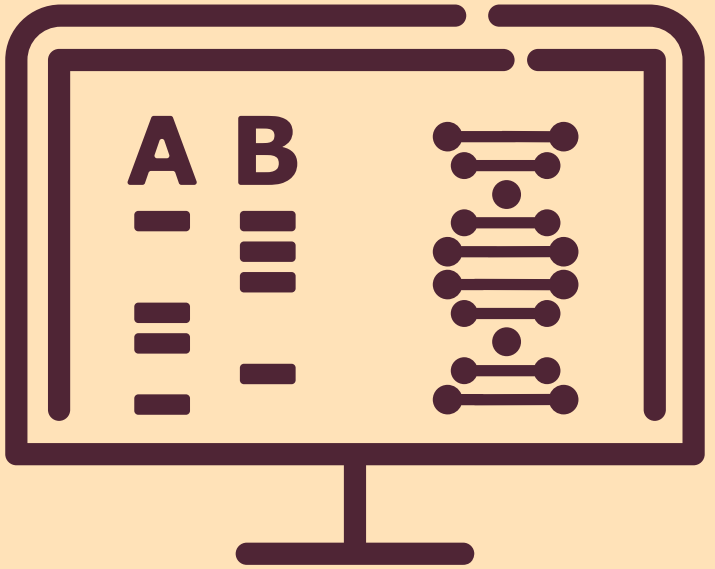
- Industrials Sector Risk
- Information Technology Sector Risk

Industrials Sector Risk. The industrials sector includes companies engaged in the aerospace and defense industry, electrical engineering, machinery, and professional services. Companies in the industrials sector may be adversely affected by changes in government regulation, world events and economic conditions. In addition, companies in the industrials sector may be adversely affected by environmental damages, product liability claims and exchange rates. *Aerospace and Defense Company Risk*. Companies in the aerospace and defense industry rely to a large extent on U.S. (and other) Government demand for their products and services and may be significantly affected by changes in government regulations and spending, as well as economic conditions and industry consolidation. *Professional Services Company Risk*. Professional services companies may be materially impacted by economic conditions and related fluctuations in client demand for marketing, business, technology and other consulting services. Professional services companies' success depends in large part on attracting and retaining key employees and a failure to do so could adversely affect a company's business. There are relatively few barriers to entry into the professional services market, and new competitors could readily seek to compete in one or more market segments, which could adversely affect a professional services company's operating results through pricing pressure and loss of market share. **Information Technology Sector Risk.** The information technology sector includes companies engaged in internet software and services, technology hardware and storage peripherals, electronic equipment instruments and components, and semiconductors and semiconductor equipment. Information technology companies face intense competition, both domestically and internationally, which may have an adverse effect on profit margins. These companies may have limited product lines, markets, financial resources or personnel. The products of information technology companies may face rapid product obsolescence due to technological developments and frequent new product introduction, unpredictable changes in growth rates and competition for the services of qualified personnel. Failure to introduce new products, develop and maintain a loyal customer base, or achieve general market acceptance for their products could have a material adverse effect on a company's business. Companies in the information technology sector are heavily dependent on intellectual property and the loss of patent, copyright and trademark protections may adversely affect the profitability of these companies.

Next Generation DNA Sequencing

Next-generation DNA sequencing is the driving force behind the genomic revolution. DNA sequencing costs are dropping dramatically. Since 2003 the cost to sequence a whole human genome has dropped from nearly $3 billion to less than $1,000, leveraging advances in biochemistry and computation.

ARK believes that as costs continue to drop, sequencing could become the clinical standard of care, introducing more science and knowledge to decision-making in health, agriculture, disease, and drug discovery.



Sequencing the Human Genome: A Retrospective

1953
DNA Structure[1]

Watson and Crick propose the double-helical model of human DNA at Cambridge University.

1980
Sanger Sequencing[2]

Frederick Sanger is awarded the Nobel Prize for developing a method to sequence DNA rapidly and accurately.

2003
Human Genome Project[3]

NIH and Craig Venter sequence the first whole human genome.

2009
Next Generation Sequencing ("NGS")[4]

Solexa, now owned by Illumina, commercializes high-throughput, high-accuracy DNA sequencing.

2014
$1,000 Genome[5]

Illumina reduces the cost for whole human genome sequencing to less than $1,000 (USD).

2018
ILMN Acquires PACB[6]

Illumina and "PacBio" join forces, offering a comprehensive view of the genome.

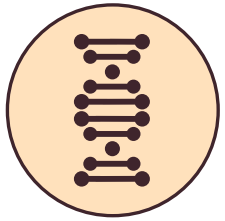
2020
Outlook

AI-based bioinformatics tools and long-read sequencing cost declines could power NGS clinical adoption in the early 2020's.

Forecasts are inherently limited and cannot be relied upon.

[1] Rettner, Rachael. "DNA: Definition, Structure & Discovery." *LiveScience*, 7 Dec. 2017, https://arkinv.st/2SMKg3P.
[2] "Frederick Sanger – Facts." *Nobel Media*, 2018, https://arkinv.st/2Fd6Z5K.
[3] "International Consortium Completes Human Genome Project." *National Human Genome Research Institute (NHGRI)*, 14 Apr. 2003, https://arkinv.st/2sfja9z.
[4] Barba, Marina et al. "Historical perspective, development and applications of next-generation sequencing in plant virology." *Viruses* vol. 6,1 106-36. 6 Jan. 2014, https://arkinv.st/2TDqW9b.
[5] Hayden, Erika C. "Technology: The $1,000 Genome." *Nature*, 19 Mar. 2014, https://arkinv.st/2TyuzNC.
[6] "Illumina to Acquire Pacific Biosciences for $1.2 Billion." *GenomeWeb*, 1 Nov. 2018, https://arkinv.st/2AzS95j.

NGS Has Turbocharged the Progress of DNA Sequencing



Next Generation Sequencing ("NGS")[1]

NGS is a high-speed, high-throughput methodology to detect the base pair sequence of DNA and RNA samples that combines novel biochemistry as well as optical and computing technologies.

ARK believes that innovation platforms like DNA sequencing:

Cause Rapid Cost Declines

NGS has cut sequencing costs to under $1,000 per whole human genome, creating new therapeutic and diagnostic market opportunities.[2]

Cut Across Sectors and Geographies

Lower costs have enabled NGS research and commercialization in sectors ranging from healthcare to agriculture.

Spawn Further Innovation

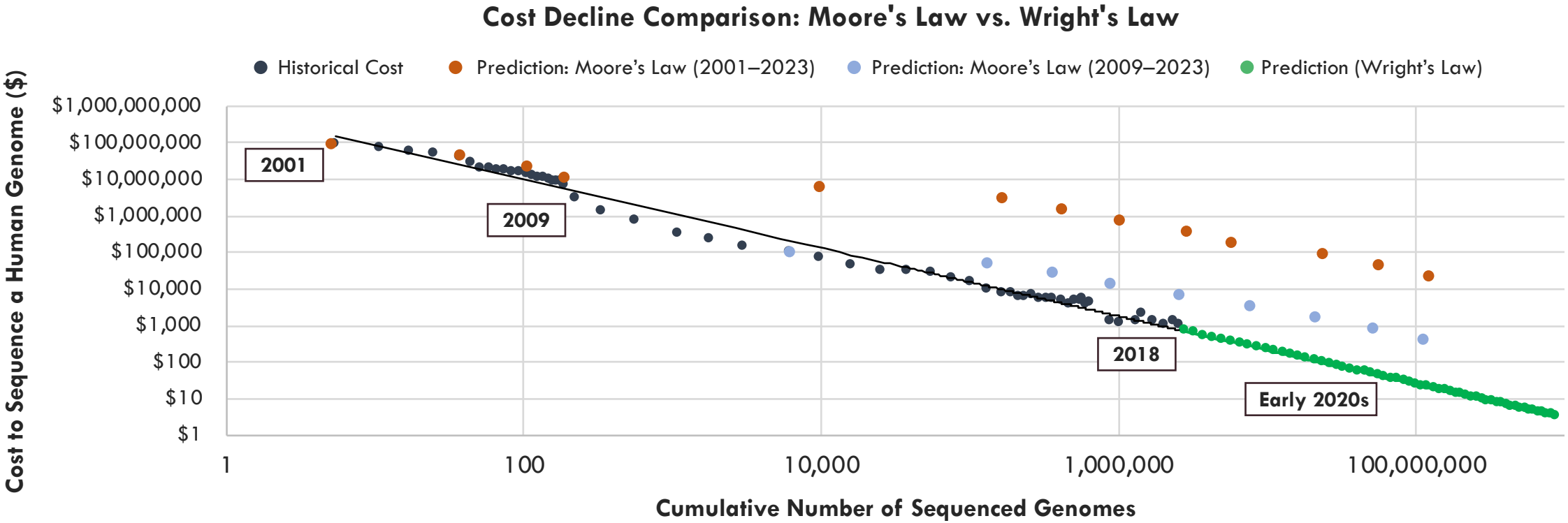
NGS instruments have spurred advancements in sample prep, polygenic risk scoring, neural networks, and new gene editing technologies.

[1] "What Is Next-Generation DNA Sequencing." *EMBL-EBI*, 8 June 2016, https://arkinv.st/2RfkwQL.
[2] Wetterstrand KA. "DNA Sequencing Costs: Data." *National Human Genome Research Institute (NHGRI)*, 25 Apr. 2018, https://arkinv.st/2RDopym.

The Cost of DNA Sequencing Is Declining at a Rapid Rate

ARK believes that NGS is following **Wright's Law**—calculating unit cost declines for every cumulative doubling in units produced.[1]

In 2009, projections of the cost in the early 2020's to sequence a whole human genome were $1,000 based on **Moore's Law**, 10x higher than that predicted by Wright's Law.[2]



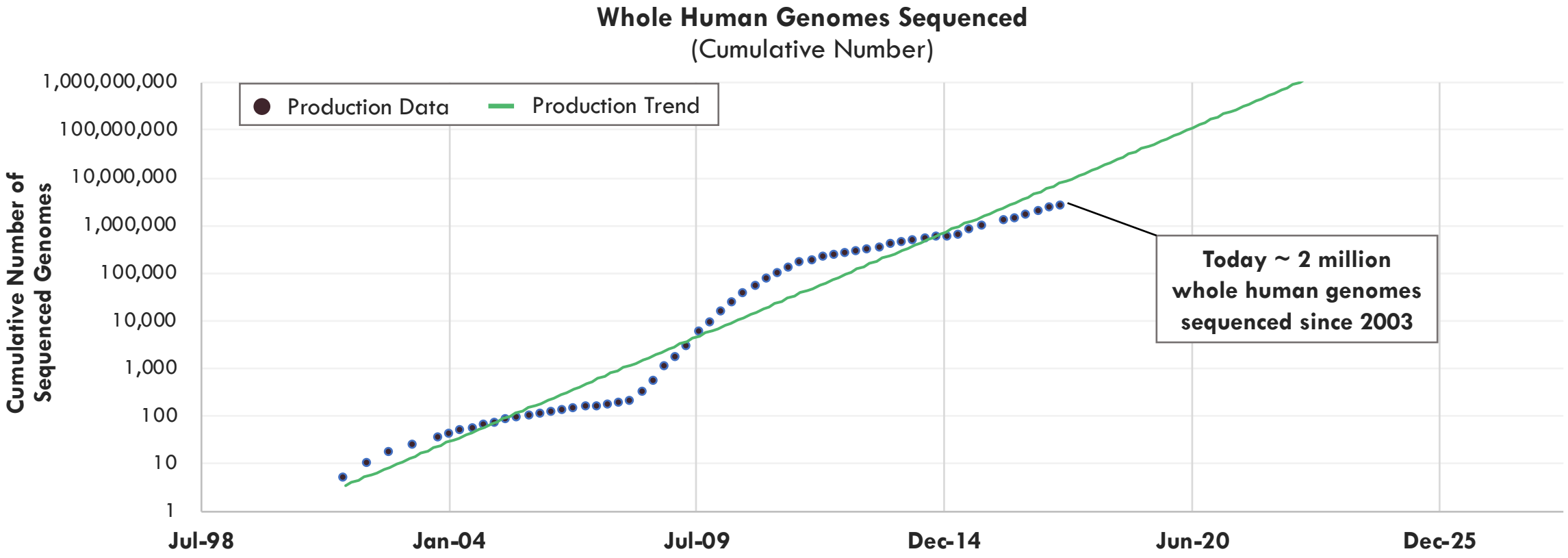
Forecasts are inherently limited and cannot be relied upon.

