CHARTING DISRUPTION

GLOBAL X by Mirae Asset

OUTLOOK FOR 2024 AND BEYOND

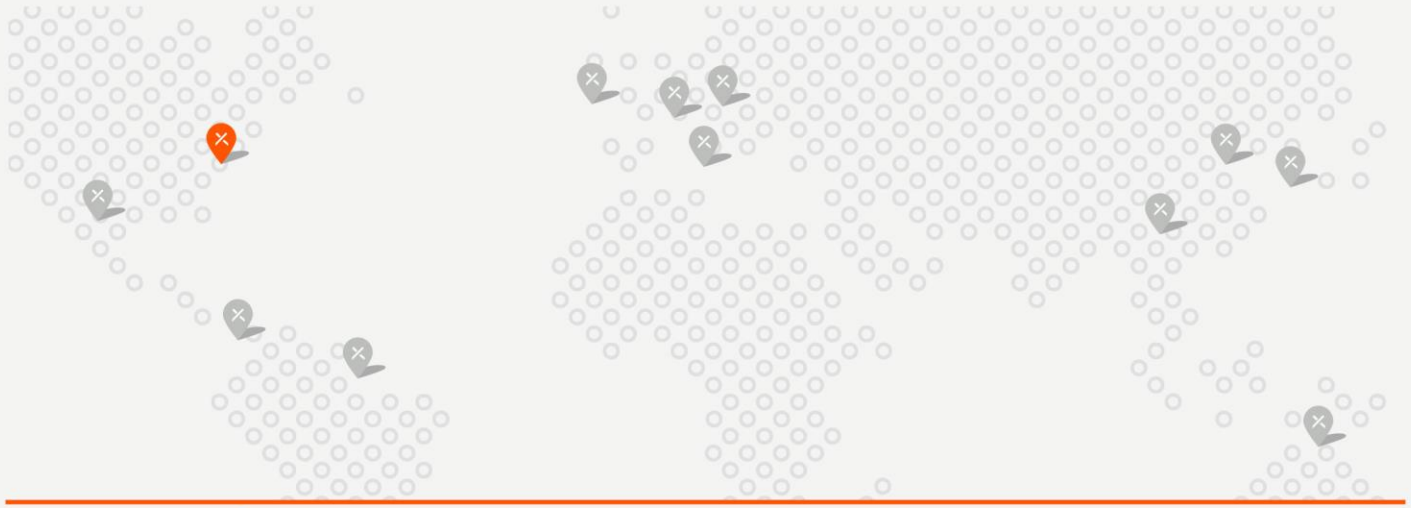
2024 EDITION

GLOBAL X
by Mirae Asset

Beyond Ordinary ETFs®

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

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



$46bn in AUM across more than 200 ETF strategies[1]

Primary Listings by Office

United States
107 ETF Listings

Europe
34 UCITS ETF &
5 Crypto ETP Listings

Australia
35 ETF Listings

Latin America
32 ETF Listings
in Brazil & Colombia

Hong Kong
27 ETF Listings

Japan
36 ETF Listings

MIRAE ASSET
Building on principles

Global X ETFs is a fully-owned subsidiary of Mirae Asset Financial Group, a global industry leader with 55 offices and over 12,000 employees worldwide. Founded in 1997 as one of Asia's pioneering fund management companies, the Group now oversees **$565bn in client assets** across a portfolio that includes real estate, insurance, private equity, and venture capital.[2]

[1]As of October 31, 2023 [2]As of June 30, 2023

Charting Disruption 2024

Our future constantly develops and changes right in front of us. Yet much of the potential disruption seems unimaginable—until it happens.

Our flagship research project, Charting Disruption, aims to shed a quantifiable light on what the future may hold. It's where we explore the interplay between innovation and emerging technological as well as behavioral trends that can shape financial markets and their performance.

In charting potential disruption, we think it's helpful to zoom out to get a more complete view of where technology was and how far it's come. The advances in just the last 25 years alone prove momentous and the momentum of this trend of innovation continues.

It wasn't that long ago, for example, that people found it challenging to envision a world linked through smartphones and the internet. Before too long, most people won't be able to remember life without them.

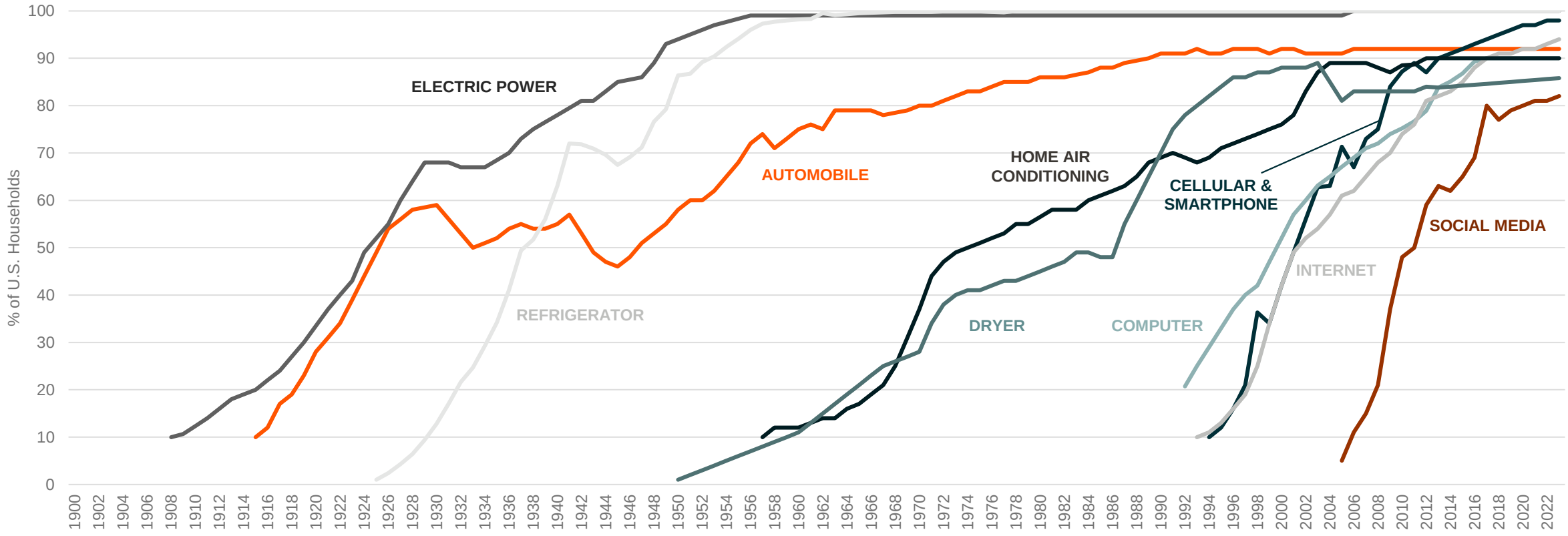
To explore the depth of changes like these, we partnered with handpicked experts in fields such as Artificial Intelligence, Digital Assets, CleanTech, Autonomous Vehicles, Genomics & Biotech, Battery Technology, and Food Innovation.

In what follows, we present unique forecasts, datasets, and analyses that reveal what we expect to disrupt our world in 2024 and beyond.

We hope you enjoy and gain a better understanding of what's possible.

Zooming Out for a Comprehensive View of Disruption

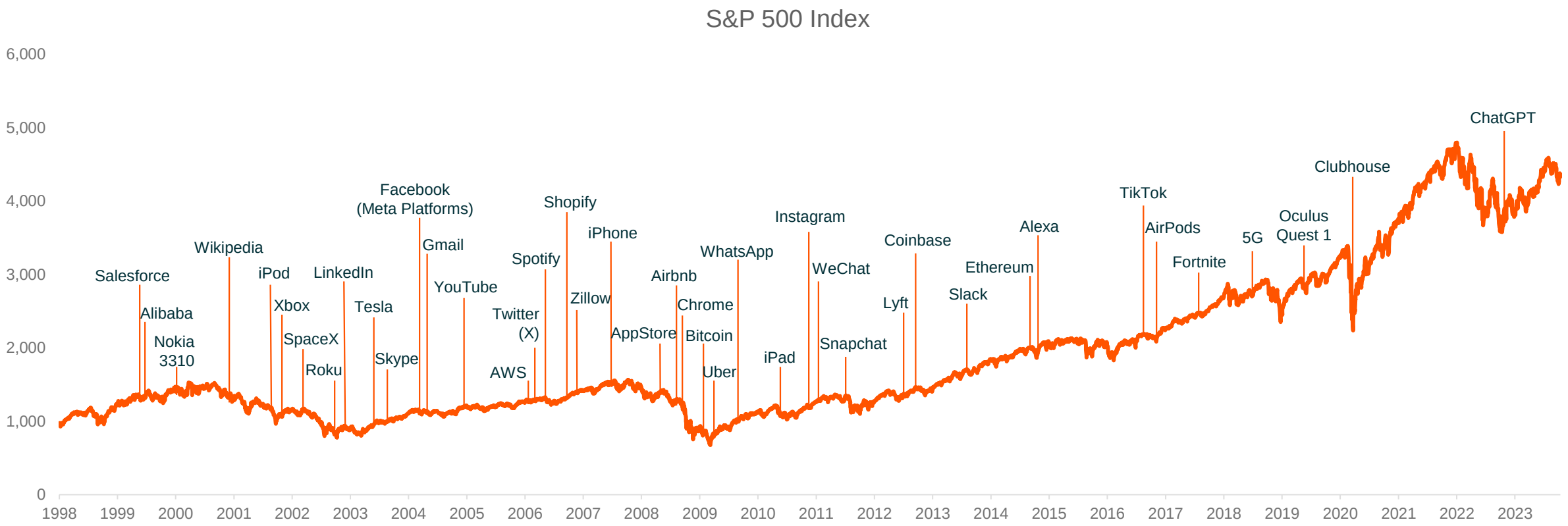
We may often underestimate how much the world can change within a lifetime. Recognizing past dramatic shifts can help us envision a vastly different world in the years or decades ahead.



Sources: Our World in Data. (2019, July 27). Share of United States Households Using Specific Technologies.

Things That Didn't Exist 25 Years Ago

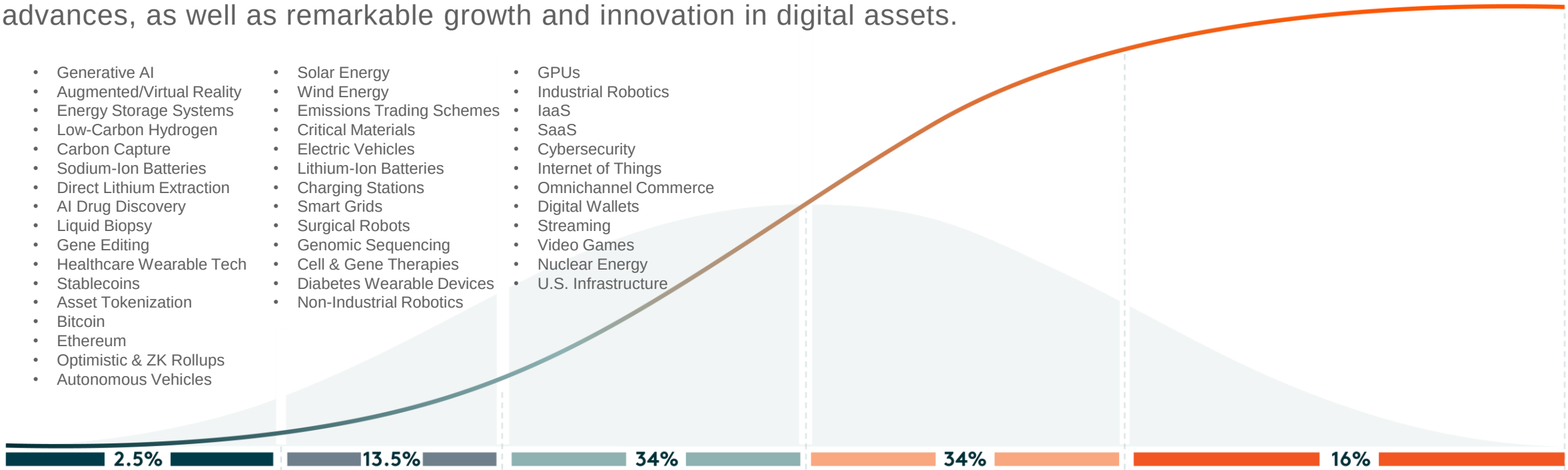
Throughout market cycles, innovation has not stopped. What's familiar to us today – social media, mobile payments, or e-commerce – was unimaginable to our ancestors a few generations ago.



Source: Bloomberg, L.P. (n.d.). [S&P 500 Index] [Data set]. Retrieved on October 13, 2023 from Global X ETFs Bloomberg terminal.

The Unimaginable Today Will Be Familiar Tomorrow

Anticipate a future marked by groundbreaking technologies, greener solutions to global issues, pioneering medical advances, as well as remarkable growth and innovation in digital assets.



INNOVATORS
Adoption starts slowly, as only a small group of Innovators take a chance on a new technology before it is proven or widely accepted.

EARLY ADOPTERS
Early Adopters accelerate and evangelize via word-of-mouth. This is often the tipping point, as Early Adopters convince others that a particular technology is worthwhile.

EARLY MAJORITY
Early Majority, we reach the part of the Adoption S-curve where the slope is the steepest, and hence the rate of adoption is at its fastest. In this phase, sales tends to explode.

LATE MAJORITY
Adoption continues growing at a solid pace as the Late Majority are convinced to participate, and the technology appears seemingly everywhere.