[1] ARK Investment Management LLC, 2018

[2] "The Cost of Sequencing a Human Genome." *National Human Genome Research Institute (NHGRI)*, 6 July 2016, https://arkinv.st/2FfRV7i.

As Costs Decline, the Demand For Whole Human DNA Sequencing Is Taking Off

ARK believes that the number of whole human genomes sequenced since 2003 should increase 50-fold from 2 million today to 100 million in the early 2020's as NGS expands into new clinical, diagnostic, and agricultural markets.[1,2]



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[1] Wetterstrand KA. "DNA Sequencing Costs: Data." *National Human Genome Research Institute (NHGRI)*, 25 Apr. 2018, https://arkinv.st/2RDopym.
[2] ARK Investment Management LLC, 2018

DNA Sequencing Falls Into Two Categories

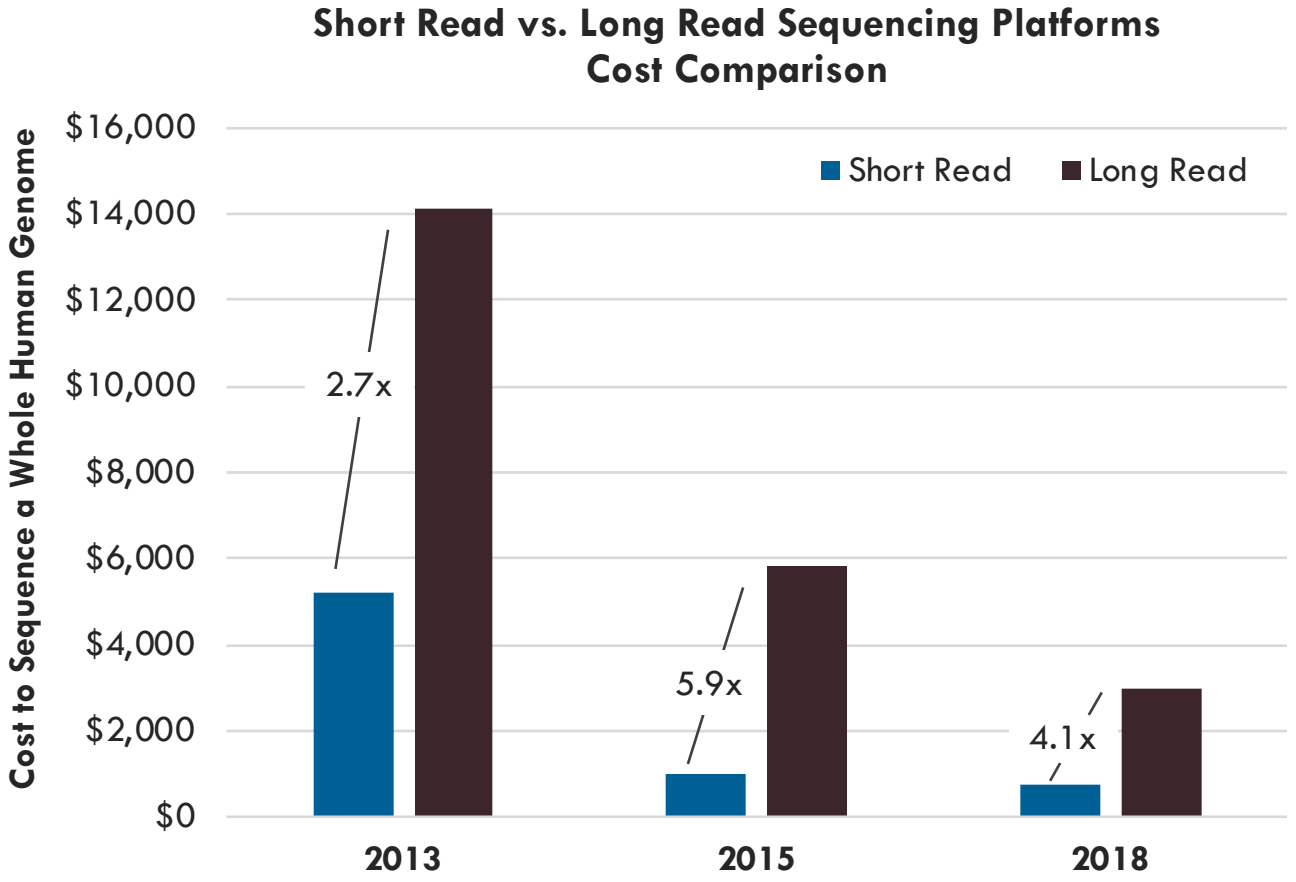
NGS falls into two categories:

Short Read NGS Instruments:

- Fragment DNA into millions of small sections.
- Rely on quicker, cheaper, powerful computational algorithms to reassemble genomes digitally.
- Cannot detect subtle mutations unique to cancer and rare disease.

Long Read NGS Instruments:

- Fragment DNA into fewer, larger sections.
- Rely on longer, expensive biochemistry workflows.
- Can detect subtle mutations found within oncology and rare disease.



Source: ARK Investment Management LLC, 2018

NGS Is Entering the Clinic

Declining costs for long and short read sequencing are enabling a wide array of clinical applications for NGS, including:

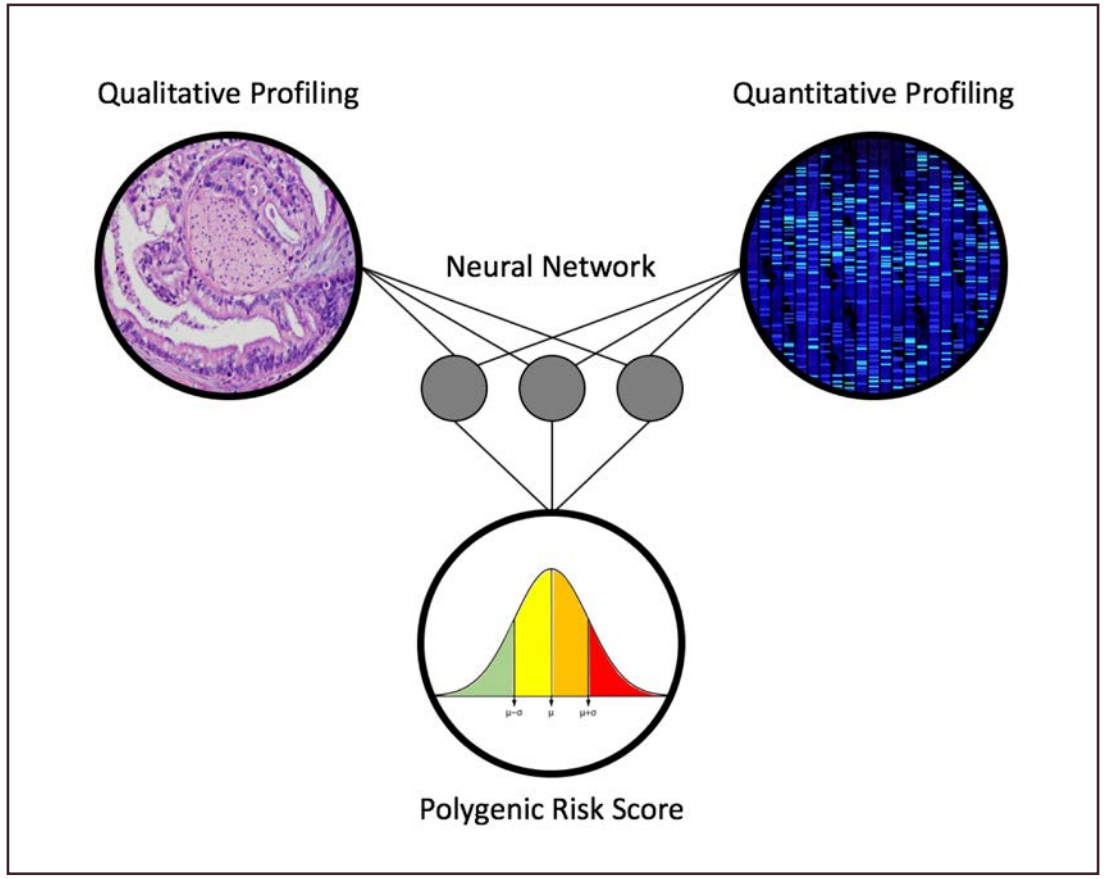
Hereditary Disease Screening

Metagenomics

- 20% of global deaths are caused by pathogens like bacteria, viruses, and parasites.[1]
- NGS can scan ALL of a patients' genetic material, including infectious agents, quickly and precisely.[2]

Polygenic Risk Scores (PRS)

- NGS instruments can recognize patterns in DNA so that genetic experts can quantify a patient's risk for cancer.
- Sophisticated neural networks are combining DNA and medical images to make PRSs more accurate.[3]

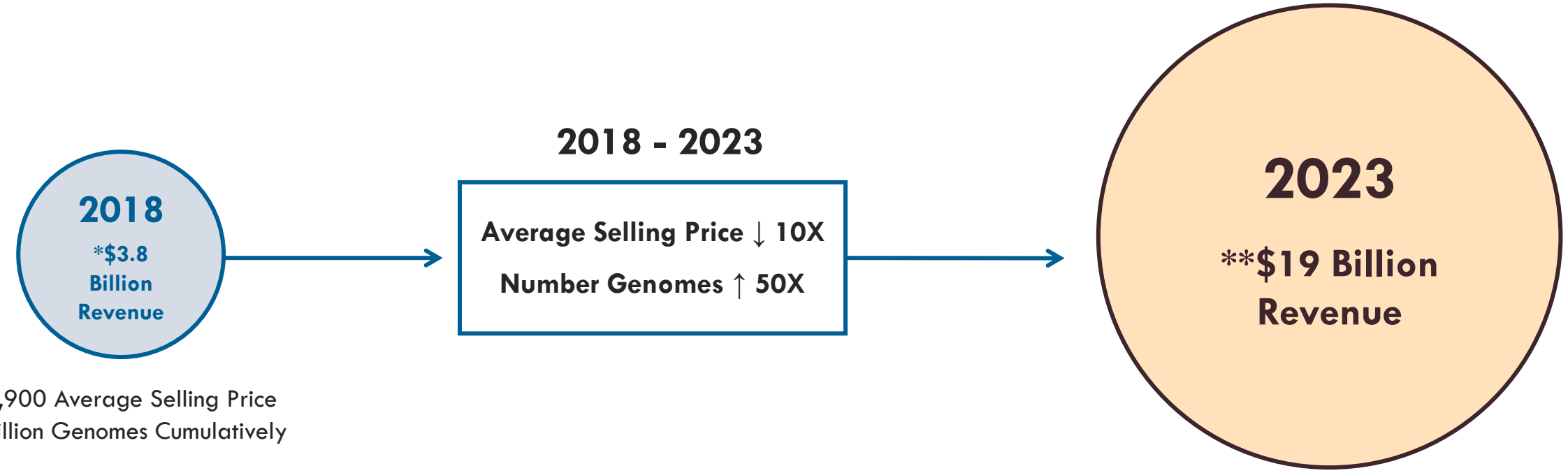


[1] Forbes, Jessica D, et al. "Highlighting Clinical Metagenomics for Enhanced Diagnostic Decision-Making: A Step Towards Wider Implementation." *Science Direct*, Computational and Structural Biotechnology Journal, 27 Feb. 2018, https://arkinv.st/2sa54qa.
[2] Hilton, Sarah K et al. "Metataxonomic and Metagenomic Approaches vs. Culture-Based Techniques for Clinical Pathology" *Frontiers in microbiology*, Apr. 2016, https://arkinv.st/2QxOfzj. [3] Chang, Peter, et al. "Deep-Learning Convolutional Neural Networks Accurately Classify Genetic Mutations in Gliomas." *American Journal of Neurology*, vol. 10, no. 7, 15 July 2018, https://arkinv.st/2QwdyS2.

Sizing the Opportunity

NGS Revenues Could Scale From Roughly $4 Billion Today to $19 Billion in 2023.

As costs continue to decline, the number of whole human genomes sequenced should scale rapidly.



*$1,900 Average Selling Price
2 Million Genomes Cumulatively

**$190 Average Selling Price
100 Million Genomes Cumulatively

Forecasts are inherently limited and cannot be relied upon.
Source: ARK Investment Management LLC, 2018

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- Health Care Sector Risk
- Biotechnology Company Risk
- Pharmaceutical Company Risk

Health Care Sector Risk. The health care sector may be affected by government regulations and government health care programs, restrictions on government reimbursement for medical expenses, increases or decreases in the cost of medical products and services and product liability claims, among other factors. Many health care companies are: (i) heavily dependent on patent protection and intellectual property rights and the expiration of a patent may adversely affect their profitability; (ii) subject to extensive litigation based on product liability and similar claims; and (iii) subject to competitive forces that may make it difficult to raise prices and, in fact, may result in price discounting. Many health care products and services may be subject to regulatory approvals. The process of obtaining such approvals may be long and costly, and delays or failure to receive such approvals may negatively impact the business of such companies. Additional or more stringent laws and regulations enacted in the future could have a material adverse effect on such companies in the health care sector. In addition, issuers in the health care sector include issuers having their principal activities in the biotechnology industry, medical laboratories and research, drug laboratories and research and drug manufacturers, which have the additional risks described below. **Biotechnology Company Risk.** A biotechnology company's valuation can often be based largely on the potential or actual performance of a limited number of products and can accordingly be greatly affected if one of its products proves, among other things, unsafe, ineffective or unprofitable. Biotechnology companies are subject to regulation by, and the restrictions of, the U.S. Food and Drug Administration, the U.S. Environmental Protection Agency, state and local governments, and foreign regulatory authorities. **Pharmaceutical Company Risk.** Companies in the pharmaceutical industry can be significantly affected by, among other things, government approval of products and services, government regulation and reimbursement rates, product liability claims, patent expirations and protection and intense competition.

CRISPR: GENOME-EDITING

For Human Therapeutics

CRISPR is a powerful DNA editing tool that should be able to delete, replace or repair genes easily, inexpensively, and precisely.

We believe CRISPR is the most promising way to cure diseases – from sickle cell anemia to cystic fibrosis to pediatric blindness to cancer. CRISPR genome-editing should shift the health care system from treating symptoms to curing disease.

CRISPR Gene-Editing Will Revolutionize Genomic Medicine

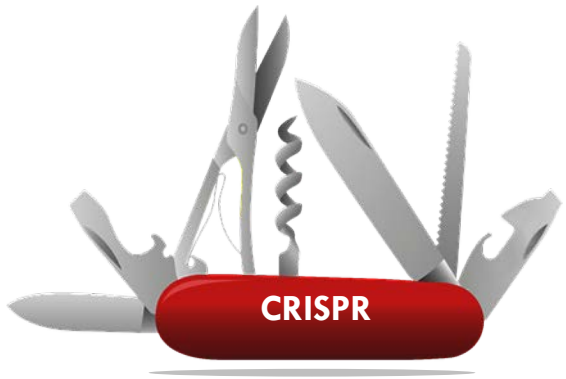
- CRISPR enables cheap and rapid “write” capabilities to correct defects and cure diseases.
- Genetic defects in the human code cause many diseases including cancer, heart disease, diabetes, cystic fibrosis, and Alzheimer's.

CRISPR: Clustered Regularly Interspaced Short Palindromic Repeats

a “molecular swiss army knife” with a rapidly expanding number of tools that perform different functions:

Cut DNA/ RNA | **Insert DNA/RNA** | **Activate/Silence Genes** | **Record and Track Molecular Event** | **Detect molecules**

DNA Sequencing	Targeted Therapy	Cell Therapy	Gene Therapy	Genome Editing (e.g. CRISPR)
READ	Monoclonal antibodies	CAR-T; T-Cell; Immunotherapies	Stem Cell Therapy; Restoration of gene function	WRITE

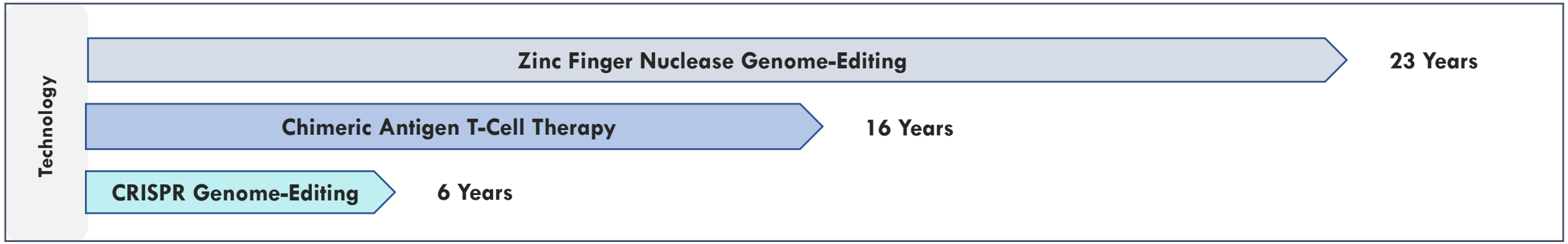


Source: ARK Investment Management LLC, 2018; Image Source: Arup

The First CRISPR Human Trials Are Underway in the US

ARK expects innovations based on CRISPR to accelerate thanks to its ease of use, cost-efficiency, efficacy, safety profile, and AI-powered nuclease selection tools.

Time from Discovery to First Human Clinical Trials



CRISPR Therapeutics

Blood Disorder[1]
- Trial Start: Oct 2018
- 360,000 annual births
- $2-4 billion USD annual market opportunity

Sickle Cell Disease/ Beta-Thalassemia

Editas Medicine

Childhood Blindness[2]
- Trial Start: Dec 2018
- 6,000 patients worldwide
- $6-27 billion USD annual market opportunity

Leber Congenital Amaurosis 10

Intellia Therapeutics

Misfolded Protein Build-up[3]
- Trial Start: Est 2020
- ~50,000 patients worldwide
- $23 billion USD total market opportunity

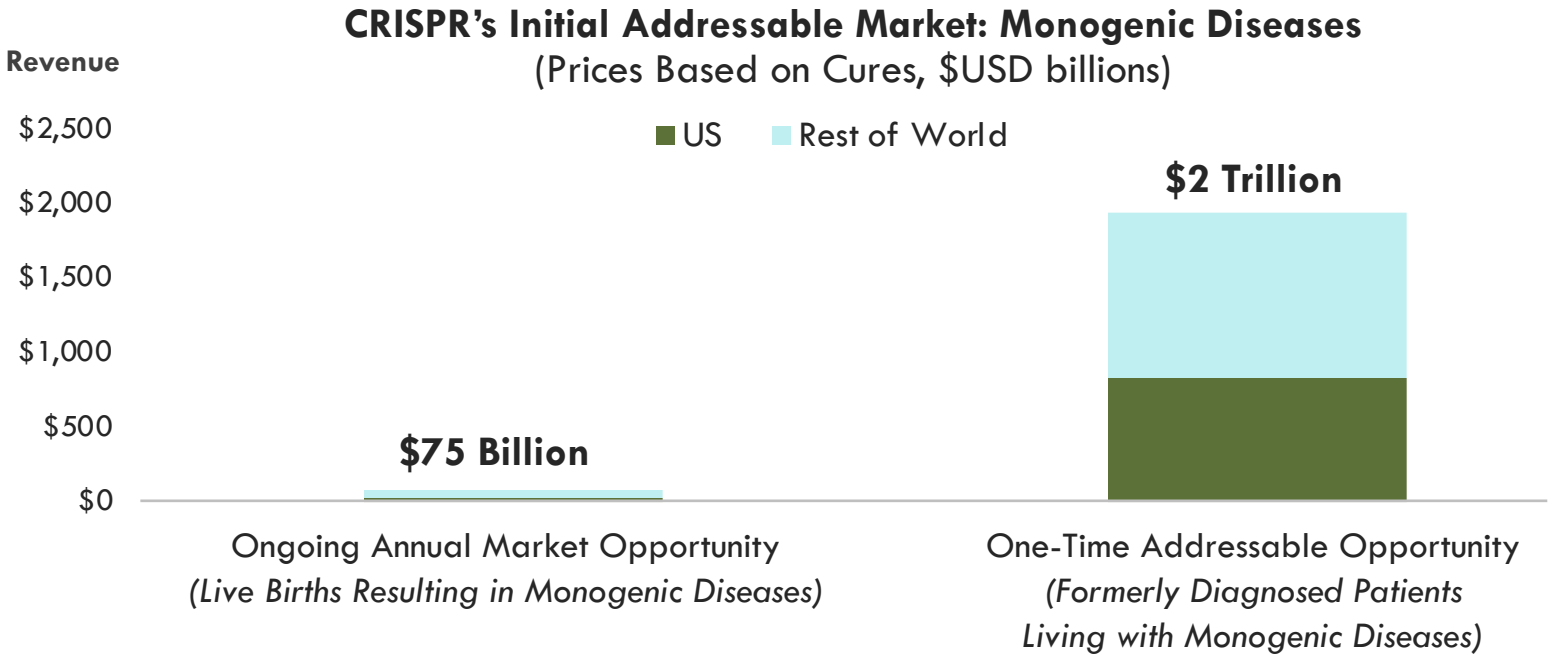
Transthyretin Amyloidosis

Source: ARK Investment Management LLC, 2018
[1] "CRISPR Therapeutics Investor Presentation", 2018
[2] "Investor Presentation." *Editas Medicine*, 7 Jan. 2019, https://arkinv.st/2TNaRgY.
[3] Herper, Matthew. "Alnylam Prices First Gene Silencing Drug At $450,000 Per Patient, But Offers Money-Back Guarantee." *Forbes*, 10 Aug. 2018, https://arkinv.st/2LXEidA. | "Intellia Investor Presentation" 2018

Sizing the Opportunity

CRISPR Should Address All Monogenic Diseases, Potentially Generating $75 Billion in Global Revenue Per Year.

Only 5% of 10,000 monogenic diseases, conditions caused by an error in a single gene, respond to any treatment today.