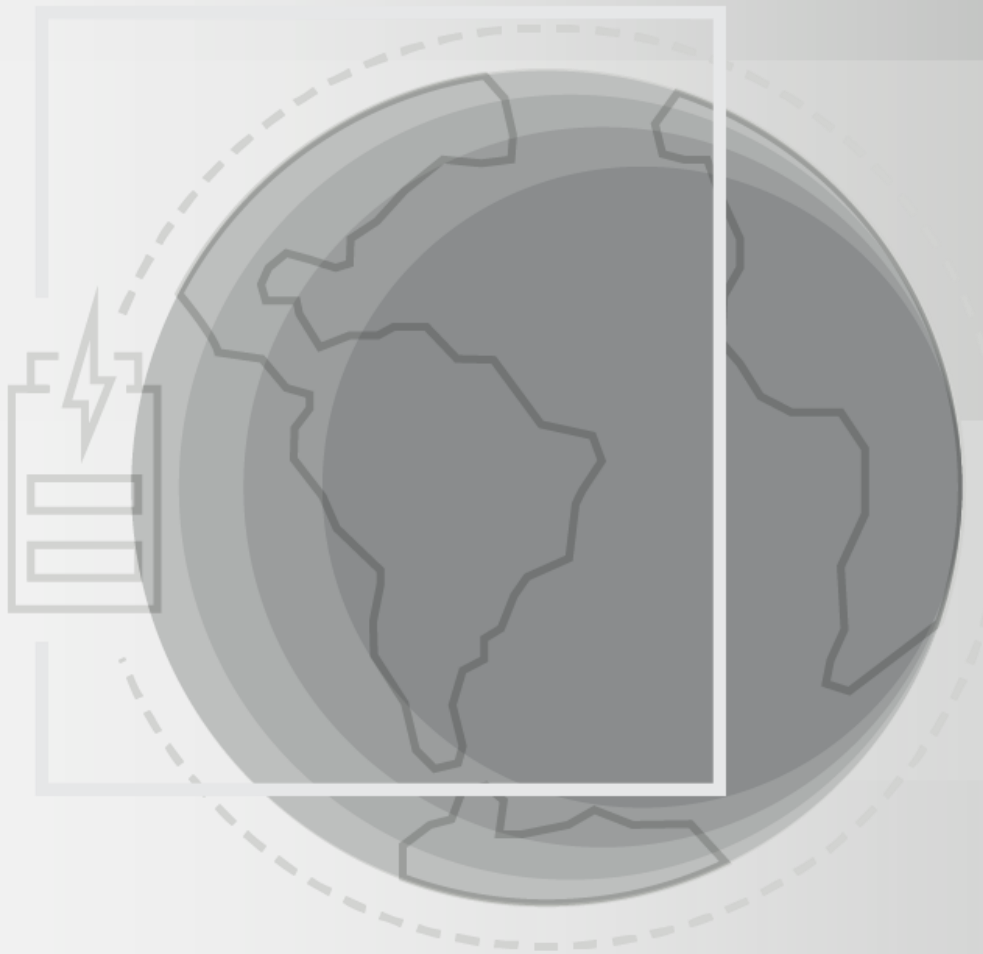
LAGGARDS
Finally, holdouts, begrudgingly acquiesce and accept/adopt a technology.

PHASES OF ADOPTION

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

Charting Disruption 2024

Earth’s Evolution



Earth’s Evolution

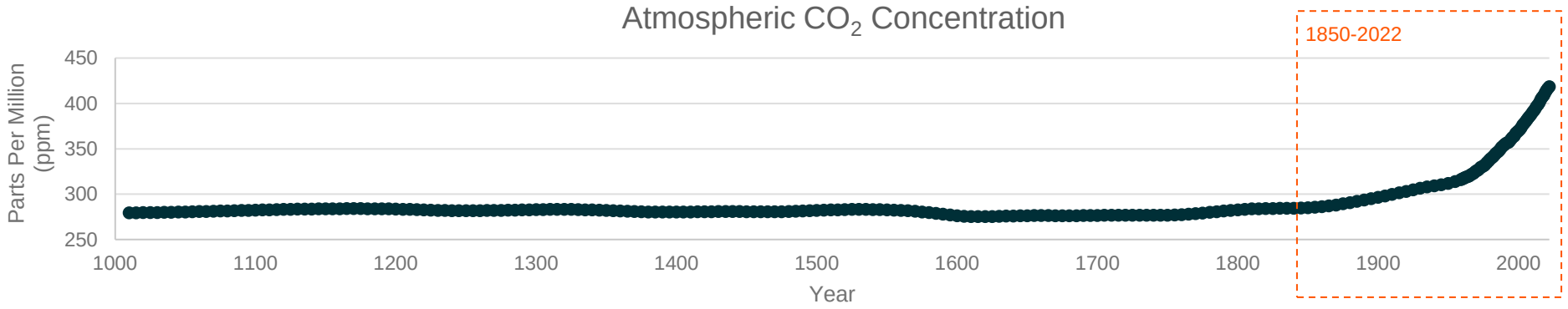
CleanTech & Beyond

The Push for Net Zero Emissions

The average temperature of the Earth is rising, resulting in a range of negative environmental and societal impacts. While there is still time to limit the effects of climate change, it requires rapid, deep, and sustained greenhouse gas emissions reductions. Fortunately, technology-driven solutions already exist that can push the world closer towards net zero emissions, including renewable energy, energy storage, low-carbon hydrogen, carbon capture utilization and storage, as well as plant-based meat.

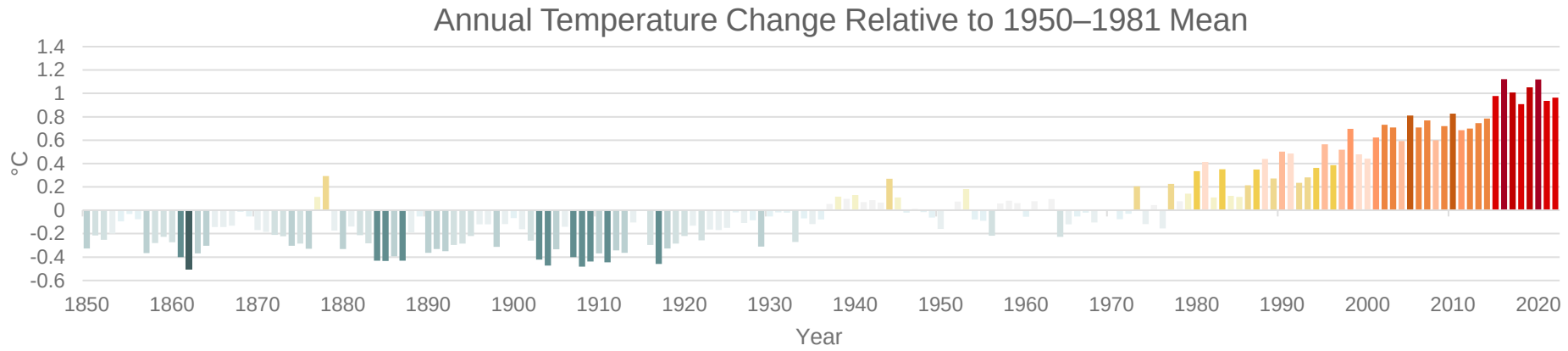
Earth's Global Surface Temperature Has Increased More Than 1°C Due to Human Activities[1]

The rapid rise in human-produced greenhouse gas emissions is causing unprecedented changes to the Earth's climate. Since 1970, the global surface temperature has increased at a faster rate than any other 50-year period in 2000+ years.[2]



+50%

increase in the atmospheric CO_2 concentration from the 1750–1800 average to 2022. Concentrations increased from an average of 279ppm to nearly 419ppm.[3,4]



1.1°C

increase in global surface temperature from the pre-industrial period of 1850–1900 to 2010–2020. Only +/-0.1°C could be from natural drivers like solar activity.[5]

Sources: Text: 1. Intergovernmental Panel on Climate Change (IPCC), 2023; 2. Carbon Brief, 2023; 3. Etheridge, et al, 1998; 4. National Oceanic and Atmospheric Association (NOAA), n.d.; 5. IPCC, March 2023; Charts: Top: Etheridge, et al, 1998; NOAA, n.d.; Bottom: Berkley Earth, n.d.

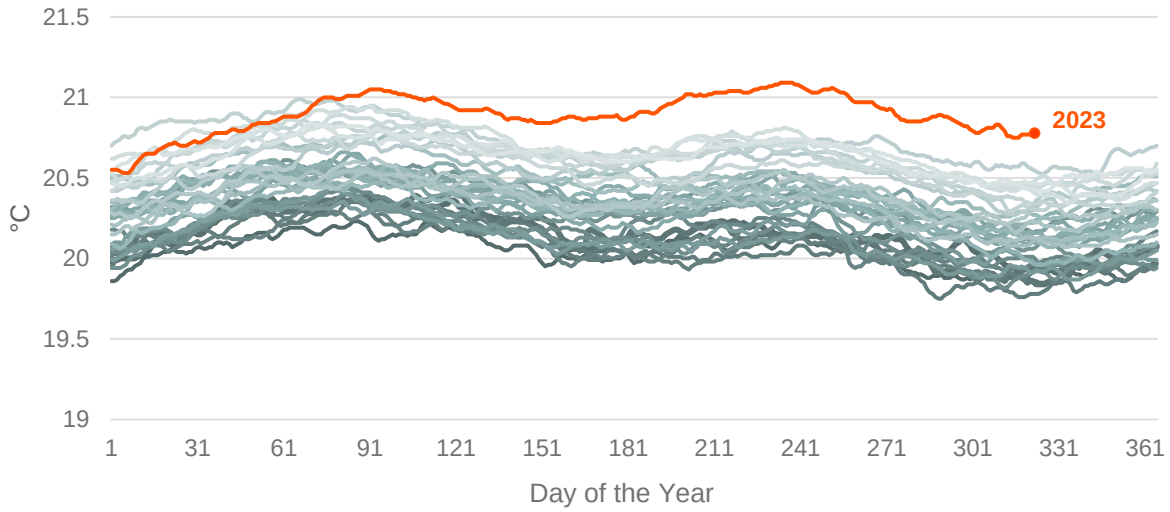
Current Levels of Warming Already Having Negative Effects

Notable shifts in the physical environment are evident at current levels of temperature change. 2023 is on track to be the warmest year ever recorded as the effects of a strong El Niño event are being compounded by climate change.[1]

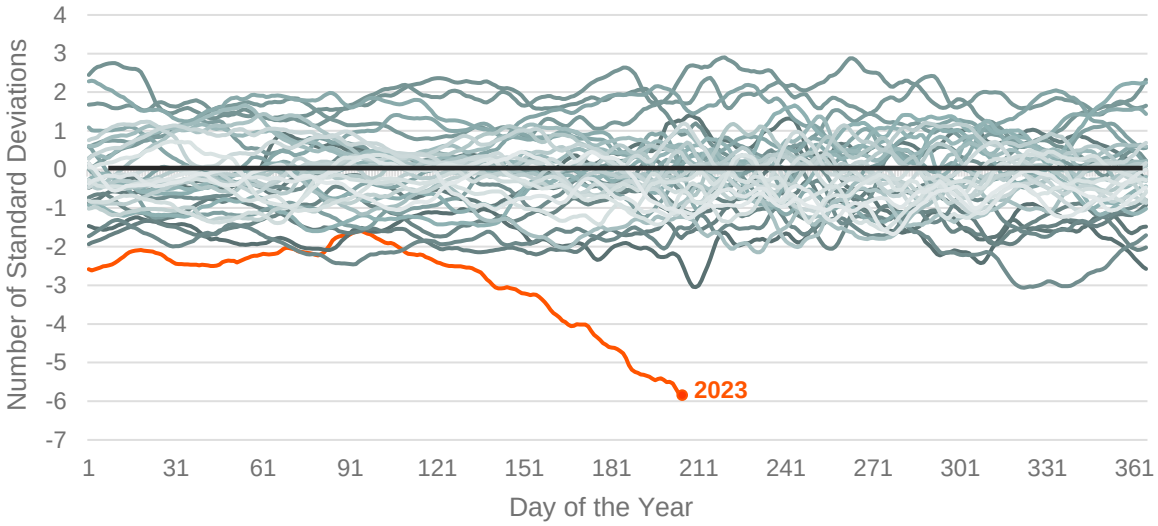
Record-breaking sea surface temperatures (SST) have been recorded around the world in 2023. In July, the Mediterranean Sea hit a record 28.7°C and the North Atlantic was at a record 24.9°C. Waters off Florida's coast reached a significant 38.3°C.[2]

In 2023, Antarctic sea ice reached its lowest levels since official records began over 40 years ago.[3] In July, sea ice extent represented a nearly six-sigma event, which equates to a once-in-7.5-million-year event.[4] Given the Arctic's natural state, scientists believe that human-induced climate change is the cause.[5]

Daily Average Sea Surface Temperature Between 60°N & 60°S, 1989–2023



Daily Standard Deviation for Antarctic Sea Ice Extent, 1989–2023 (Compared to 1991–2020 Mean)



Sources: Text: 1. Carbon Brief, 2023; 2. Phys.org, 2023-Jul; 3. National Aeronautics and Space Administration (NASA) Earth Observatory, 2023; 4. Phys.org. 2023-Aug; 5. Ibid.; Charts: Left: Climate Reanalyzer, n.d.; NOAA, n.d.; Right: Vishop. n.d.

Concerns About Climate Change Rise with More Extreme Weather Events

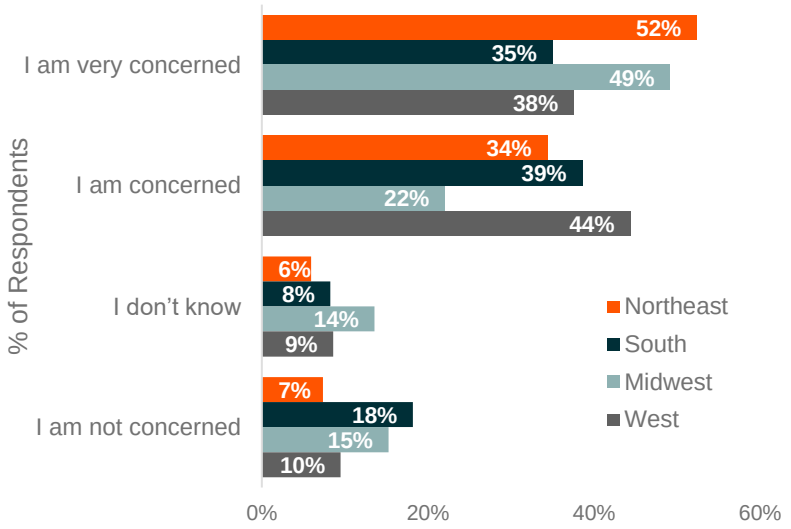
Climate change is affecting the strength and likelihood of extreme weather events, including drought conditions in the Western United States and extreme heat events globally – impacting levels of concern over climate change.