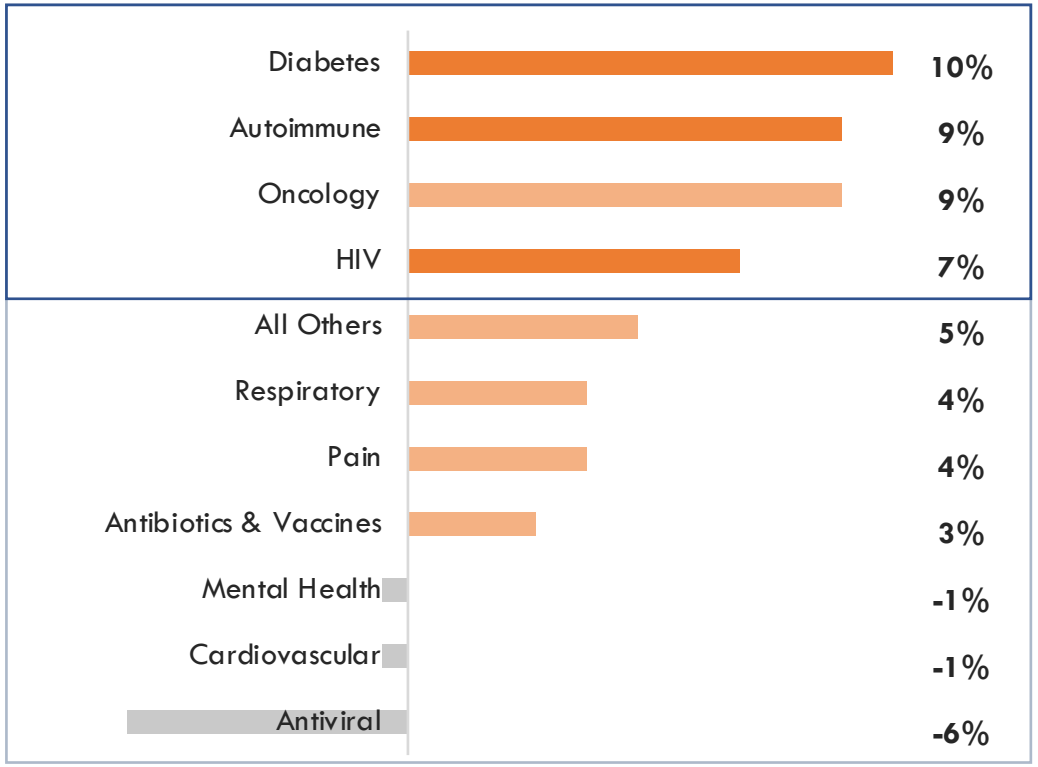
- 1 in 100 live human births results in a monogenic disease.[1]
- CRISPR entered human trials in 2018
- If CRISPR were to address individuals already living with monogenic diseases, its one time global addressable market would be $2 trillion.

Forecasts are inherently limited and cannot be relied upon.
Source: ARK Investment Management LLC, 2018
[1] Krimsky, Sheldon, and Jeremy Gruber, editors. *Genetic Explanations: Sense and Nonsense*. Harvard University Press, 2013.

CRISPR Is Addressing Genetic and Infectious Diseases

CRISPR technology is addressing the disease areas that will place the most demand on the global healthcare system during the next 5 years.

Global Healthcare Spend $US, 2017-2022 CAGR



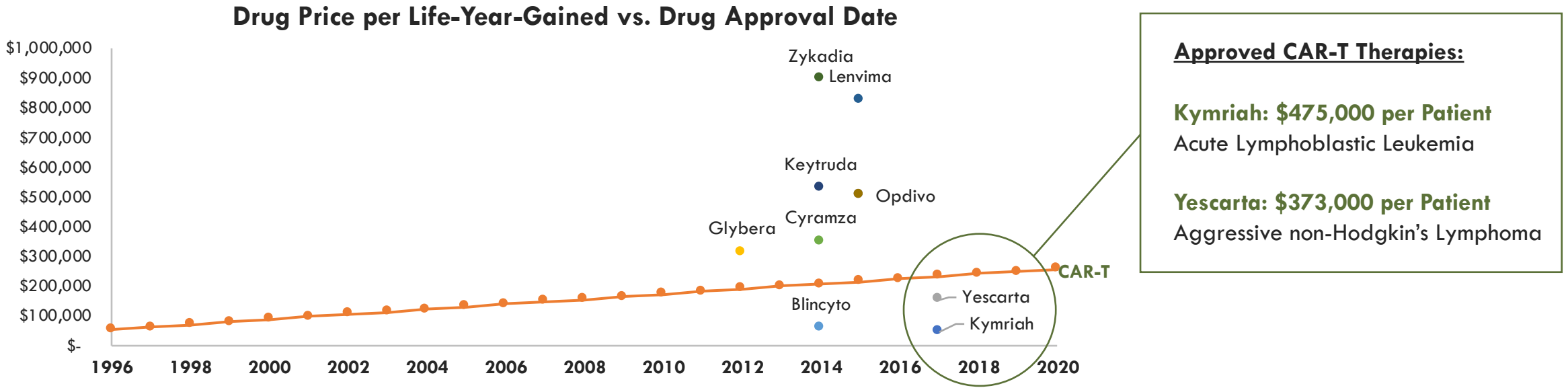
Global Impact by 2025

Disease	Patients	Spending
Diabetes	700 million	$1.2 trillion
Rheumatoid Arthritis	30 million	$30 billion
HIV	40 million	$50 billion

Forecasts are inherently limited and cannot be relied upon. | Sources: "Cost of Diabetes Hits 825 Billion Dollars a Year." *Harvard T.H. Chan School of Public Health*, 2016, https://arkinv.st/2AzlGfG
"Rheumatoid Arthritis Drugs/Therapeutics Market Size Analysis Report 2018 - 2025." *Grand View Research*, Feb. 2018, https://arkinv.st/2FkfyLh.
"CRISPR Eradicates Latent HIV-1, Offering Hope of 'Functional Cures.'" *GEN - Genetic Engineering and Biotechnology News*, 21 May 2018, https://arkinv.st/2Fczbpz.
Ryan, Benjamin. "Global HIV Spending Tops Half a Trillion Dollars in 15 Years." *POZ*, 19 Apr. 2018, https://arkinv.st/2RiwxVm.
Dryden, Jim. "Stem Cells Edited to Fight Arthritis." *Washington University School of Medicine in St. Louis*, 27 Apr. 2017, https://arkinv.st/2SJpzpp.

CRISPR Is Enabling Next-Generation CAR-T Targeting Cancer

- Chimeric Antigen Receptor T-cell (CAR-T) therapy is a novel immunotherapy that modifies a patient's own T-cells to target and kill malignant cells while keeping healthy cells intact.
- In 2017, the FDA approved first-generation CAR-T immunotherapies after trials showed high complete remission rates in liquid tumors. Based on life-years gained, CAR-T therapy is cheaper than other approved cancer immunotherapies.

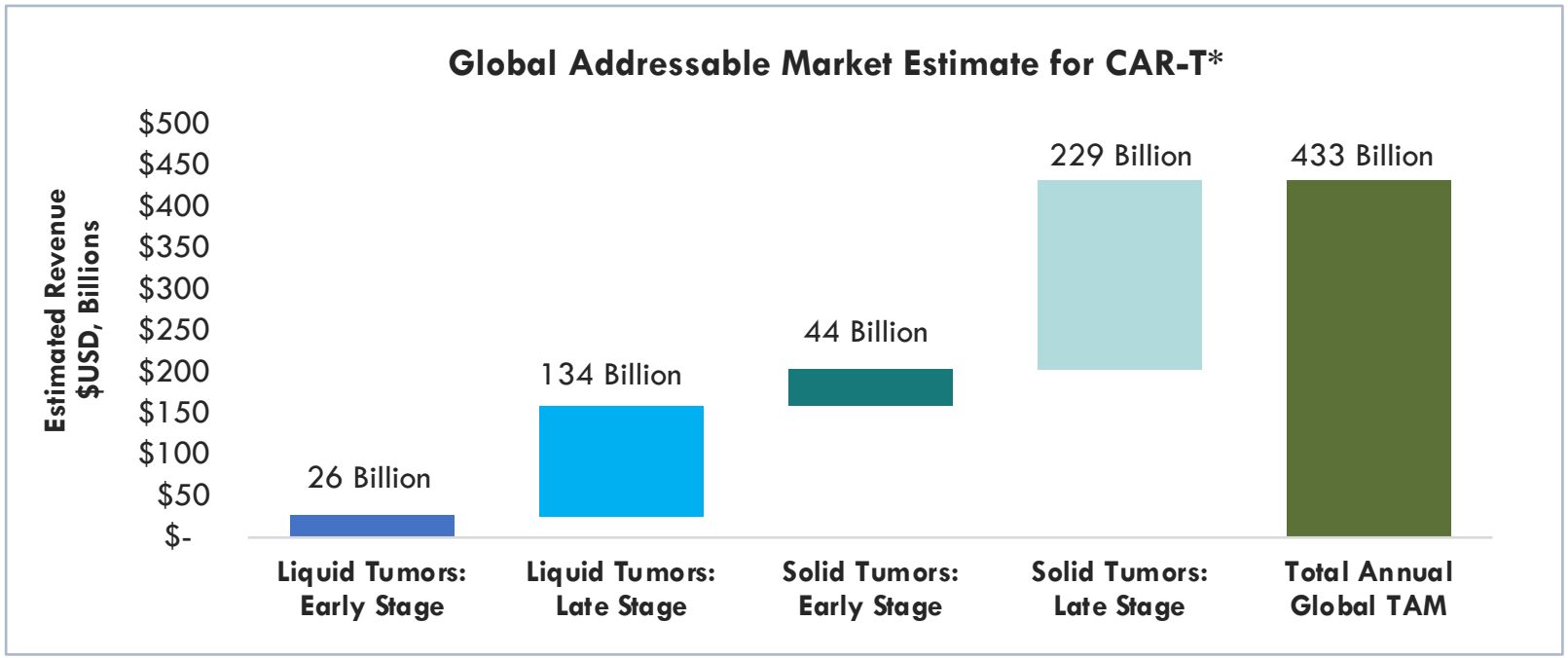


Forecasts are inherently limited and cannot be relied upon.
Source: ARK Investment Management LLC, 2018 | Note: Orange line represents fair value of a cancer drug per Quality-Adjusted Life Years (QALY).

Sizing the Opportunity

Globally, CAR-T Cancer Immunotherapy Could Generate Revenues of $433 Billion Per Year in Revenues, With Royalties Payable to CRISPR Companies.

CRISPR should enhance the safety and efficacy of next generation CAR-T therapies.



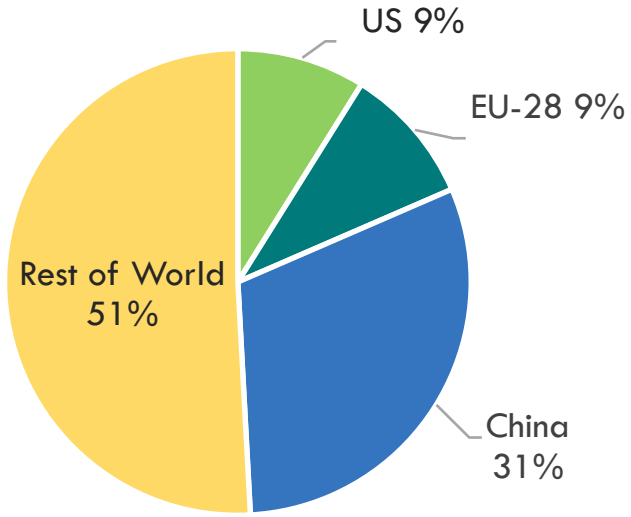
- Early stage cancer and solid tumor indications are the biggest value drivers for CAR-T therapy.
- In the past year, CRISPR has increased the probability that CAR-T will be successful in addressing solid state tumors.

Forecasts are inherently limited and cannot be relied upon.
Source: ARK Investment Management LLC, 2018
* CAR-T projections include TCR technologies. Estimated for future years.

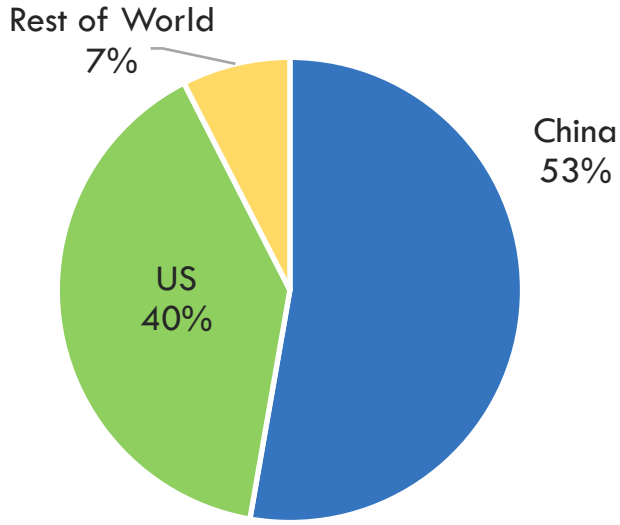
Case Study: China Is on the Leading Edge of Immunotherapy Research, Particularly CAR-T

- With 3.5x more cancer diagnoses than in the US, China is investing aggressively in novel therapies.[1]
- Today, China is conducting more CAR-T clinical trials than any other country in the world.
- Given the prevalence of cancer in China, ARK anticipates accelerated enrollments in its trials.

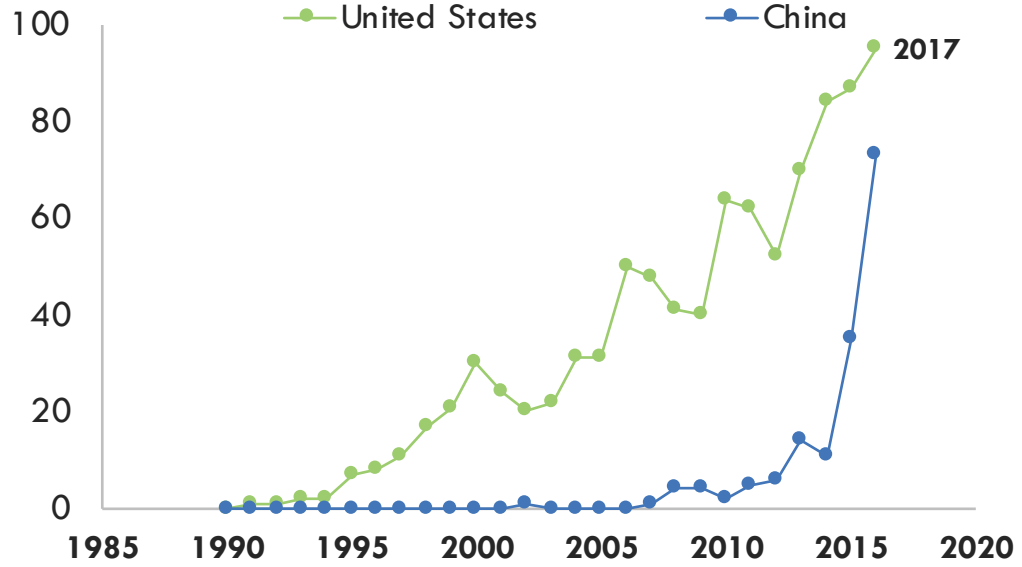
New Cancer Diagnoses by Region, 2020



Registered Number of CAR-T Trials



New Immunotherapy Trials Registered Per Year



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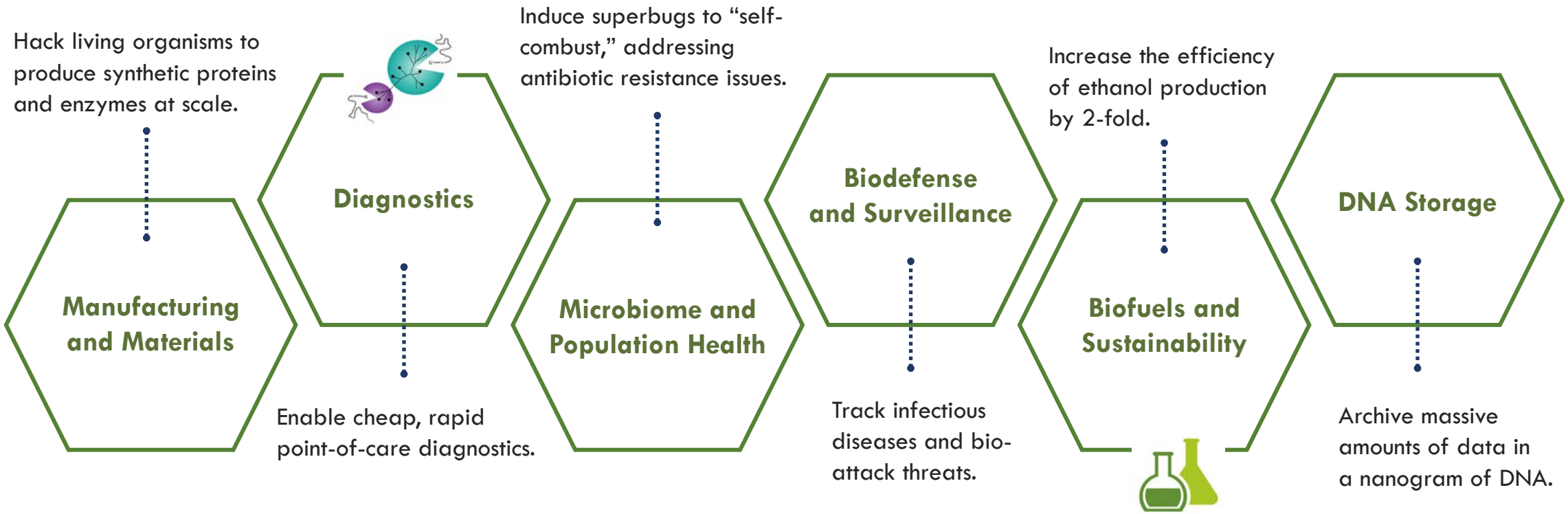
Source: ARK Investment Management LLC, 2018. [1] Wang, Yong-chuan et al. "Comparison of Cancer Incidence between China and the USA." *National Center for Biotechnology Medicine*, Jun 2012, https://arkinv.st/2VTmHlu.

Outlook

CRISPR's Toolbox Should Disrupt More Than Therapeutics and Agriculture.



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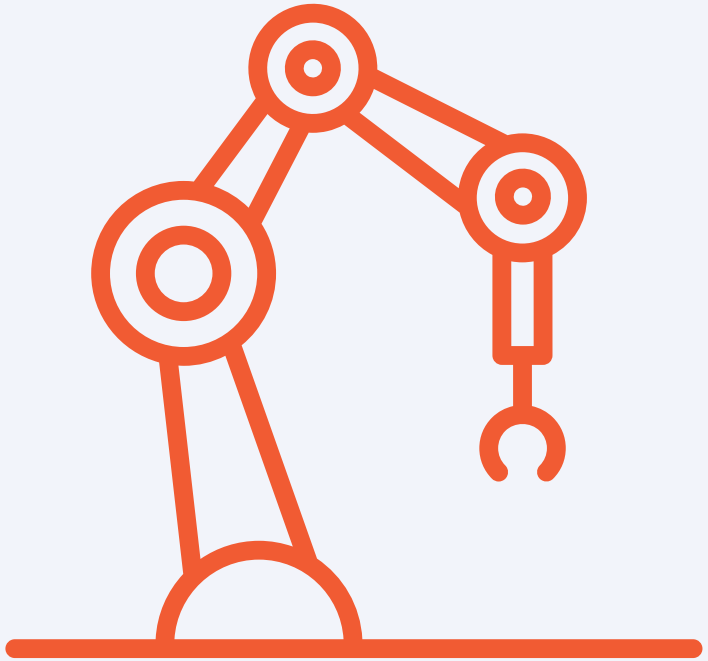
- Biotechnology Company Risk
- Pharmaceutical Company Risk

Health Care Sector Risk. The health care sector may be affected by government regulations and government health care programs, restrictions on government reimbursement for medical expenses, increases or decreases in the cost of medical products and services and product liability claims, among other factors. Many health care companies are: (i) heavily dependent on patent protection and intellectual property rights and the expiration of a patent may adversely affect their profitability; (ii) subject to extensive litigation based on product liability and similar claims; and (iii) subject to competitive forces that may make it difficult to raise prices and, in fact, may result in price discounting. Many health care products and services may be subject to regulatory approvals. The process of obtaining such approvals may be long and costly, and delays or failure to receive such approvals may negatively impact the business of such companies. Additional or more stringent laws and regulations enacted in the future could have a material adverse effect on such companies in the health care sector. In addition, issuers in the health care sector include issuers having their principal activities in the biotechnology industry, medical laboratories and research, drug laboratories and research and drug manufacturers, which have the additional risks described below. **Biotechnology Company Risk.** A biotechnology company's valuation can often be based largely on the potential or actual performance of a limited number of products and can accordingly be greatly affected if one of its products proves, among other things, unsafe, ineffective or unprofitable. Biotechnology companies are subject to regulation by, and the restrictions of, the U.S. Food and Drug Administration, the U.S. Environmental Protection Agency, state and local governments, and foreign regulatory authorities. **Pharmaceutical Company Risk.** Companies in the pharmaceutical industry can be significantly affected by, among other things, government approval of products and services, government regulation and reimbursement rates, product liability claims, patent expirations and protection and intense competition.

Collaborative Robots

Robots are increasing their footprint and creating jobs. Collaborative robots (cobots) are designed to work along side humans and are retrained easily, adding to labor productivity.

Collaborative robot costs are lower than those of traditional industrial robots and leverage the power of deep learning. ARK believes that all robots will be collaborative in the long run.



Traditional Industrial Robots vs. Collaborative Robots

TRADITIONAL ROBOTS: SOFTWARE

Industrial robots are defined by ISO 8373:2012 as an automatically controlled, reprogrammable, and multipurpose manipulator, programmable in three or more axes which can be either fixed in place or mobile.

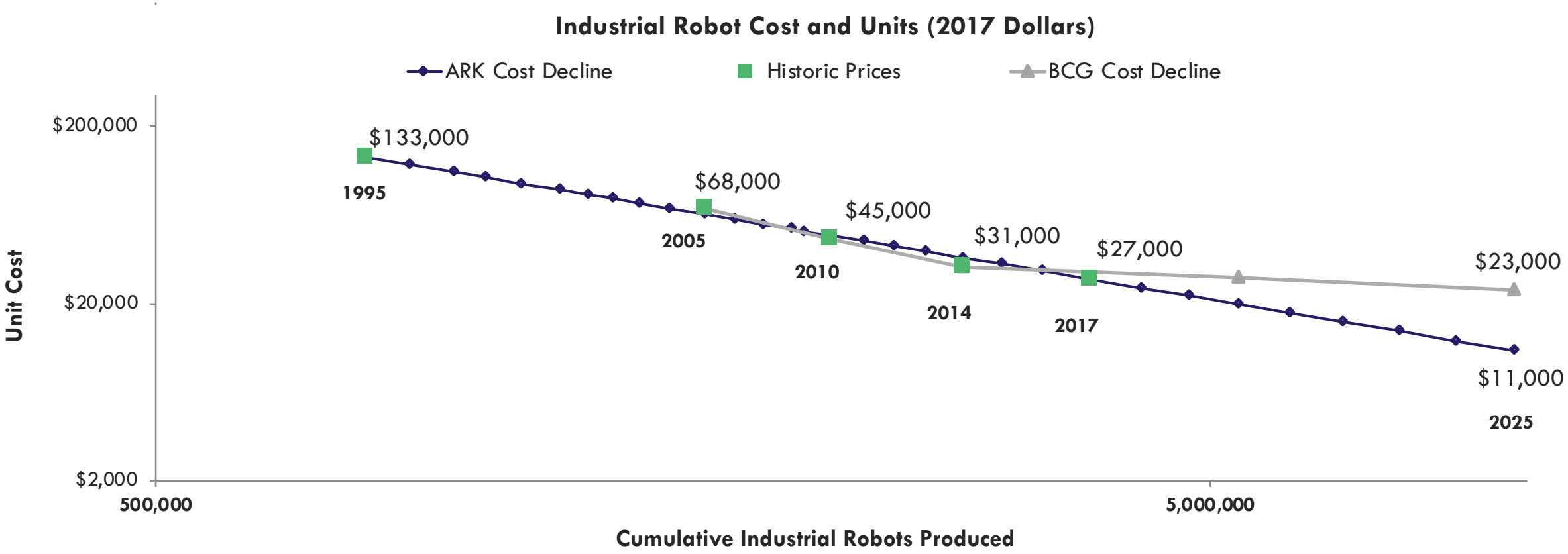
COBOTS: DEEP LEARNING

A collaborative robot ("cobot") is a robot designed to share a workspace with humans with whom they may have direct physical interaction. They are a subset of industrial robots.