Climate change has been linked to magnifying the intensity and/or likelihood of many recent extreme weather events throughout the world.[1]

- **Western Mediterranean heat wave in April 2023:** Occurrence at least 100x more likely due to climate change.[2]
- **Argentina's record heat wave in December 2022:** Occurrence at least 60x more likely due to climate change.[3]
- **West Africa's severe rainfall and flooding in 2022**: Occurrence at least 80x more likely due to climate change.[4]
- **Northern Hemisphere droughts in 2022 (United States, Europe, China):** Occurrence at least 20x more likely due to climate change.[5]

In the United States, 81% of respondents to a recent Global X ETFs survey are concerned about climate change, with the Northeast and West regions showing the highest levels.[6]

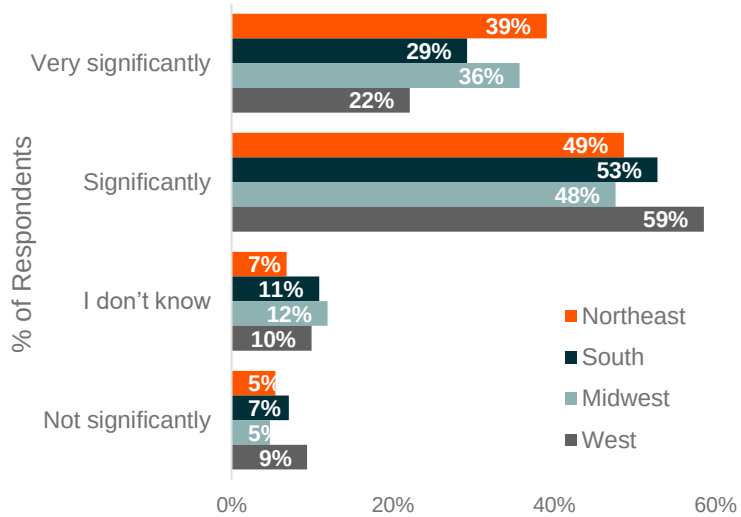
Q: How concerned are you about climate change?



Note: Number of respondents = 1,065.

Among those concerned about climate change, recent extreme weather events played a significant role in increased levels of concern.

Q: How has your level of concern been impacted by new extreme weather events?



Note: Number of respondents = 856. Only answered by individuals who responded "I am very concerned" or "I am concerned" to the previous question.

Sources: Text: 1. Carbon Brief, 2022-Aug; 2. Carbon Brief, 2023-May; 3. Carbon Brief, 2022-Dec; 4. Carbon Brief, 2022-Nov; 5. Carbon Brief, 2022-Oct; 6. De, 2023; Charts: De, 2023

Every Fraction of Warming Can Rapidly Escalate the Impacts on People and Ecosystems

Global consensus is that the world must limit warming to 1.5–2°C to avoid the worst impacts. However, the world is on track for as much as 3°C by 2100.[1] The difference in potential impacts at these levels is sizeable.

Projections Show Heightened Risks for Extreme Weather, Sea Level Rise, and Biodiversity Loss as Temperatures Rise

Level of Warming	1.5°C	2.0°C	3.0°C
Floods Percent increase in global population exposed to flooding	24%	30%	Data not available
Fires Percent increase in burnt area across Mediterranean Europe	40-54%	62-87%	96-187%
Extreme Heat Increase in number of days per year with max temperature of 35°C+	45 to 58 Days	52 to 68 Days	66 to 87 Days
Food Security Costs for adaptation and residual damage to major crops globally	$63B	$80B	$128B

Level of Warming	1.5°C	2.0°C	3.0°C
Biodiversity Loss Maximum percent of terrestrial species at high risk of extinction	14%	18%	29%
Coral Reefs Projected further percent decline in coral reefs	70-90%	99%	Data not available
Drought Dryland pop. exposed to water/heat stress as well as desertification	0.95B People	1.15B People	1.29B People
Sea Level Rise Global mean sea level rise by 2100 (meters)	0.28m to 0.55m	0.33m to 0.61m	0.44m to 0.76m

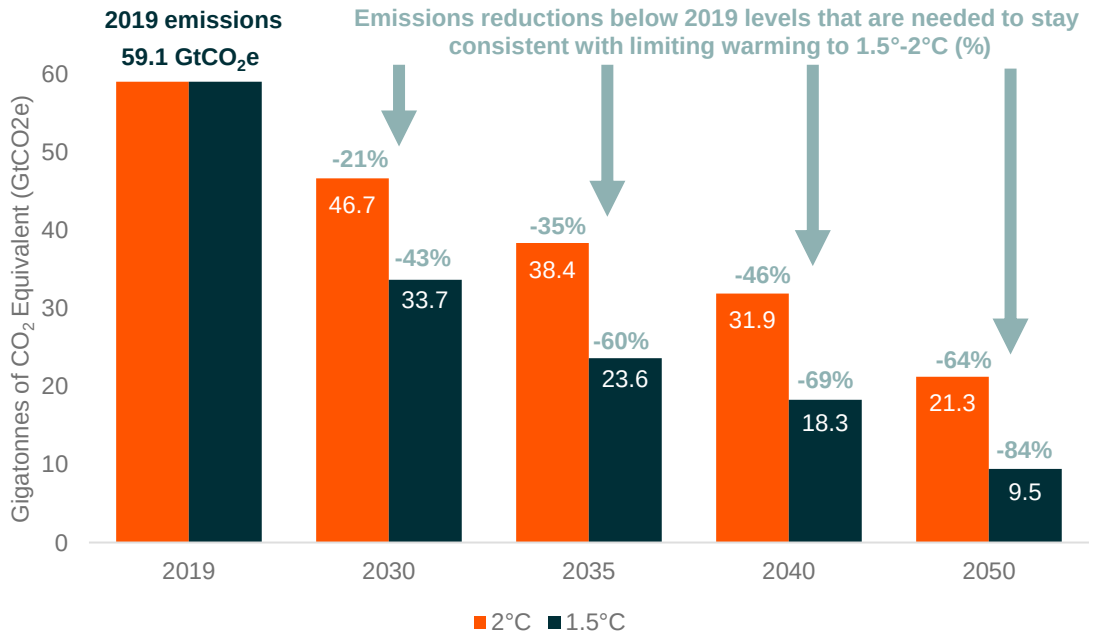
Sources: Text: 1. IPCC, 2023. Charts: IPCC, 2023; World Resources Institute, 2023

Deep, Rapid, and Sustained Emissions Cuts Can Limit Warming, but More Investment Needed

Global investment across all energy transition technologies must total an estimated $150 trillion from 2023–2050 to limit warming to 1.5°C, or about $5 trillion annually.[1] CleanTech investment is projected to reach $1.7 trillion in 2023.[2]

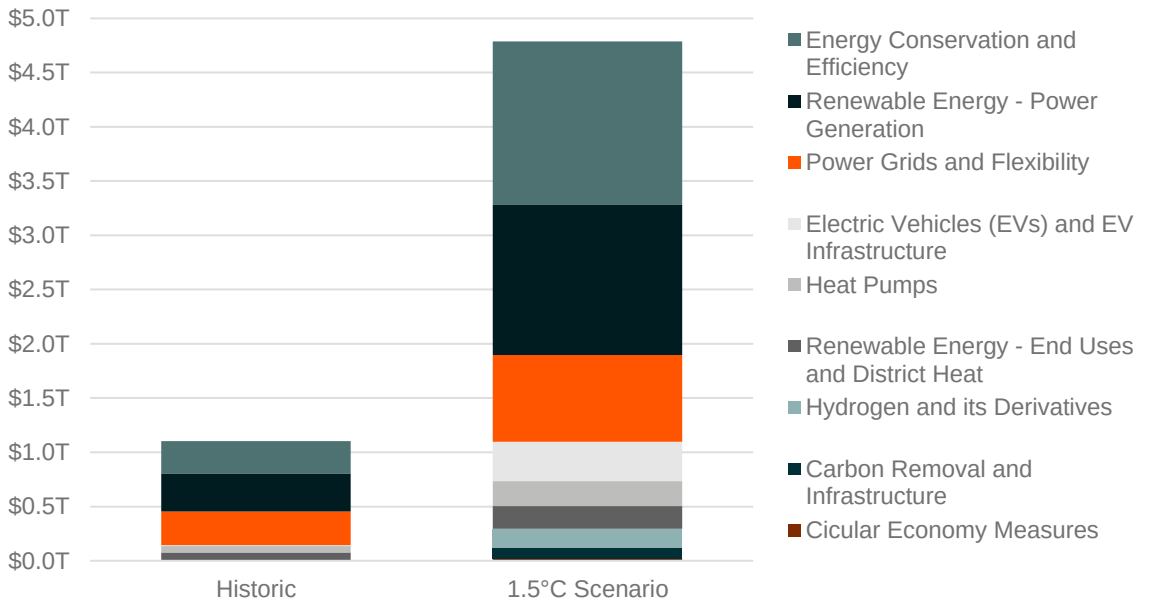
Rapid Decline in Emissions Is Needed to Limit Warming

Projected CO2 Emissions in 1.5°C and 2°C Mitigation Pathways



CleanTech Investment Needs to Accelerate to Stay on Track

Annual Historic and Projected CleanTech Investments



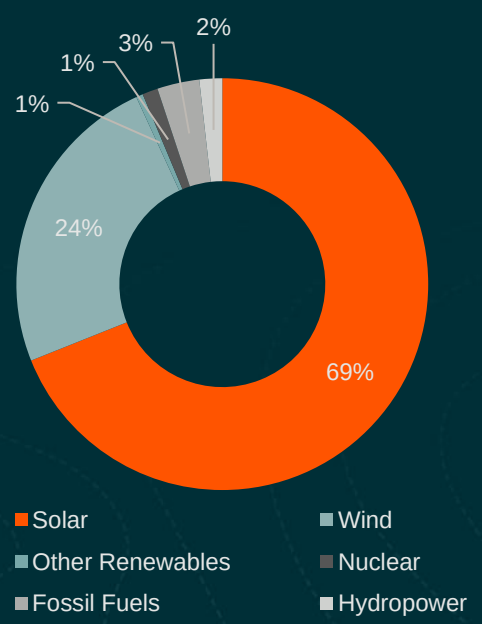
Sources: Text: 1. International Renewable Energy Agency (IRENA), 2023; 2. International Energy Agency (IEA), 2023; Charts: Left: IPCC, 2023; Right: IRENA, 2023

Widespread Adoption of Renewables Can Decarbonize the Power Sector

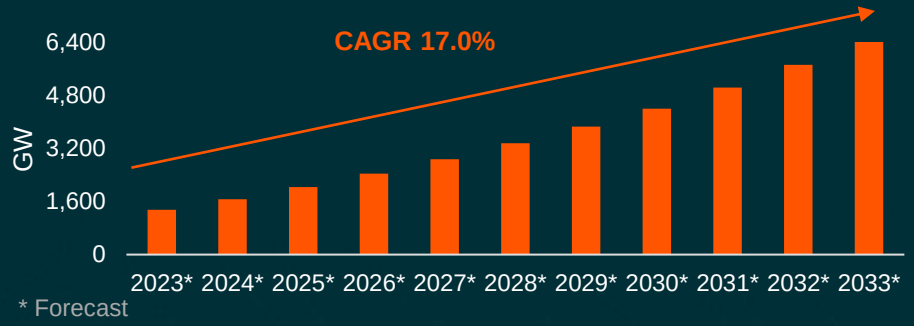
The global clean energy transition is well underway. Non-hydropower renewable electricity generation is forecast to increase 3.2x between 2023 and 2033.[1] By 2033, non-hydro renewables could account for 38% of generation.[2]

Global Non-Hydropower Renewable Capacity Is Forecast to Increase from 2,508 Gigawatts (GW) in 2023 to 9,475 GW in 2033.[3]

Share of Forecasted Net Capacity Additions from 2023–2033 (%)

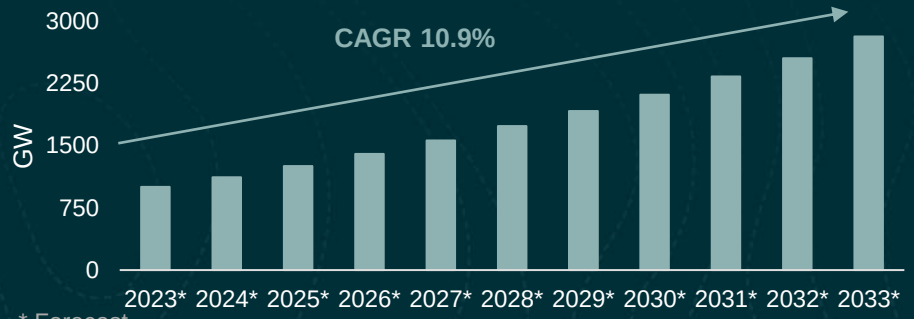


Global Solar Power Capacity



* Forecast

Global Wind Power Capacity



* Forecast

Key Drivers of Renewables Growth

- **Favorable Policy Environments:** Over 150 countries have economy-wide net zero emissions targets, with governments using measures such as tax credits and project tenders to encourage renewables growth.[4] The U.S. Inflation Reduction Act (IRA) and the European Union's RePowerEU plan are prime examples of policies that can boost growth.
- **Corporate Sustainability Efforts:** Many corporations are becoming increasingly interested in using renewable energy to reduce operational emissions.
- **Technology Improvements:** Advancements in wind and solar power components, such as solar modules and wind turbines, can improve system performance and efficiency while further cutting costs.
- **Increased Cost Competitiveness:** Onshore wind and solar photovoltaic (PV) power costs declined 68% and 88%, respectively, between 2010 and 2021.[5] While costs have been elevated in recent years, tech advancements and addressing supply issues can yield further price declines.

Sources: Text: 1. Global X forecast based on information derived from several sources – see Appendix: CleanTech & Beyond: Sources; 2. Ibid; 3. Ibid; 4. Net Zero Tracker, n.d.; 5. IRENA, 2022.