Sources: ARK Investment Management LLC, 2018

Robot Costs Are Dropping

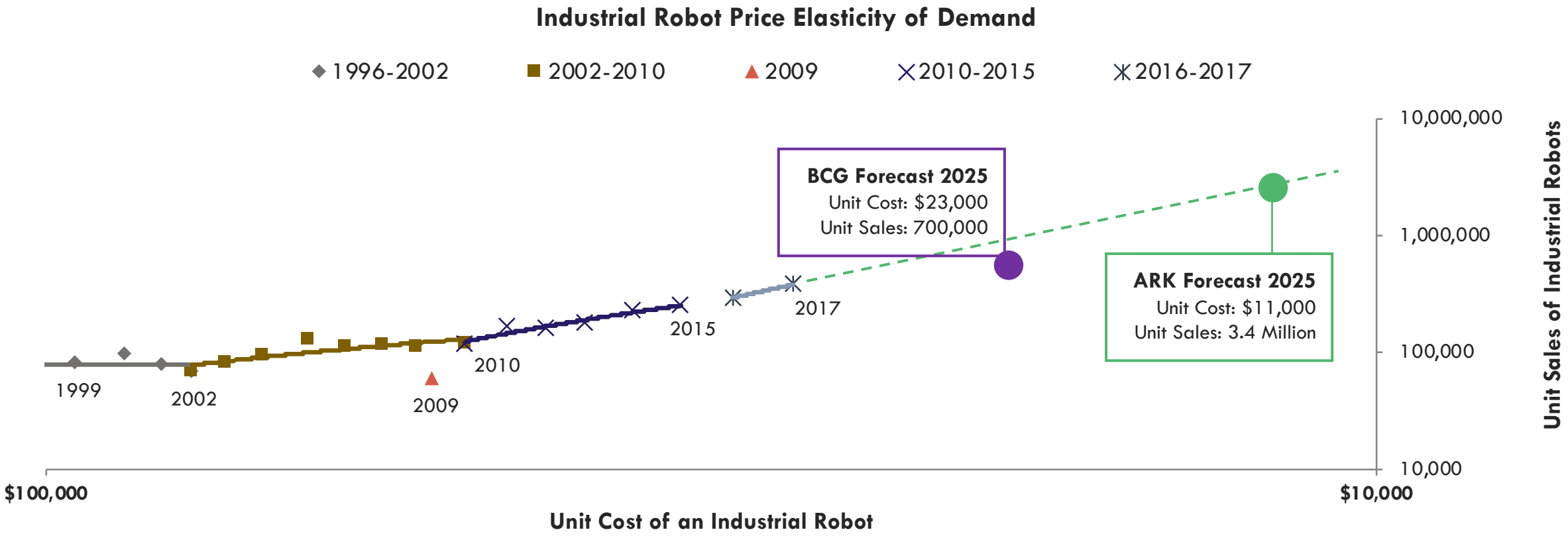
As industrial robot costs continue to decline, their addressable market will expand.



Forecasts are inherently limited and cannot be relied upon.
Sources: ARK Investment Management LLC, 2018.
Data from: United Nations Economic Commission for Europe; International Federation of Robotics; Sirkin, Hal, et al. "How Robots Will Redefine Competitiveness." *BCG*, 23 Sept. 2015, https://arkinv.st/2VLo0Jt.

Robot Demand Is Responding to Lower Costs

As industrial robots have declined in cost, demand growth has accelerated.



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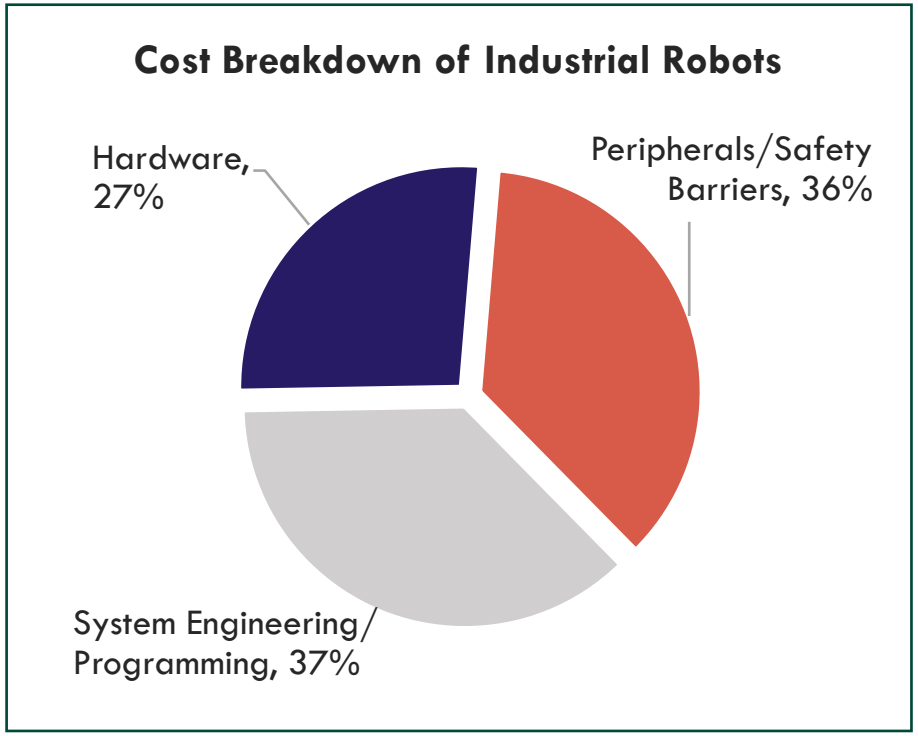
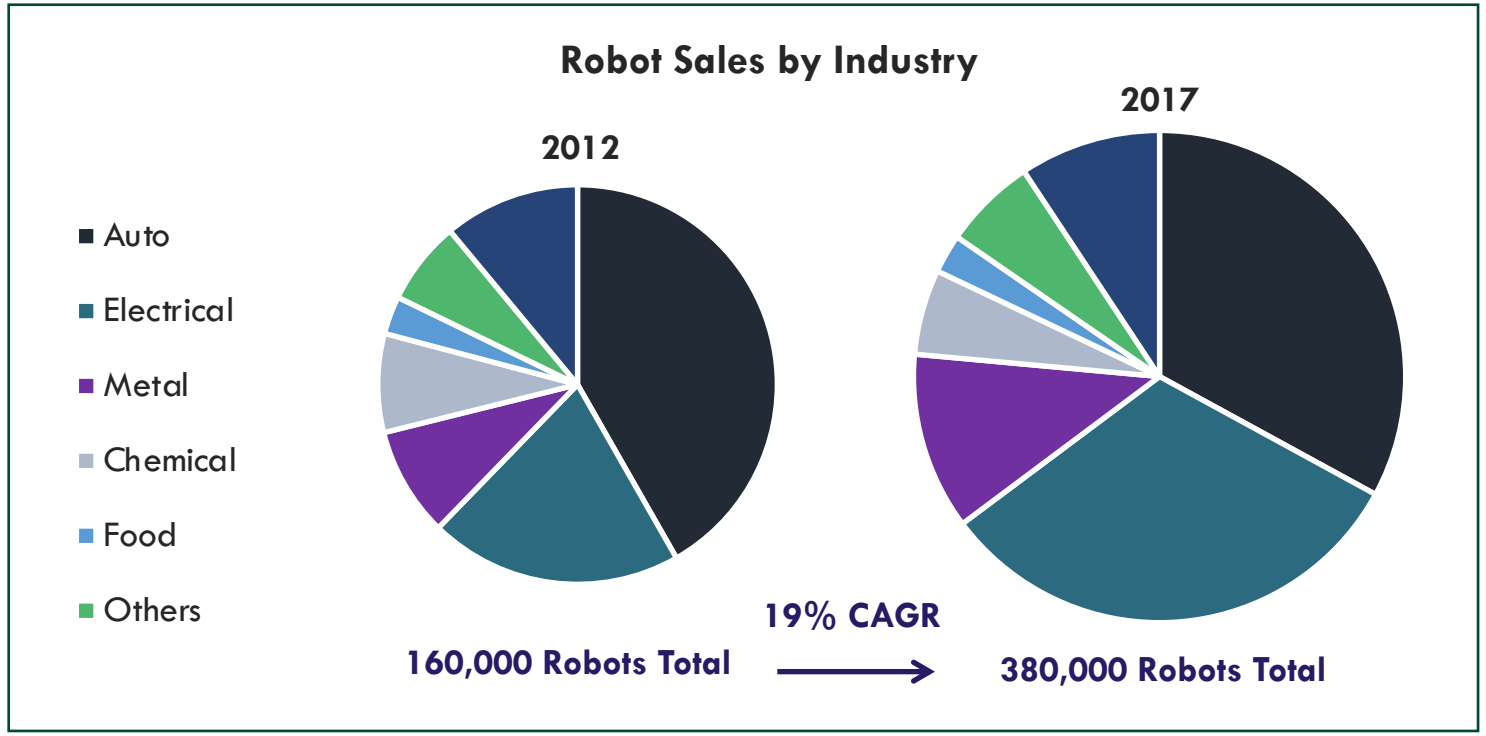
Collaborative Robots Are Expanding the Market

High system engineering and programming costs have limited industrial robots to companies that manufacture products in high volumes, like the auto industry. Cobots are decreasing the programming costs and eliminating the safety barriers associated with traditional industrial robots, allowing them to penetrate new markets.

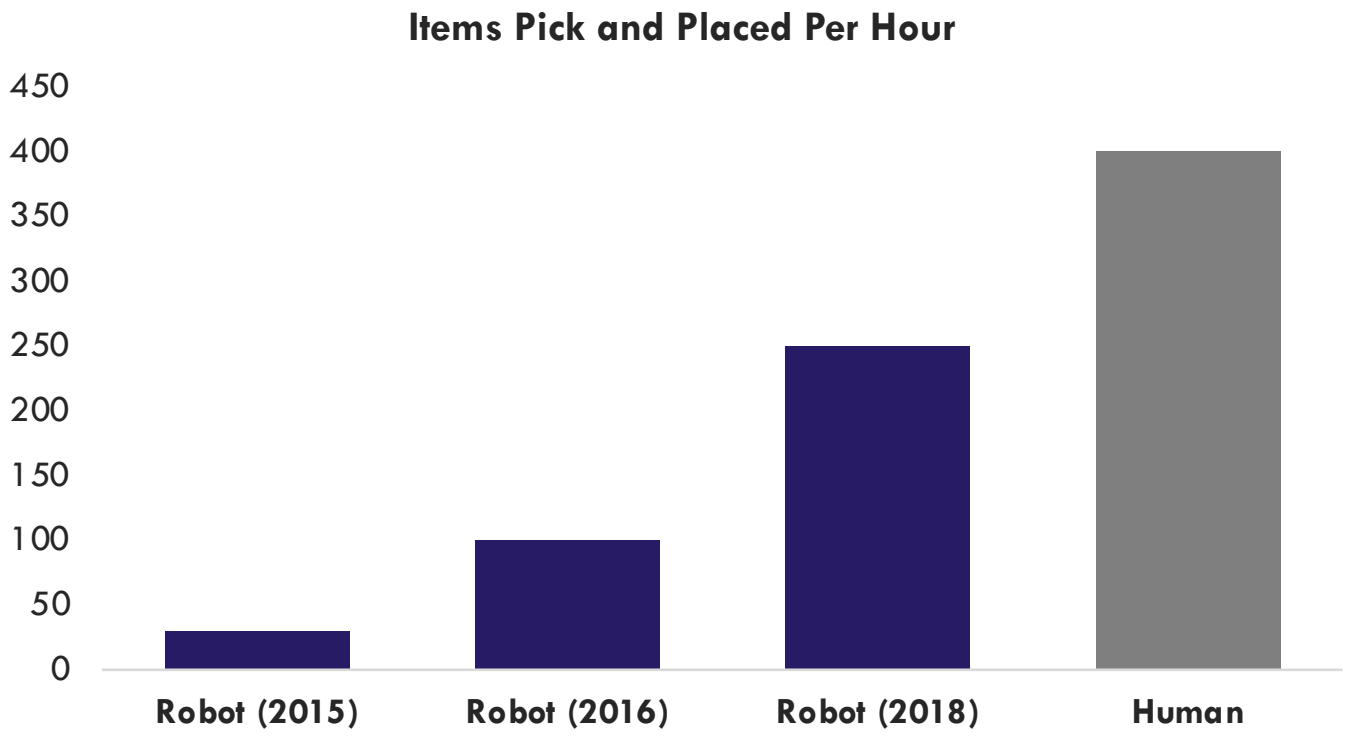




Source: ARK Investment Management LLC, 2018. Data from: Boston Consulting Group

Software 2.0 Is Opening Up Use Cases for Collaborative Robots

Deep learning applied to robotics is making the previously impossible, possible.