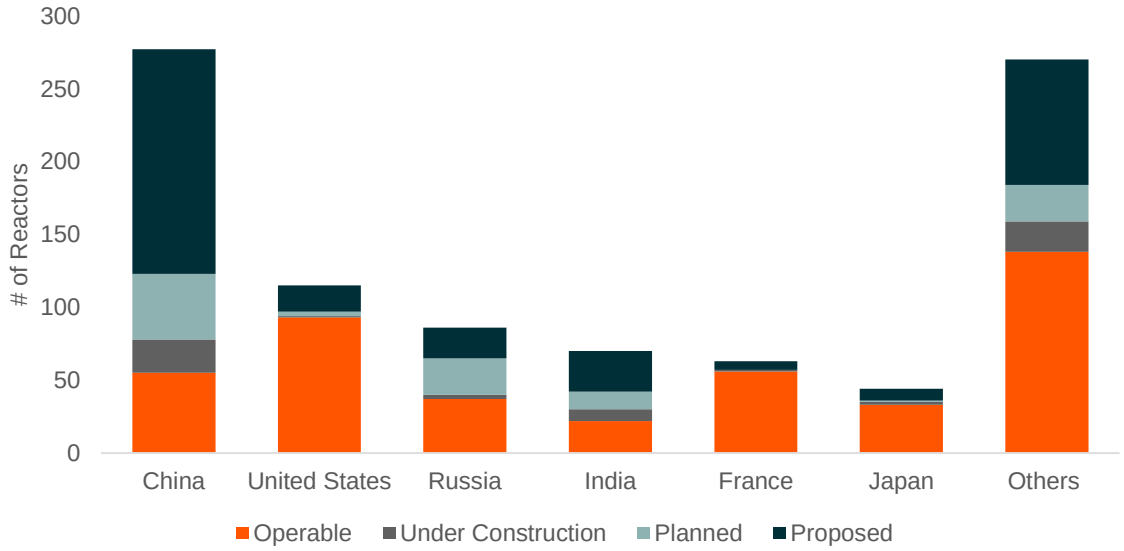
Many Governments Continue to Support Nuclear Power for a Clean Energy Future

Nuclear energy is one of the cleanest, most reliable ways to make electricity, as plants can operate at full capacity 90% of the time.[1] Nuclear power can help governments improve energy security and mitigate climate change.

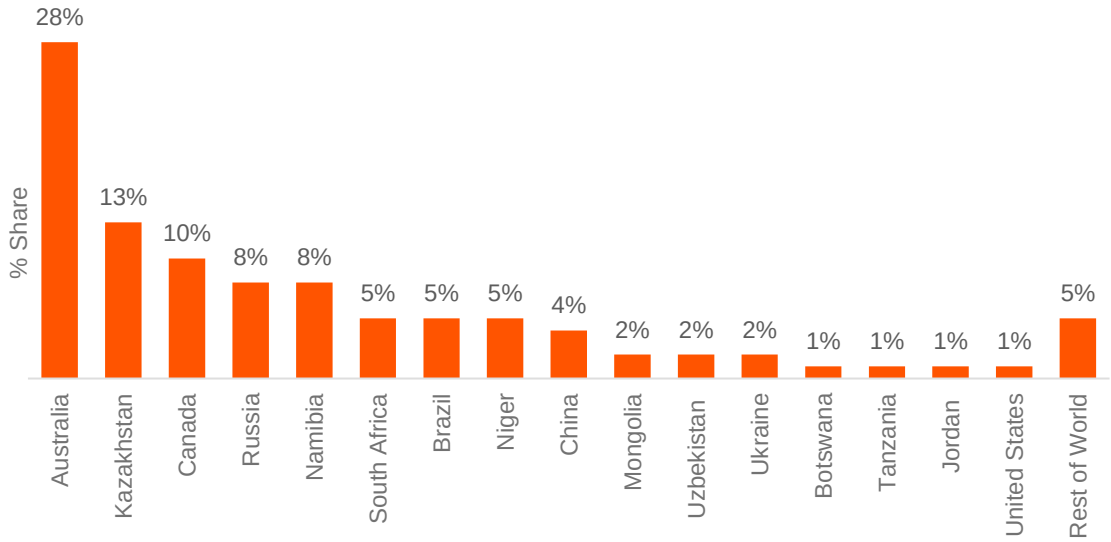
Next-generation small modular reactor (SMR) technologies offer a safer, more modular, and less expensive alternative to traditional nuclear power plants.[2] The recent nuclear fusion breakthrough is a decades-long scientific accomplishment that has the potential to advance clean power.[3]

Given nuclear power's benefits for energy security and decarbonization, as well as the industry's growth potential, exploration expenditures for uranium grew by a significant 60% year-over-year in 2022.[4] For example, the U.S. Department of Energy started to support a strategic domestic uranium reserve.

Nuclear Reactors Under Development, by Stage and Country



Uranium Reserves Worldwide

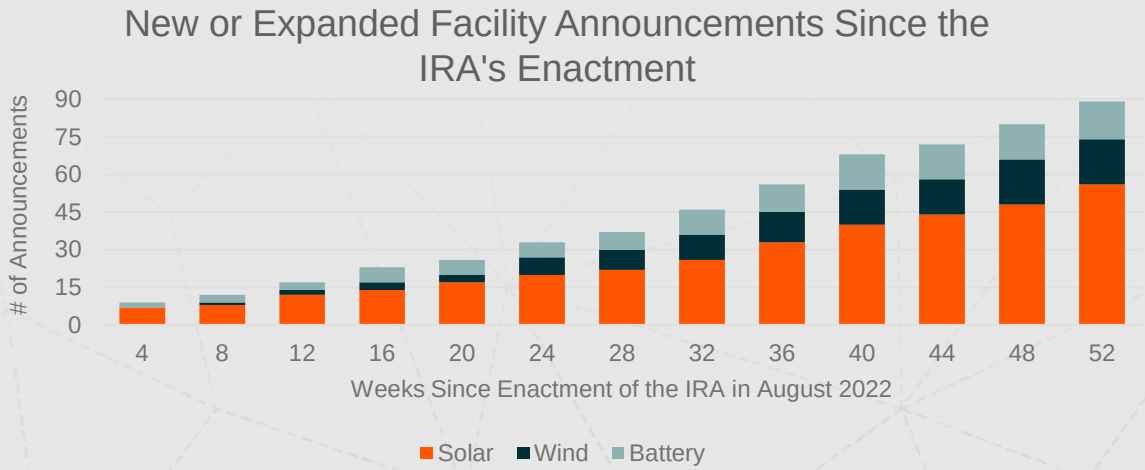


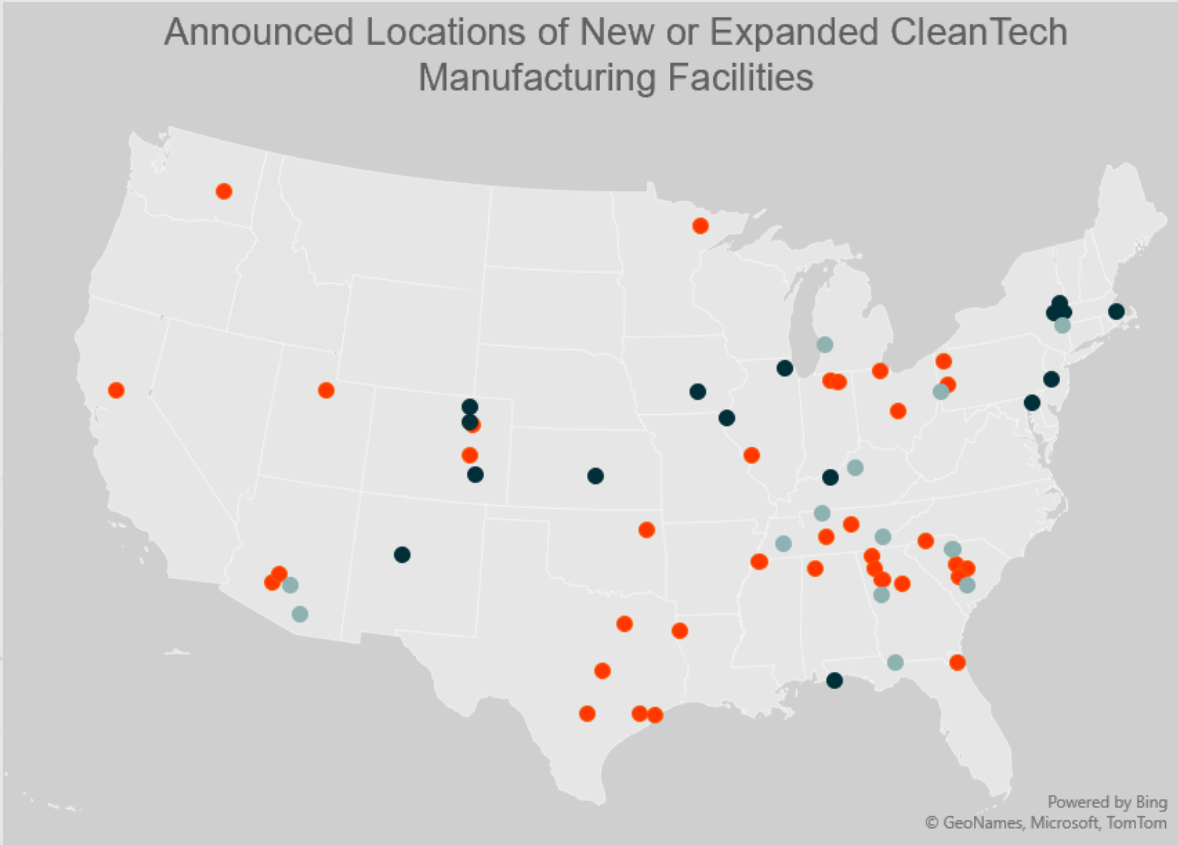
Sources: Text: 1. Energy Industry Association (EIA), 2022; 2. International Atomic Energy Agency, 2023; 3. Reuters, 2023; 4. IEA, 2023; Charts: Left: World Nuclear Association, 2023a; Right: World Nuclear Association, 2023b

Policy Highlight: The IRA Has Spurred Significant Clean Energy Investment

Katherine Hamilton

Over $270 billion in investments across the wind, solar, and battery value chains is attributable to the Inflation Reduction Act (IRA). In the IRA's first year, 80+ new or expanded clean energy production facilities were announced.





U.S. Renewables Supply Chain Led by Solar

The supply chain is crucial to the deployment of renewables, especially given the domestic content mandate built into tax credits and ongoing tariff discussions in the U.S. solar industry. Solar companies announced 50+ new or expanded manufacturing facilities in the IRA's first year. Combined, these facilities could add more than 70GW of solar power equipment manufacturing capacity. Canadian Solar, Enphase, First Solar, Meyer Burger, Jinko Solar, JA Solar, and Polar Racking are among the companies that made announcements.

Sources: Text and Charts: American Clean Power, n.d.

Policy Highlight: IRA Can Speed Up Solar's Reach in Underserved Communities

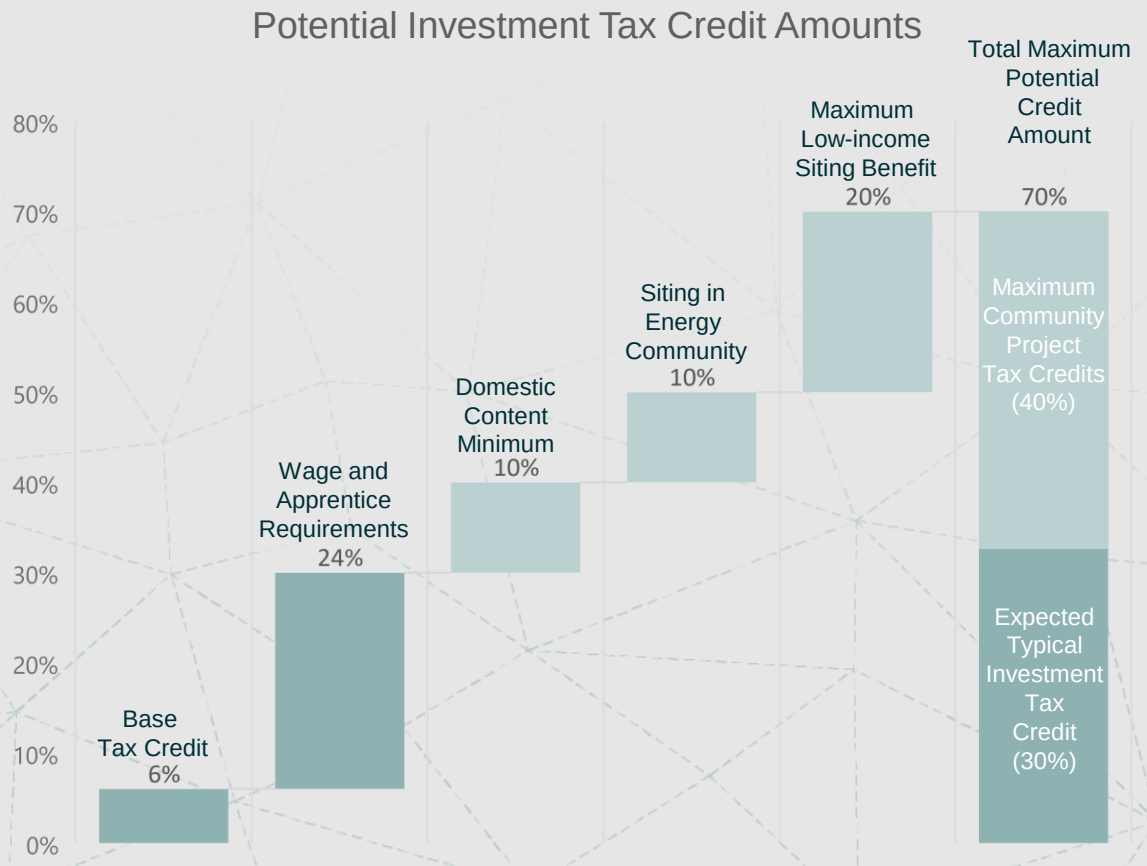
Katherine Hamilton

Developers that build in underserved communities can potentially benefit from a tax credit of up to 70%.[1] These measures, combined with solar's scalability and cost advantages, are likely to lead to robust solar power growth.

The IRA Takes an Inclusive Approach to the Clean Energy Transition

By ensuring that a wider range of communities can benefit, the IRA greatly expands the potential growth opportunities for the U.S. solar power sector. The stacking of economic incentives aims to help renewables reach areas in most need of well-paying jobs, economic growth, and clean air. With these tax credits, it can become more cost-effective to build solar in communities that have previously not had much access.

Highlighted Tax Credit Incentive	Requirements for Credit	Maximum Credit %
Wage and Apprenticeship Requirements Credit	Developers pay laborers prevailing wages and employ apprentices for a set number of hours, as determined by the U.S. Department of Labor.[2]	24%
Domestic Content Credit	Developers surpass required amount of domestically produced project components of steel or iron.[3]	10%
Siting in Energy Community Credit	Project is built in an Energy Community, which can be defined as an area that has disproportionally suffered from the impact of fossil fuels.[4]	10%
Siting in Low-Income Community Credit	Project is under 5MW in total size and built in designated low-income community.[5]	Up to 20%



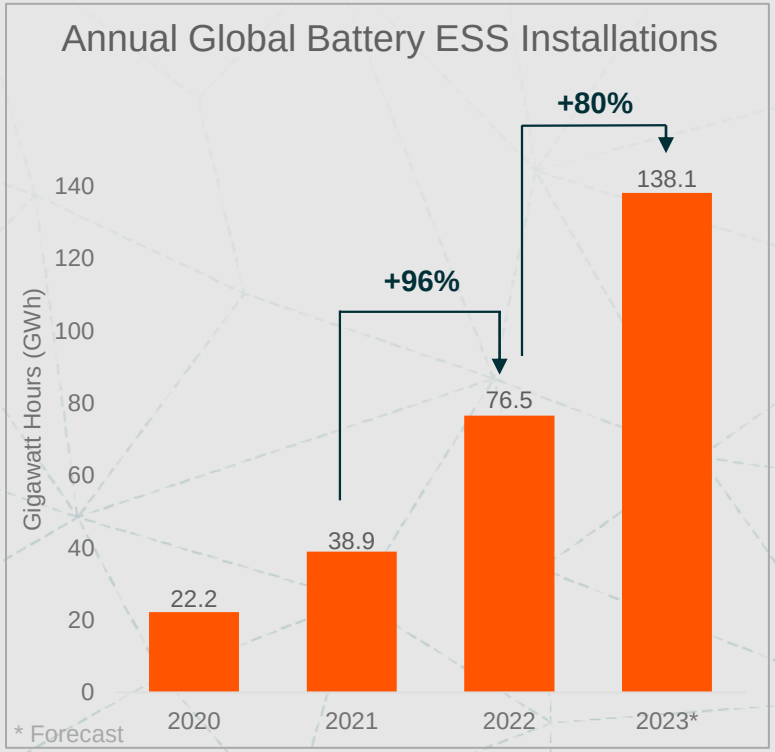
Sources: Text: 1. Center for American Progress (CAP), 2023; 2.Internal Revenue Service (IRS), n.d.; 3. Bond, Davis, Rodgers, & Saccomanno, 2023; 4. U.S. Department of the Treasury, 2023; 5. U.S. Department of Energy (DOE), n.d.; Charts: CAP, 2023.

Rapid Growth in Energy Storage Is a Positive Sign for the Energy Transition

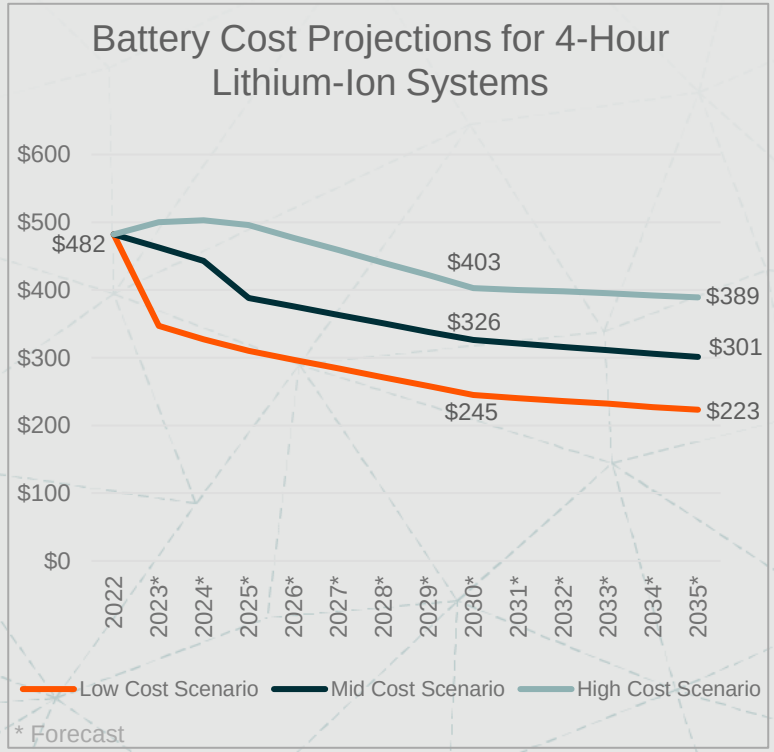
Katherine Hamilton

The expected growth in energy storage systems (ESS) speaks volumes about the world's ability to integrate renewable energy and balance greener power grids. Supportive policies are likely to make ESS more cost-effective over time.

Strong ESS Growth Forecast for 2023



ESS Costs Expected to Decline Rapidly



Policies Support Positive ESS Outlooks

Policy Highlights

- **United States:** The IRA creates a standalone tax credit for energy storage systems.[1] Additionally, the Infrastructure Investment and Jobs Act includes potential financing support for long-duration storage technologies and ESS manufacturing facilities.[2]
- **China:** Policies that require renewables projects to be paired with ESS could help energy storage capacity grow to over 50GW by 2025.[3]
- **European Union:** In March 2023, the European Commission published an analysis that outlines best practices and financing frameworks that can help boost ESS deployment in the region.[4]
- **India:** In August 2023, India's government published its National Electricity Plan, which targets 74GW/411GWh of energy storage by 2032.[5] The government is planning to expand measures to encourage ESS growth over the coming years.

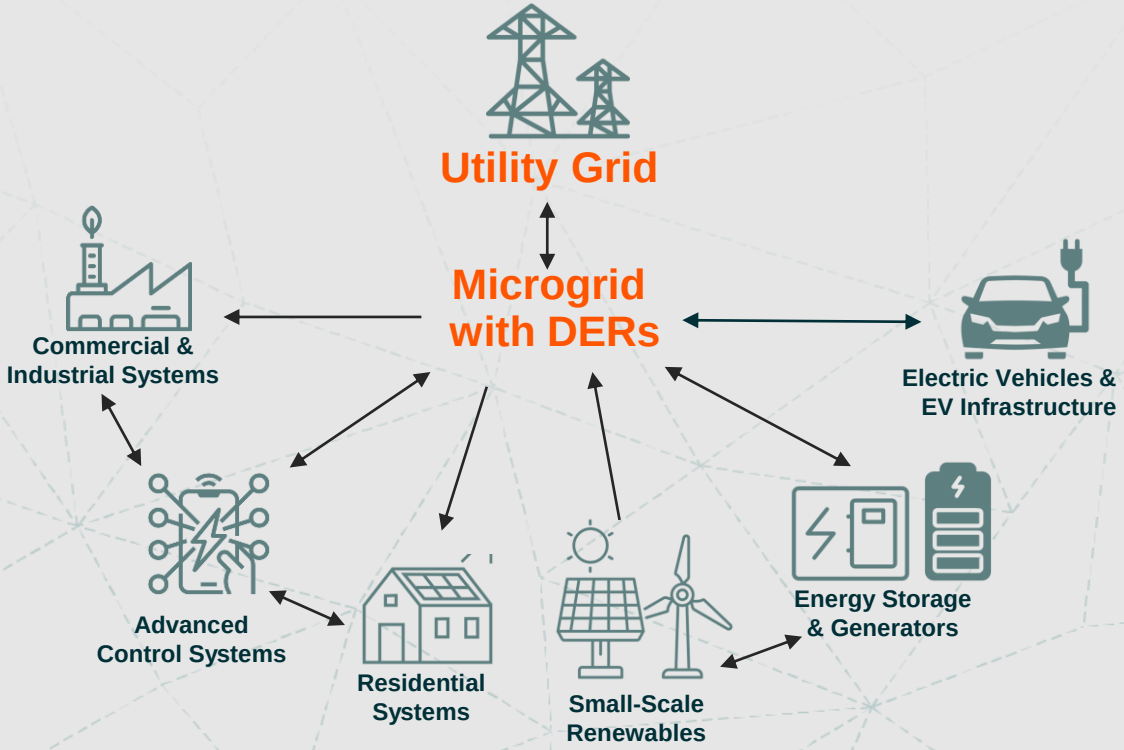
Sources: Text: 1. Energy Storage News, 2023-Jan; 2. DOE, n.d.; 3. South China Morning Post, 2023; 4. European Commission, 2023; 5. Energy Storage News, 2023-Sept; Charts: Left: Rho Motion, 2023; Right: National Renewable Energy Laboratory (NREL), 2023.

Distributed Energy Resources (DERs) Can Further Increase Grid Resilience

Katherine Hamilton

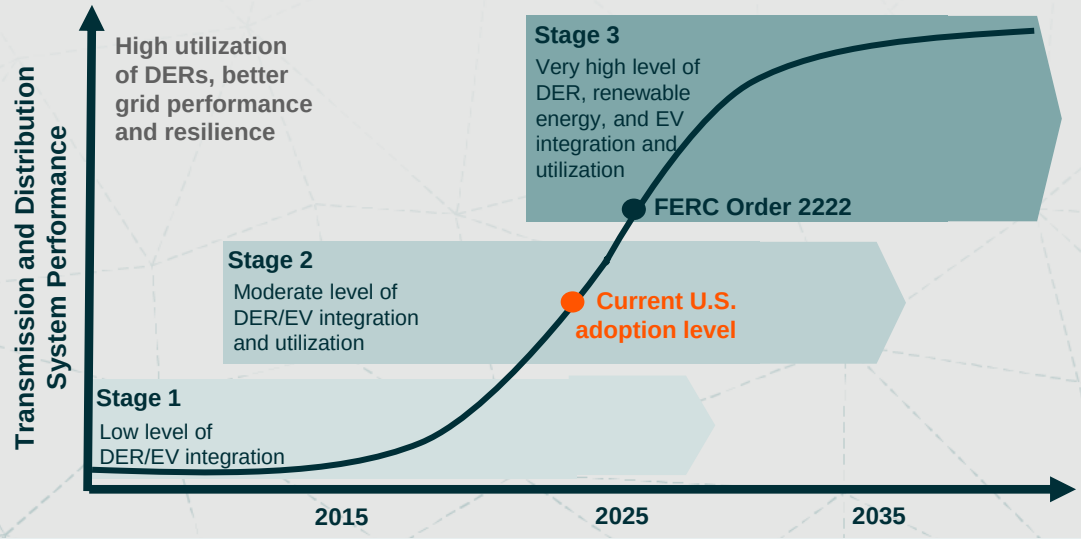
DERs - such as microgrids with residential solar power systems, electric vehicle (EVs), heat pumps, and energy storage - are crucial to balancing power systems and ensuring that grids can absorb 100% clean energy.

DERs Included in Microgrids Can Boost Capacity on Utility Grids



Grids Expected to Become More Reliable with Uptake of DERs

Status of DER Integration in the United States



Order 2222: The U.S. Federal Energy Regulatory Commission (FERC) calls for the integration of DERs into wholesale energy markets by 2025.[1] This order poses challenges, but it can also boost grid capacity and provide other benefits.

Sources: Text: 1. PCI Energy Solutions, 2023.; Charts: Left: VectorMine, n.d.; Right: Berkley Lab, 2023-Apr 25; Berkley Lab, 2023-Apr 13

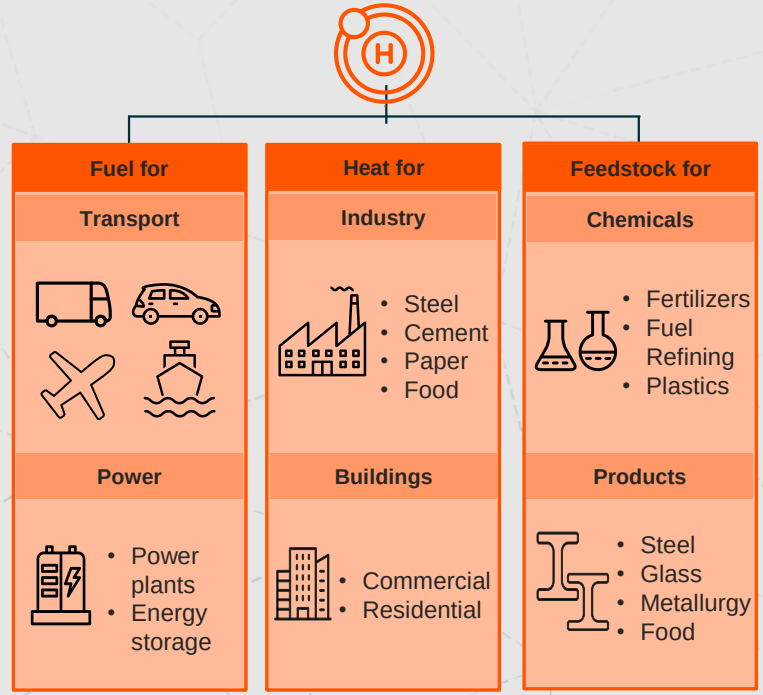
Nascent Yet Growing Technologies Can Reach the Hardest-to-Abate Sectors

Katherine Hamilton

We envision a fully decarbonized world with solutions such as low-carbon hydrogen and carbon capture giving industries like steel, cement, and petrochemicals clear pathways to decarbonize.