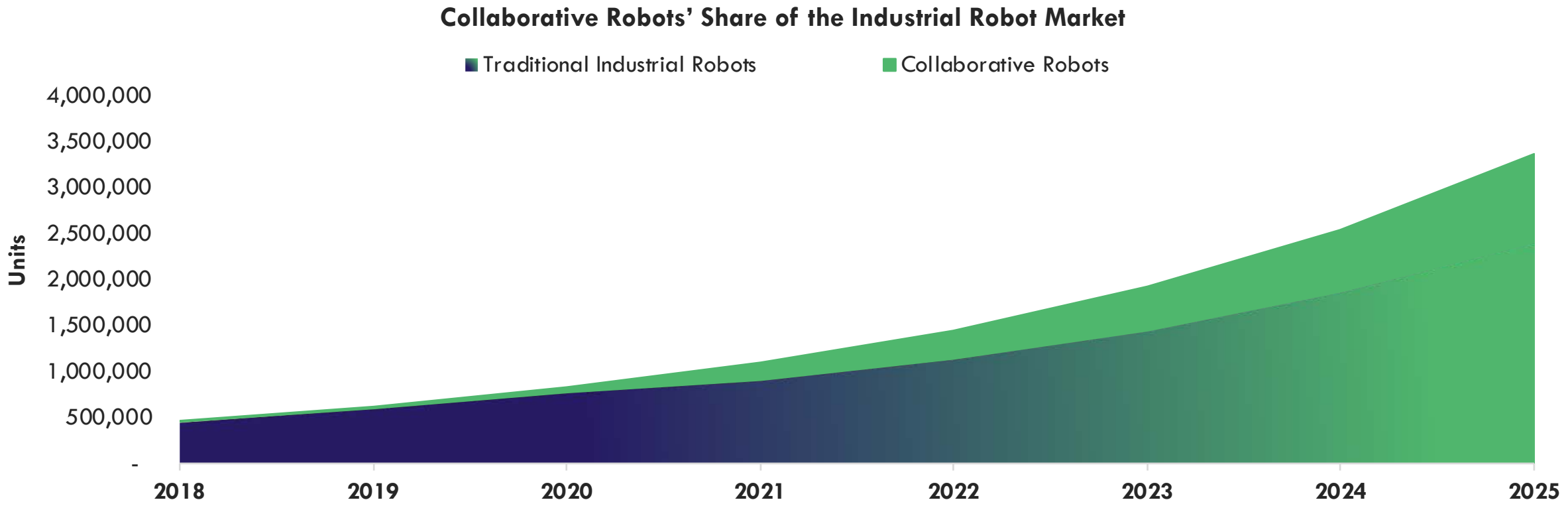
Object Manipulation

Pick and Place

Sources: ARK Investment Management LLC, 2018.
Data from: United Nations Economic Commission for Europe; International Federation of Robotics; Sirkin, Hal, et al. "How Robots Will Redefine Competitiveness." *BCG*, 23 Sept. 2015, https://arkinv.st/2VLo0Jt.

Sizing the Opportunity

Collaborative Robots Are Gaining Market Share. ARK Believes That Ultimately All Robots Will Be Collaborative.



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Sources: ARK Investment Management LLC, 2018; "Financial Results for Q3 2018." *Teradyne*, 24 Oct. 2018, *https://arkinv.st/2SQm0O6*

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- Industrials Sector Risk
- Information Technology Sector Risk

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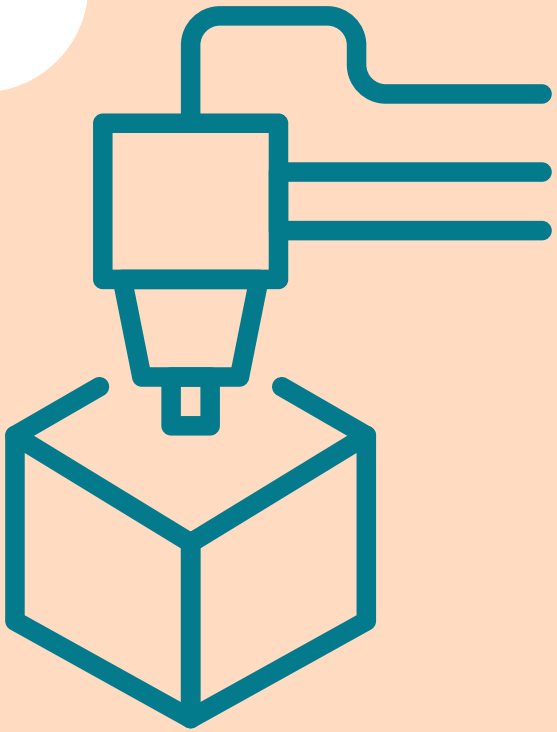
3D Printing for End-Use Parts



3D printing is a form of additive manufacturing that builds objects layer-by-layer instead of removing material from a larger block or using a mold.

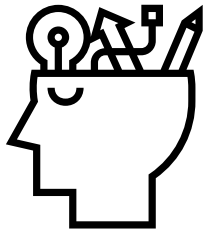
As a result, 3D printing collapses the time between design and production, shifts power to designers, and creates products with both radically new architectures and less waste, at a fraction of the cost of traditional manufacturing.

ARK believes that 3D printing will revolutionize manufacturing.

3D Printing Should Revolutionize Traditional Manufacturing

ARK separates 3D printing's addressable market into three categories — "End-Use Parts" the most promising.

1. PROTOTYPES



3D printing creates test parts quickly and inexpensively.

2. MOLDS AND TOOLS

3D printing produces parts which streamline the manufacturing process.

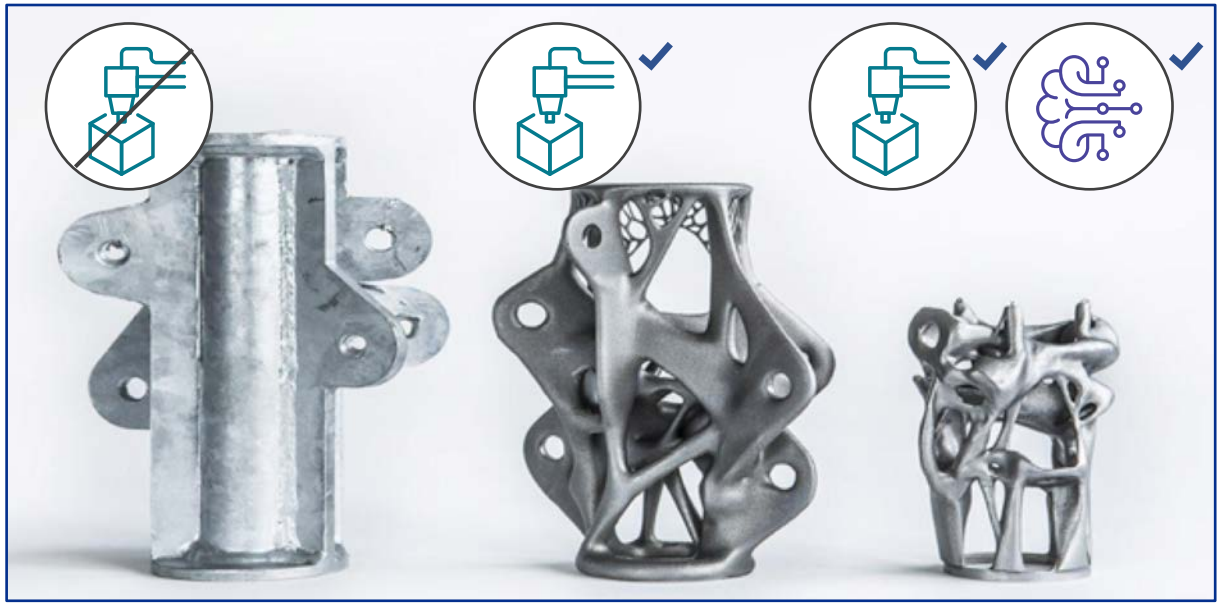
3. END-USE PARTS

3D printing manufactures parts for finished products.

Source: ARK Investment Management LLC, 2018.

3D Printing Offers a Range of Benefits

- Shortens design-to-production time
- Shifts power to designers
- Creates products with less waste
- Enables radically new architectures
- Reduces the cost of manufacturing significantly
- Creates machine learning-generated architectures



Traditional Manufacturing → **3D Printing** → **3D Printing + Machine Learning**

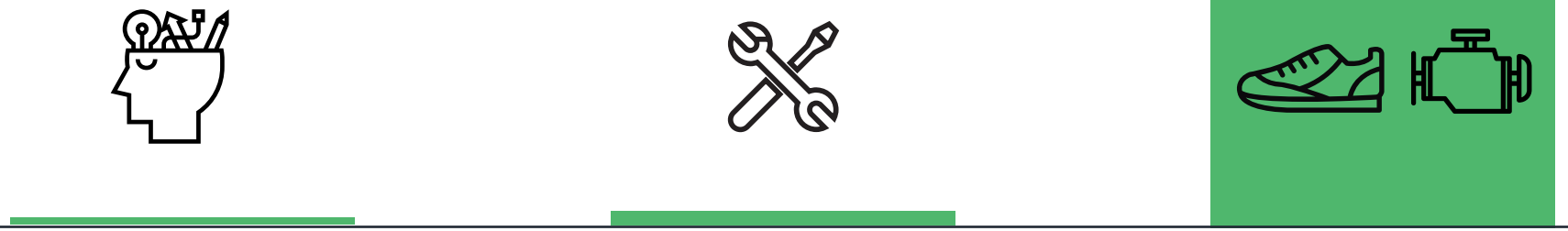
These structural units support the same weight. The 3D printed part on the right, however, weighs 75% less and is 50% the size of the traditional manufacturing part on the far left.

Source: ARK Investment Management LLC, 2018; Image Source: "Additive Manufacturing, Design Method for Critical Structural Steel Elements." *Arup*, https://arkinv.st/2AyPj0u.

3D Printing Is in Its Infancy

ARK's research shows that 3D printing for end use parts is the next frontier.

3D Printing Market Potential and Its Current Penetration



	PROTOTYPES	MOLDS & TOOLS	END-USE PARTS
Market size:	**$12.5 Billion**	**$30 Billion**	**$490 Billion**
First Applications	1980's	1990's	Early 2000's
Current Penetration	40-50%	6%	1%

Forecasts are inherently limited and cannot be relied upon.
Sources: ARK Investment Management LLC, 2018; McKinsey; Stratasys; "3D Printing History." *AV Plastics*, 14 June 2018, https://arkinv.st/2TC57H1.