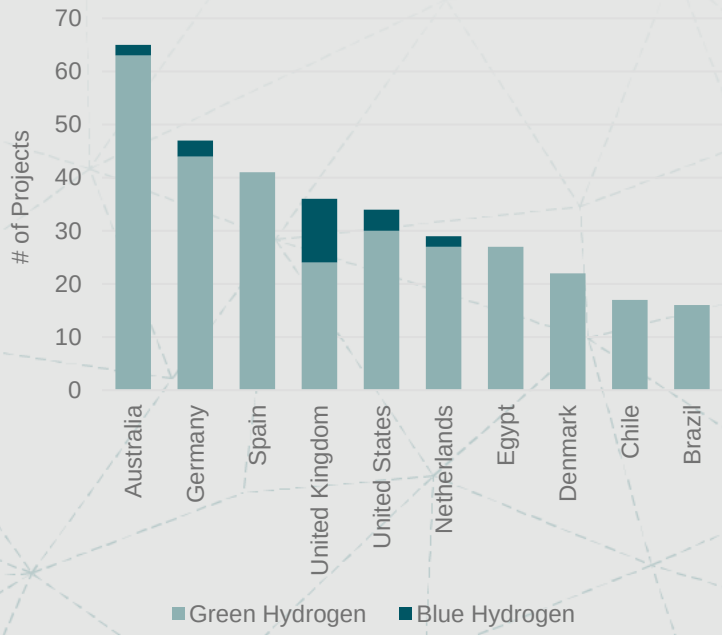
Hydrogen (H) Can Clean Up Many Sectors

Hydrogen Use Cases



500+ Clean H Projects Are in Development

Low-Carbon Hydrogen Project Pipeline, Top 10 Countries



Policies Encourage a New Global Industry

Policy Highlights

- **Australia:** Helped by its $2 billion Hydrogen Headstart Program, which will provide financial support to large-scale projects, Australia aims to be a major global exporter of clean hydrogen by 2030.[1]
- **United States:** The IRA includes a Clean Hydrogen Production Tax Credit that is expected to bring low-carbon hydrogen prices closer to cost parity with traditional grey hydrogen.[2] This credit can create political will and incentivize the production and use of low-carbon hydrogen.
- **European Union:** Among the European Union's many hydrogen-related objectives, the region aims to produce 10 million tonnes and import 10 million tonnes of low-carbon hydrogen by 2030.[3]
- **Chile:** The Chilean government intends to provide $1 billion for green hydrogen projects to help the country become a top exporter and produce the lowest-cost hydrogen over the next decade.[4]

Sources: Text: 1. Australian Government, n.d.; 2. Atlantic Council, 2022; 3. European Commission, n.d.; 4. HydrogenInsight, 2023; Charts: Left: Bloomberg, 2019; Right: Fitch Solutions, 2023

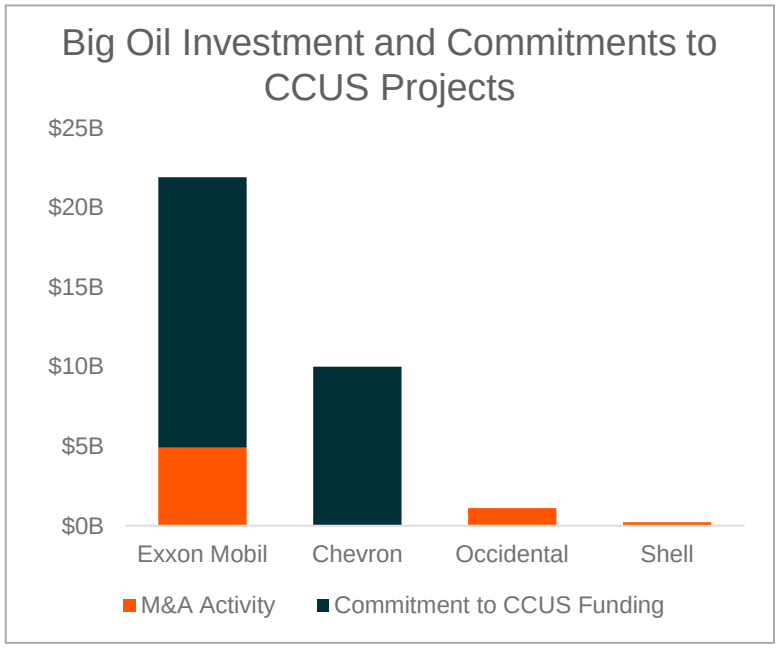
Carbon Capture Technologies Playing a Key Role in Net Zero Pursuit

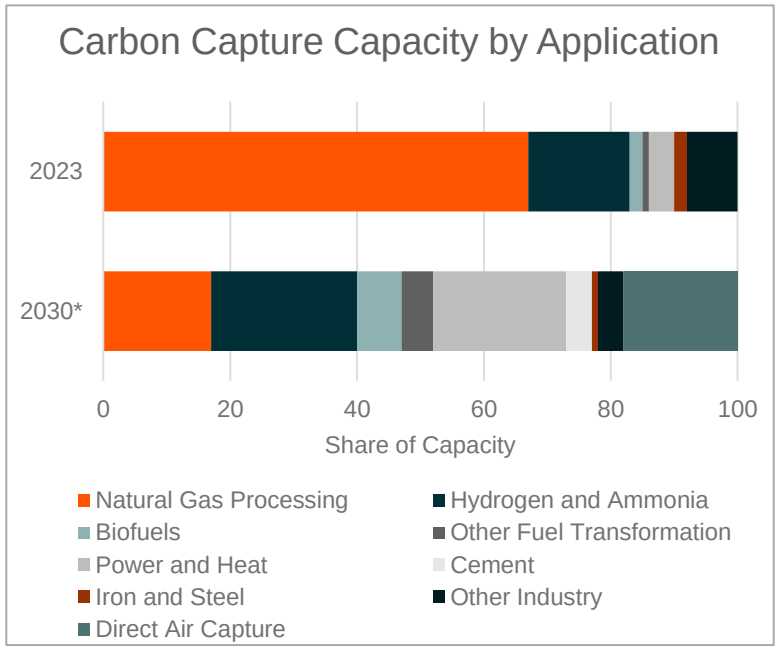
Favorable policies are incentivizing companies to invest in carbon capture technologies, such as carbon capture, utilization, and storage (CCUS) and direct air capture (DAC) systems.

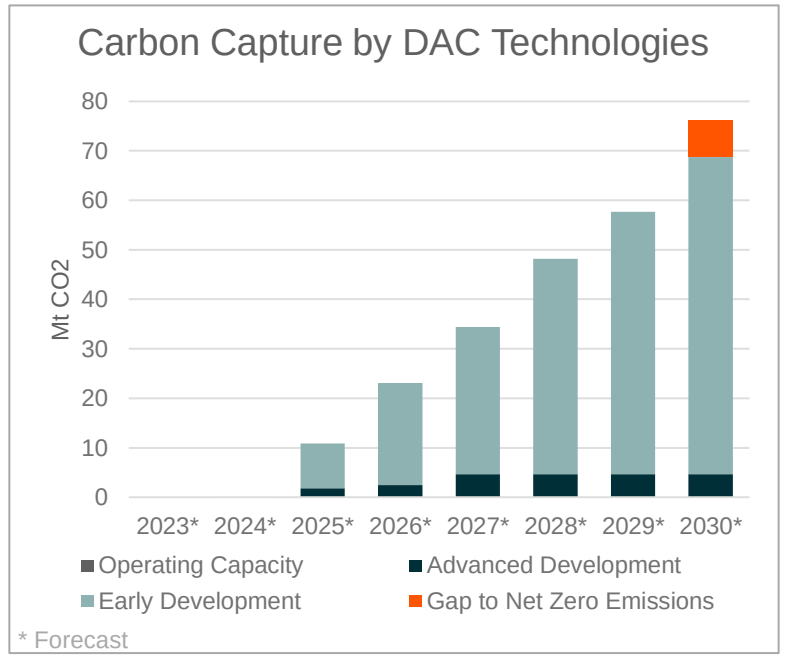
Oil and gas companies are investing in CCUS systems as well as related mergers and acquisitions, given their synergies. In July 2023, Exxon Mobil acquired carbon solutions provider Denbury Inc. for $4.9 billion.[1] Chevron has committed $10 billion for CCUS.[2]

Nearly 70% of today's operating carbon capture systems are used for natural gas processing.[3] By 2030, these systems are expected to be used in applications for power and heat, direct air capture, as well as hydrogen and ammonia production.

While CCUS systems are placed at specific sites like smokestacks, DAC systems pull carbon directly from the atmosphere. 130+ facilities are in development, which could remove 70 $MTCO_2$/year by 2030.[4] This carbon can then be stored or used as feedstock.





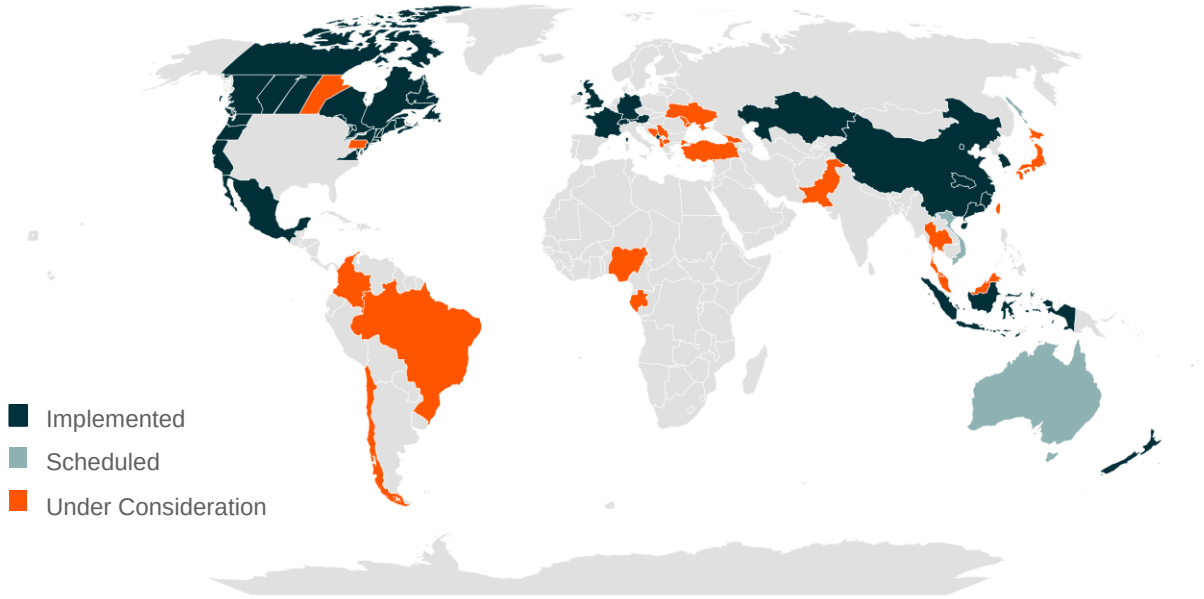


Sources: Text: 1. Exxon, 2022; 2. Chevron, 2022; 3. IEA, 2023; 4. Ibid.; Charts: Left: Exxon Mobil, 2022; Reuters,2023-Jul; Chevron, 2022; Reuters, 2023-Aug; Shell, 2022; Middle: IEA, 2023b; Right: IEA, 2023a

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

Carbon allowance ETS are another decarbonization tactic, and they could create additional growth opportunities for CCUS. New ETS are increasingly prevalent, and price activity for existing schemes is at record highs.

Status of Global Compliance Carbon Markets



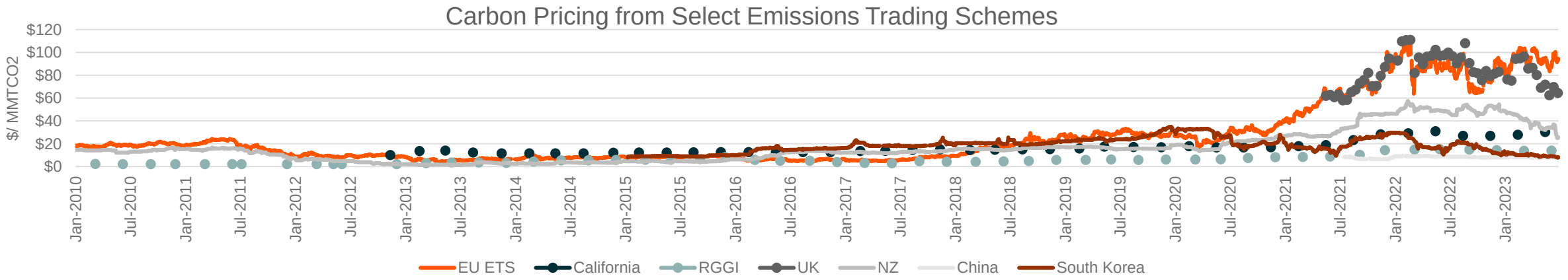
Notable ETS Developments Over the Past Year

- **European Union:** In April 2023, the EU ETS increased its ambition as part of the European Union's Fit for 55 in 2030 package. The program now targets reducing carbon emissions from ETS sectors by 62% by 2030 compared to 2005 levels. It also phases out free allowances to companies from 2026 until 2034 and creates a second ETS for additional sectors, including road transport and buildings.[1]
- **China:** China's relatively new ETS still only covers the power sector. By 2025, China's ETS is expected to expand to seven more carbon-intensive industries, such as building materials, domestic aviation, and petrochemicals.[2]
- **United Kingdom:** The UK ETS Authority published results of its consultations on reforms and proposed a new cap of 936 million allowances from 2021–2030, more than a 30% reduction from the prior 1.3 billion allowances. The supply cut is a bullish indicator for UK Allowances (UKA) prices.[3]
- **California:** The California Air Resources Board (CARB) approved the 2022 Scoping Plan, which targets a 48% reduction in the state's emissions compared to 1990 levels. The state's prior target was 40%.[4]

Sources: Text: 1. European Parliament, 2023; 2. S&P Global, 2023; 3. Reuters, 2023; 4. California Air Resources Board (CARB), 2022; Charts: Carbon Pricing Dashboard by the World Bank, 2022

Higher Prices for Carbon Allowances Can Help Reduce Polluting Activities

Increased political net zero ambitions, constricted supply, and the lack of cost-effective carbon abatement technologies continue to drive positive price movements for carbon allowances. Companies that reduce emissions stand to benefit.