3D Printing Is Penetrating the Aerospace & Aviation Industry

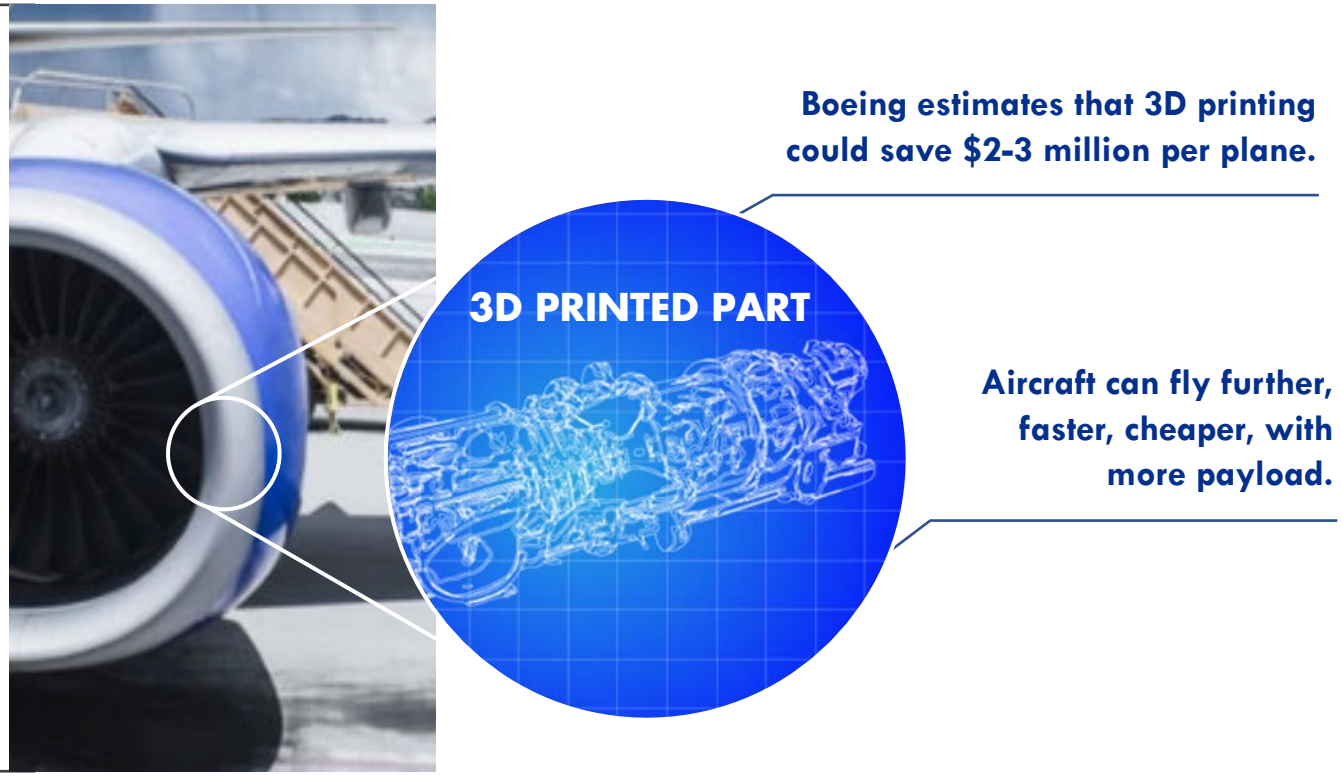
ARK estimates that 3D printing has penetrated only 1% of the addressable market for aircraft.
Given 10-20% gross margins, aerospace companies have significant incentives to adopt 3D printing.

CASE STUDY 1: Advanced Turboprop Engine (ATP)[1]

- Number of parts dropped from 855 to just 12
- Fuel burn lowered 20%
- Weight reduced by 5%
- Test schedules cut in half to 6 months

CASE STUDY 2: GEnx Engine Metal Bracket[2]

- 20 components combined into one single piece
- Manufacturing waste reduced by 90%
- Weight reduced by 10%
- New part less expensive to produce

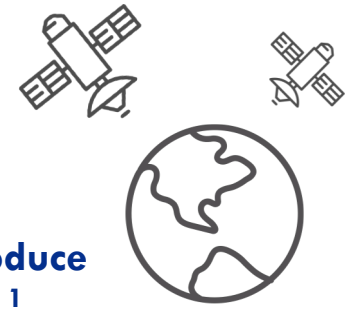


Sources: [1]Ehteshami, Mohammad. "GE Additive Oppenheimer Annual Industrial Conference ." GE.com, 9 May 2017, https://arkinv.st/2seDOXp;
[2] GE Aviation, 2018, https://www.geaviation.com/bga/engines/ge-catalyst

The End-Use Parts Market Should Grow Rapidly, Even in Space

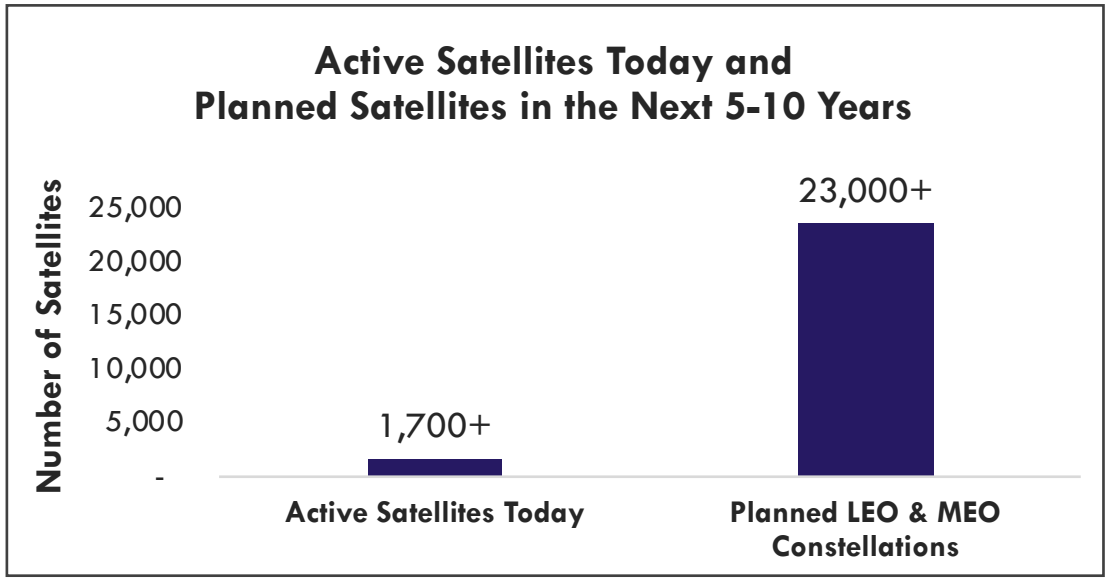
3D PRINTING ON EARTH

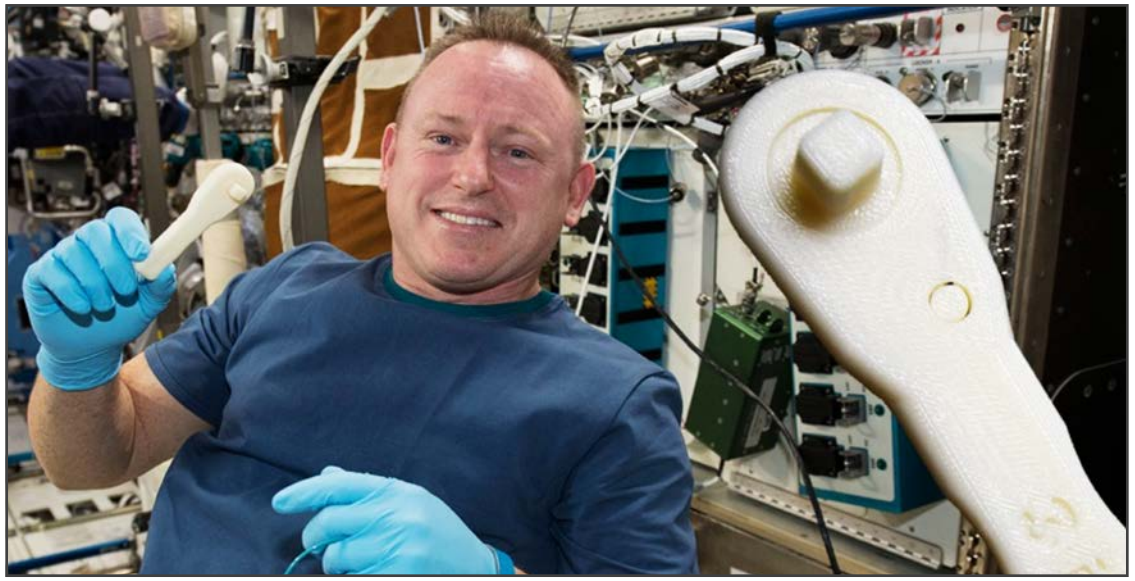
- Cost declines in rockets, satellites, and antennas are leading to a new space age.
- **Lockheed Martin estimates that it will be able to produce 3D printed satellites twice as fast at half of the cost.[1]**



3D PRINTING IN SPACE

- Today, the cost to launch an object into space is $10,000 per payload pound.
- Eventually, parts will be printed in-orbit, either with materials brought from earth or mined from Mars.





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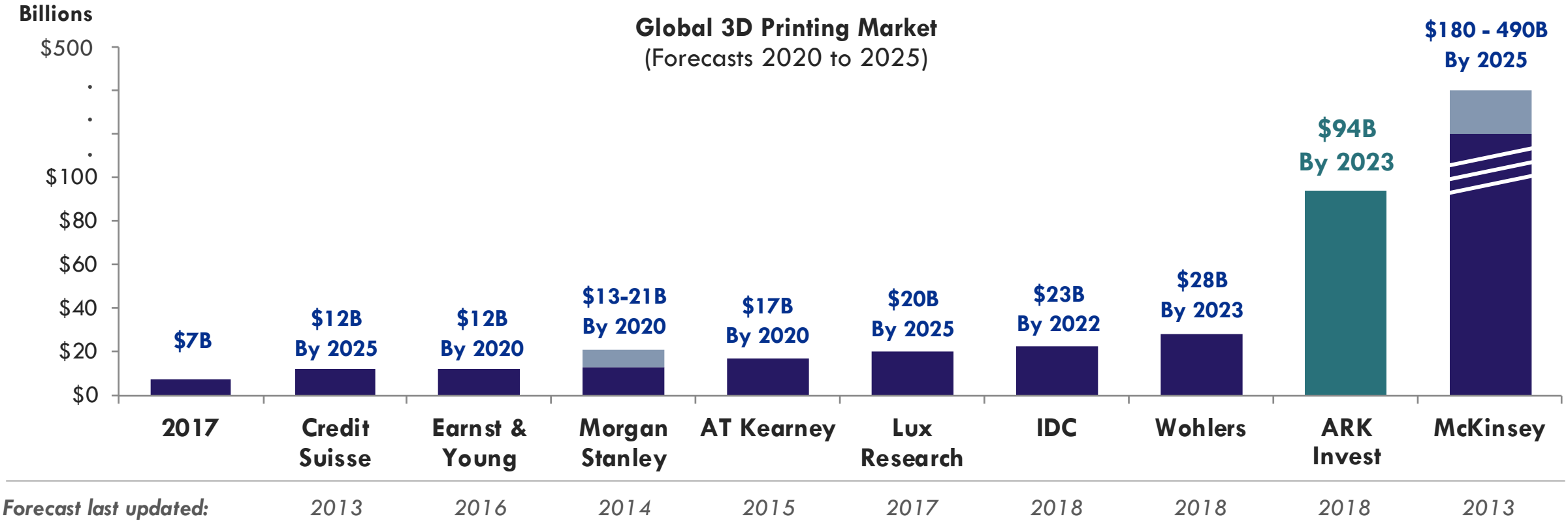
Sources: ARK Source: ARK Investment Management LLC, 2018 ; UCS Satellite Database, , https://arkinv.st/2Fptsff.
[1] Pappalardo, Joe, "Lockheed Martin Is 3D-Printing Giant Titanium Space Parts", *Popular Mechanics*, Jul 12, 2018, https://arkinv.st/2sgniGp

Sizing the Opportunity

ARK's Research Suggests That the Market For 3D Printing Could Scale More Than Tenfold to $94 Billion by 2023.



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ARK INVEST

For more research on disruptive innovation visit ark-invest.com/research

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