Global ETS Timeline

1997 — The Kyoto Protocol establishes the first international carbon market system.[1]

2005 — The EU ETS launches as the world's first international emissions trading scheme.[2]

The U.S. Regional Greenhouse Gas Initiative (RGGI) is formed as a consortium of Northeast states.[3]

2008 — The New Zealand ETS launches.[4]

2013 — California's cap-and-trade program launches. It is now the largest scheme in North America.[5]

2015 — The Paris Agreement becomes a landmark international treaty on climate change.[6]

The South Korea ETS launches, the first ETS in East Asia.[7]

2021 — Post-Brexit, the UK ETS launches.[8]

2022 — China's ETS launches and becomes the world's largest carbon market.[9]

California, the EU, and the UK make legislative progress to reduce the supply of allowances and increase net zero ambitions.[10,11,12]

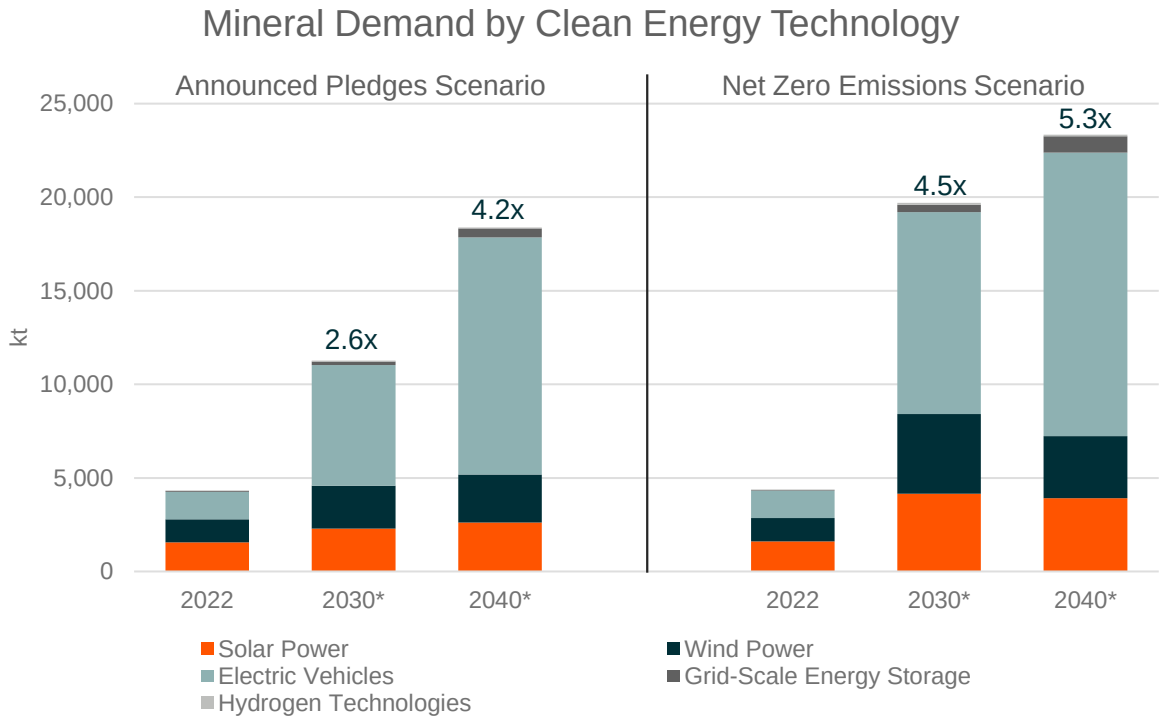
2023 — Japan announces the launch of its ETS as part of the GX Promotion Act.[13]

Sources: Text: 1. United Nations Framework Convention on Climate Change (UNFCC), n.d.b; 2. European Commission, n.d.; 3. Center for Climate and Energy Solutions (CCES), n.d.a; 4. Motu, 2016; 5. CCES, n.d.b; 6. UNFCC, n.d.a; 7. Asia Society Policy Institute, n.d.; 8. Reuters, 2023; 9. Forbes, 2022; 10. European Parliament, 2023; 11. CARB, 2022; 12. Reuters, 2023; 13. International Carbon Action Partnership (ICAP), 2023; Charts: ICAP, 2023

Significant Opportunities Are Forming for Materials at the Center of the Clean Energy Transition

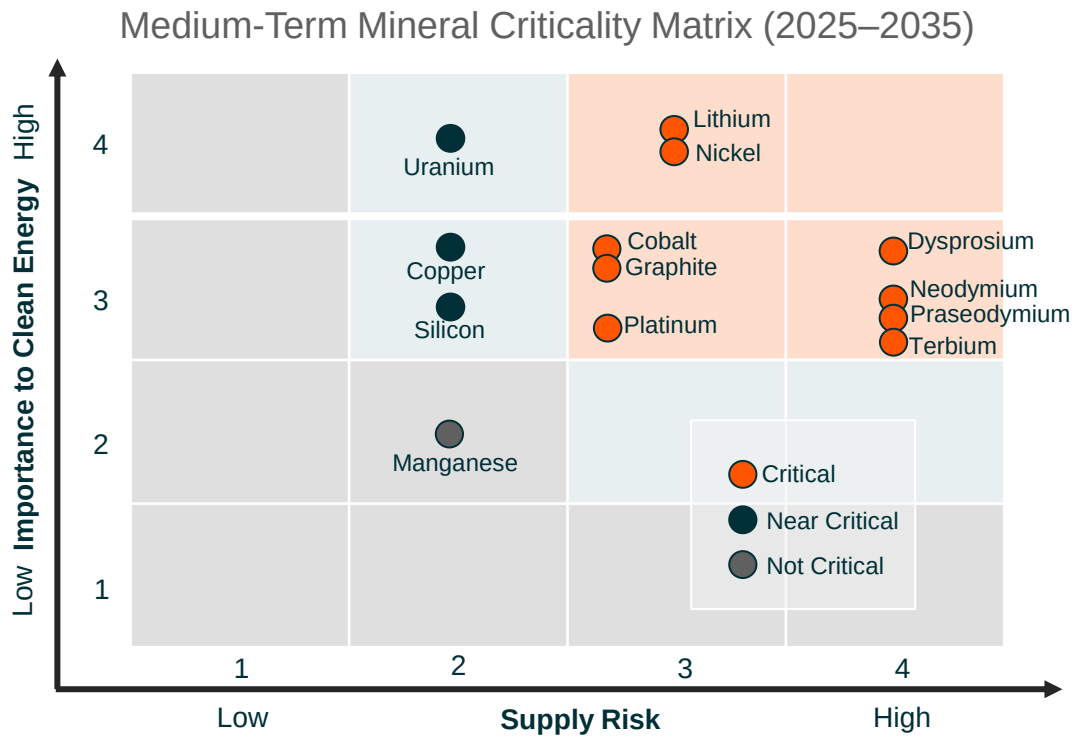
Companies involved in the mining and processing of minerals such as lithium, nickel, graphite, copper, manganese, and rare earth elements (REEs) are well positioned in the clean energy transition.

Mineral Demand Could Be 2x to 5x Higher by 2040[1]



* Forecast

Supply Shortage Risks Exist for In-Demand Minerals



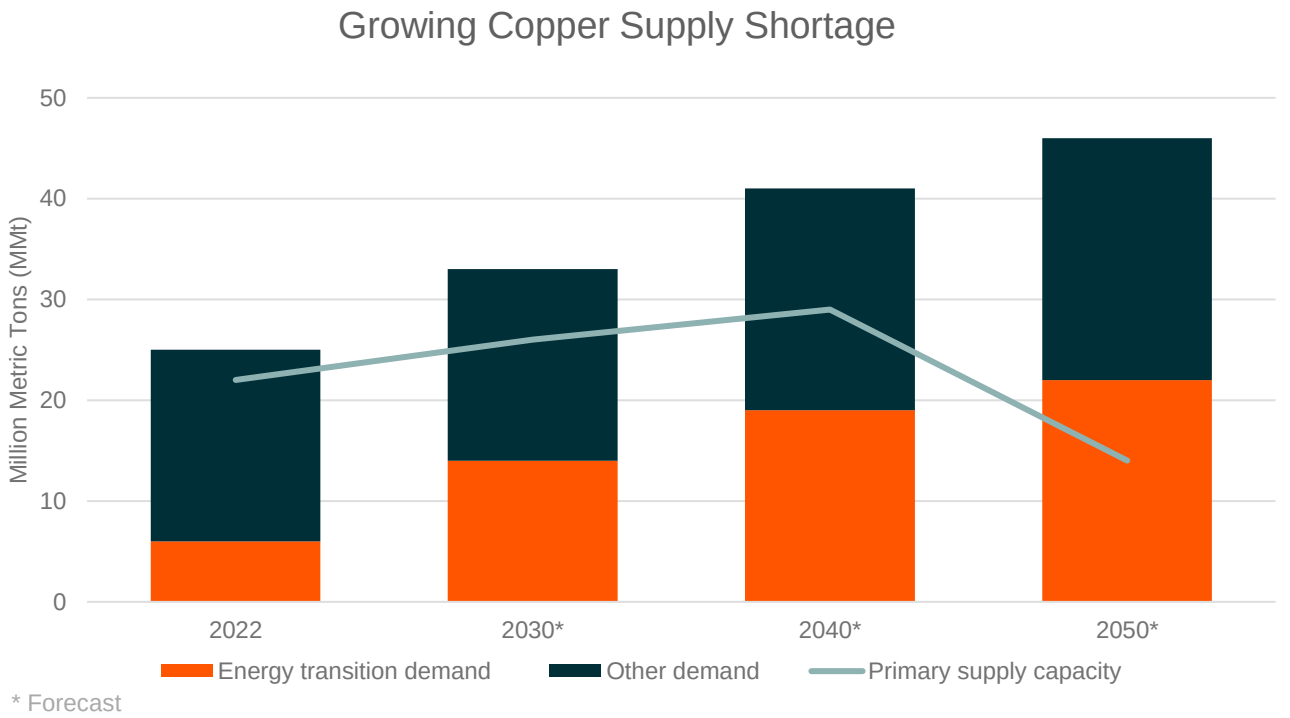
Sources: Text: 1. IEA, 2023. Charts: Left: IEA, 2023; Right: DOE, 2023

Copper Industry Critical to the Energy Transition, but Supply Risks Loom

Copper's conductive properties make it essential to such clean technologies as renewable energy systems and electric vehicles. This conductivity is forecast to result in significant demand for the eternal metal and strain supply.

Primary Copper Supply Could Fall Further Behind Demand Over the Coming Decades as the Energy Transition Gains Traction

- By 2050, copper consumption is forecast to increase to 46 million metric tonnes, up from 26 million in 2022. Power grids and transport will likely be the biggest consumers as part of the energy transition.[1]
- Wind power systems are among the applications that will require more copper. By mid-century, offshore wind farms are expected to use 2.9 tonnes of copper per kilowatt, up from 2.5 tonnes currently.[2]
- In 2022, the primary copper supply was 4 million tonnes short. If current reserves are not replaced by new geological discoveries and initiatives, this gap is forecast to rise eightfold to 32 million tonnes by 2050.[3]
- Because opening new mines is difficult, industry consolidation is a growing trend. Copper continues to be one of the main targets of M&A transactions.
- Increases in investment and exploration spending is attributable to strong cash flows and the momentum behind energy transitions.[4]



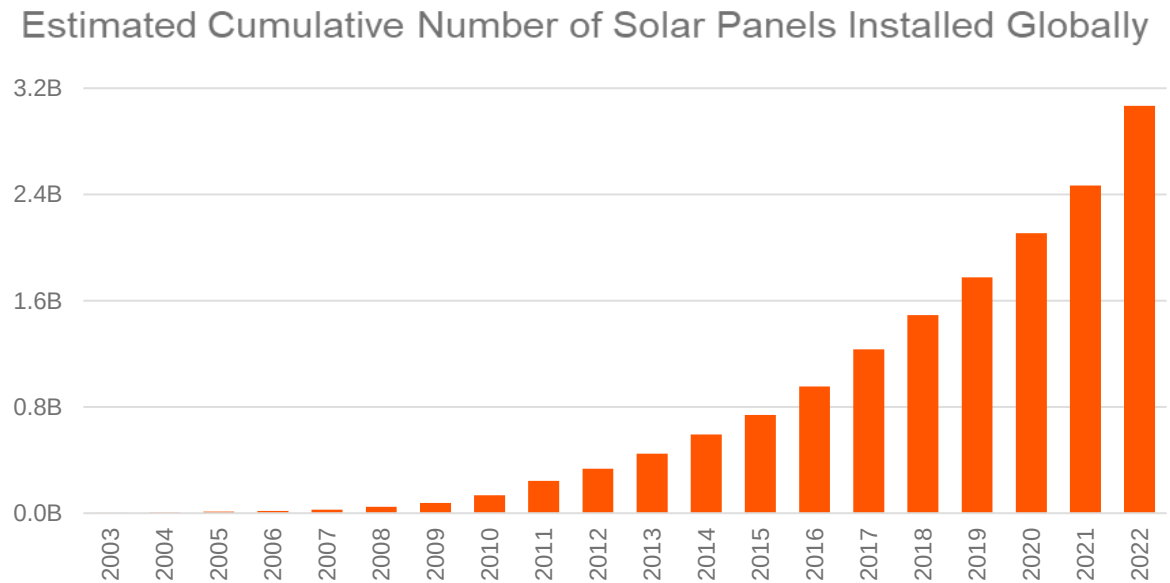
Sources: Text: 1. BloombergNEF, 2023; 2. Ibid.; 3. Ibid.; 4. IEA, 2023; Charts: BloombergNEF, 2023

Recycling Can Improve Renewables' Circularity and Reduce Supply Risks

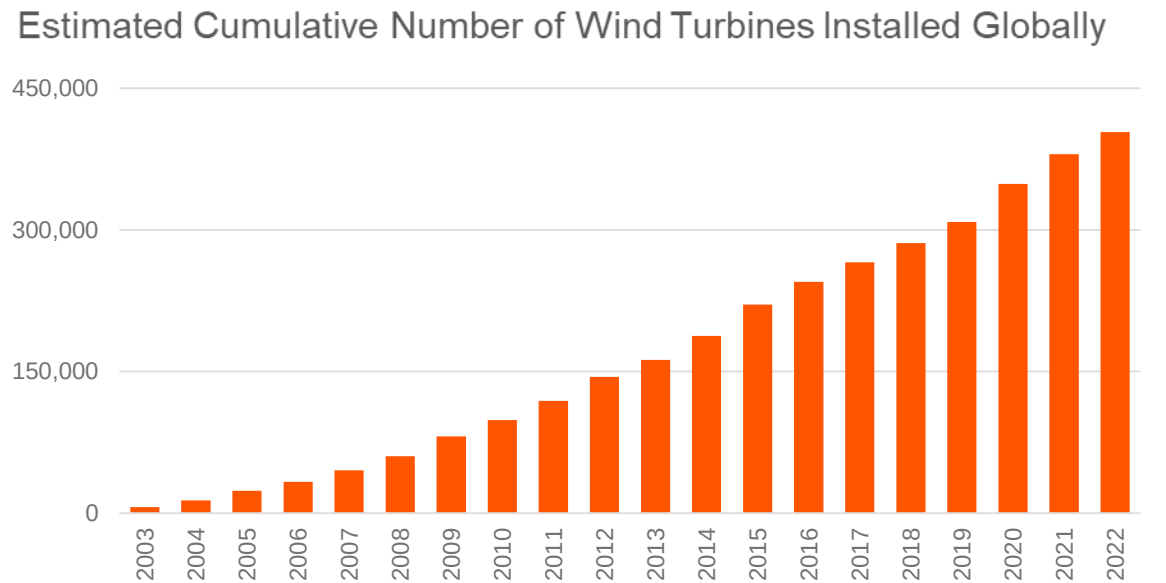
Aging solar and wind power systems may create tens of millions of tons of waste by the 2040s. Improved recycling measures can help minimize environmental impacts and boost supplies of key minerals, such as silicon and copper.

Solar panels generally last 25–30 years.[1] Few solar systems have reached their end-of-life (EOL), but more will in coming years. Total waste from EOL solar panels could exceed 61 million tons by 2045.[2] Panels contain key metals, such as copper and silicon.

Wind turbines typically last 20–25 years.[3] Waste from EOL wind turbine blades could total more than 14 million tons by the early 2040s.[4] However, in February 2023, leading wind turbine producer Vestas announced a chemical recycling technique that could be a potential breakthrough for the industry.[5]



Note: Numbers are estimates



Note: Numbers are estimates

Sources: Text: 1. Forbes Home, 2023; 2. Global X ETFs analysis of: EIA, n.d.; Energy Sage, 2023; Greentech Media, 2019; NSK Global, n.d.; Solar Energy World, 2023; DOE, 2023; 4. Global X ETFs analysis of: EIA, n.d.; Energy Sage, 2023; Greentech Media, 2019; NSK Global, n.d.; Solar Energy World, 2023; DOE, 2023; 5. Energy Monitor, 2023; Charts: Left: EIA, n.d.; Energy Sage, 2023; Greentech Media, 2019; NSK Global, n.d.; Solar Energy World, 2023; DOE, 2023; Right: EIA, n.d.; Energy Sage, 2023; Greentech Media, 2019; NSK Global, n.d.; Solar Energy World, 2023; DOE, 2023

Shifting Food Consumption Habits Can Yield Significant Climate Benefits

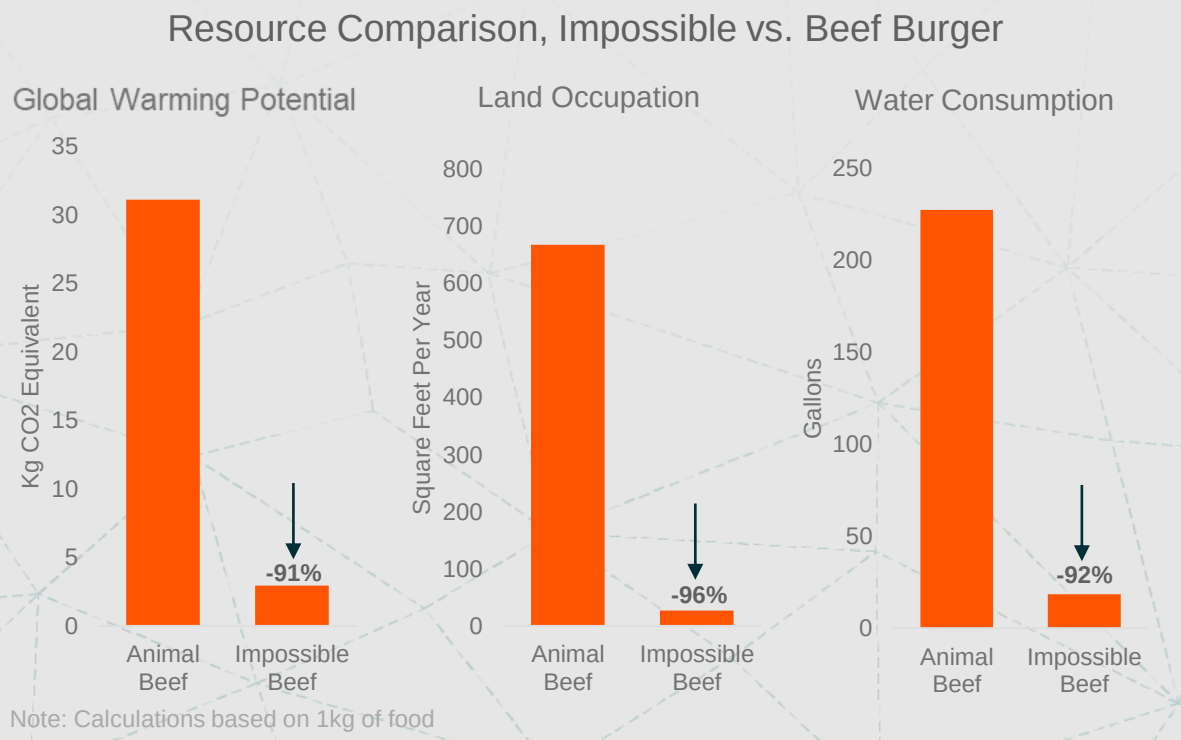
Peter McGuinness

Increased consumption of plant-based meat over beef, chicken, sausage, and pork from animals can substantially lower water usage, reduce land use, and reduce greenhouse gas emissions produced within the food chain.

Plant-Based Foods Can Provide Several Environmental Benefits

Compared to meat from animals, 10 lbs of…	Avoids the GHG emissions equivalent to approximately …	Saves the land footprint equivalent to a habitat the size of approximately …	Saves water use that is equivalent to approximately …
Impossible Beef	281.7 lbs of CO2	2,906 square feet	946.6 gallons
Impossible Sausage	52.2 lbs of CO2	119.6 square feet	520 gallons
Impossible Pork	56.1 lbs of CO2	190.4 sq ft	532 gallons
Impossible Chicken	12.4 lbs of CO2	120.5 square feet	143.7 gallons

Plant-Based Alternatives to Beef Are Produced More Efficiently



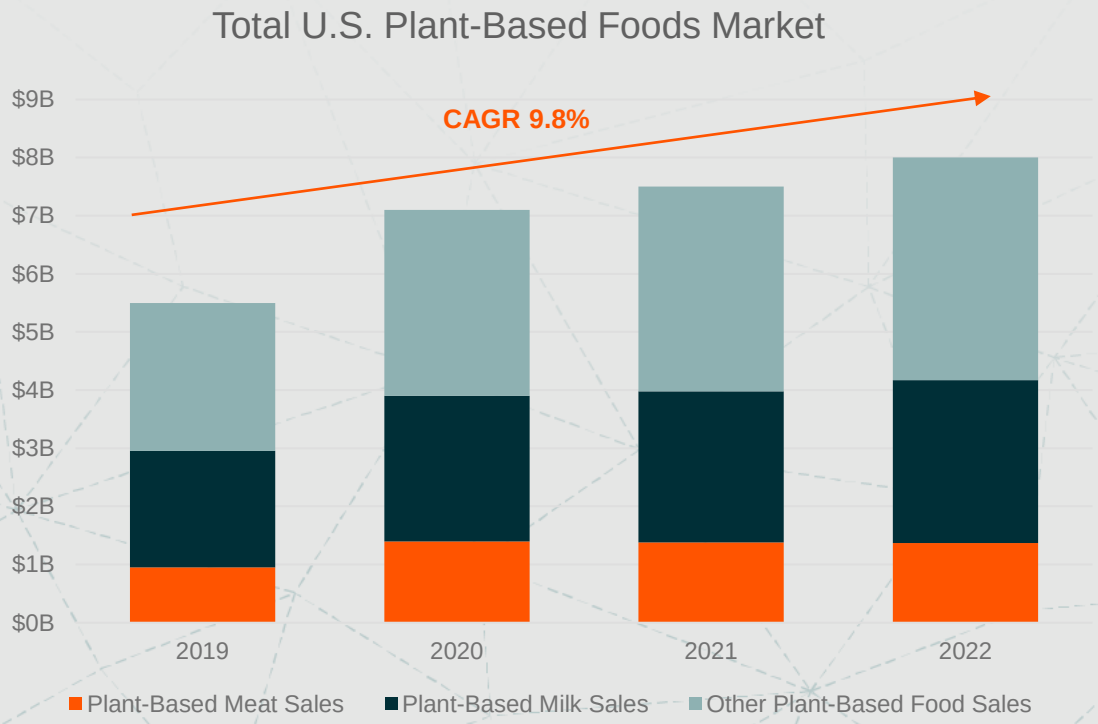
Source: Charts: Left: Impossible Foods & WSP, 2022 (ISO compliant); Impossible Foods, n.d.; Right: Impossible Foods & WSP, 2022 (ISO compliant).

Nascent Plant-Based Segment Can Capture Greater Market Share

Peter McGuinness

Plant-based foods are becoming more accessible and affordable as companies diversify and scale products. They have a growing opportunity to capture greater market share in segments like the $1 trillion+ global meat industry.

Plant-Based Milks and Meat Are Top Sales Categories in the U.S.



Plant-Based Meat Sales Remain Promising Amid Headwinds

17.5%

U.S. household penetration rate of plant-based meat products in 2022.

62.5%

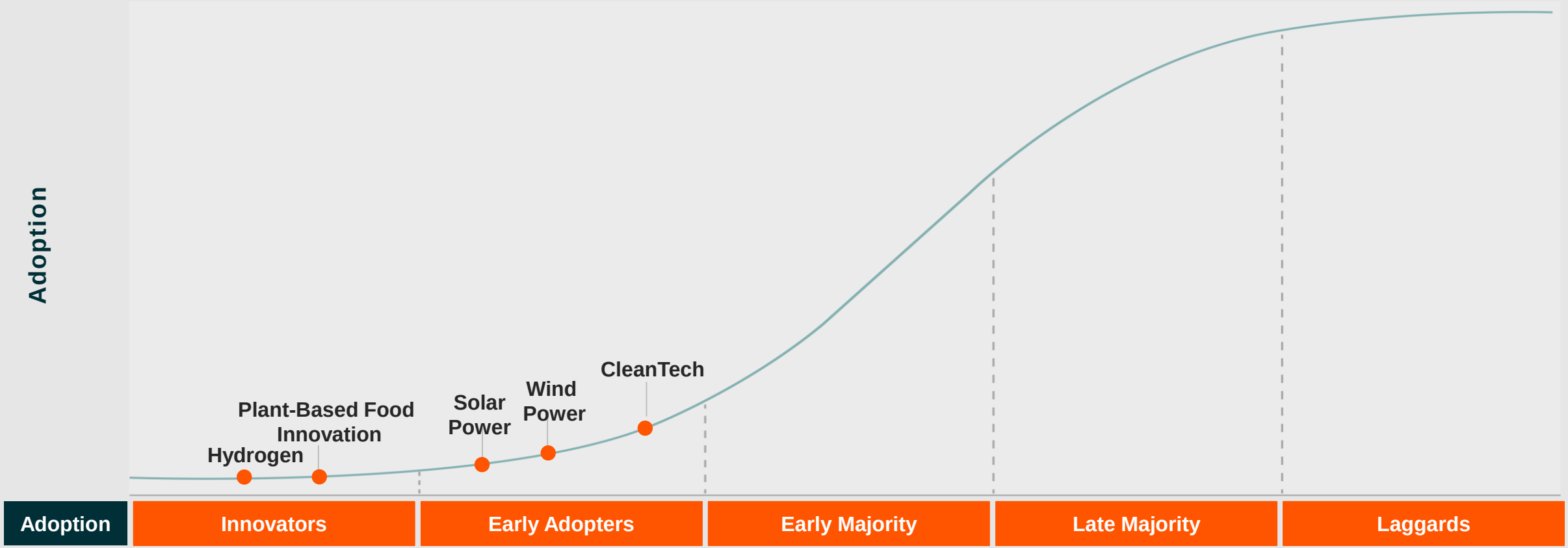
repeat purchasing rate of U.S. plant-based meat consumers in 2022.

- Plant-based meats have been around for less than a decade. While U.S. household awareness of plant-based meats is low at under 20%, the segment is in a hyper growth stage, and the repeat purchasing rate is highly positive. These dynamics give Impossible Foods and other companies in the industry significant room for growth.
- Continuous product innovation, education, and consumer adoption could lead plant-based meats to follow a similar market-share trajectory as plant-based milks. Today, plant-based milks account for 15% of total U.S. milk sales.
- Global sales of plant-based meats increased 8% YoY to $6.1 billion in 2022, despite inflation leading to higher food prices and more price-conscious consumer spending habits in key markets, such as the United States.

Source: Text and Charts: Plant Based Foods Association, 2023.

CleanTech & Beyond: S-Shaped Curve of Adoption

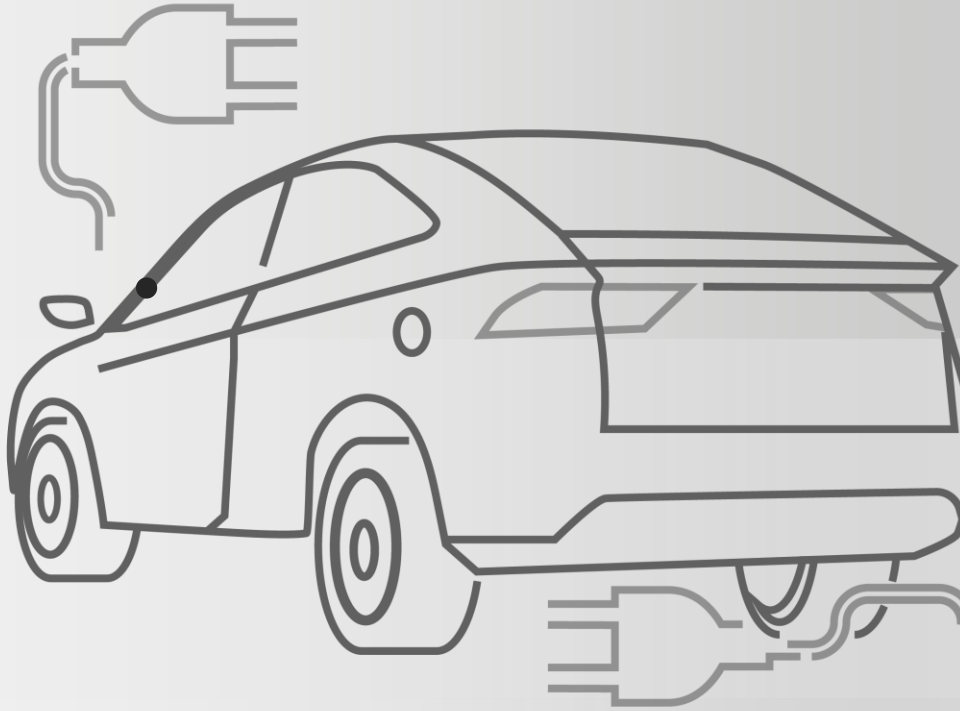
Technologies such as renewable energy are essential for mitigating climate change. Through 2050, an estimated $150 trillion in CleanTech investments is needed to limit warming to 1.5°C.[1]



Note: For illustrative purposes only.
Sources: Text: 1. IRENA, 2023

Earth’s Evolution

An Electric Future



Greener Transportation & Battery Tech Innovations

Electric vehicles (EVs) are the world’s most effective tool to chip away at emissions from the road. Fortunately, a paradigm shift in the automotive industry is already underway as legislators, automakers, and consumers align toward this shift to electrified mobility options. The continued adoption of EVs also presents important ramifications for supply chains, from materials sourcing to battery recycling.

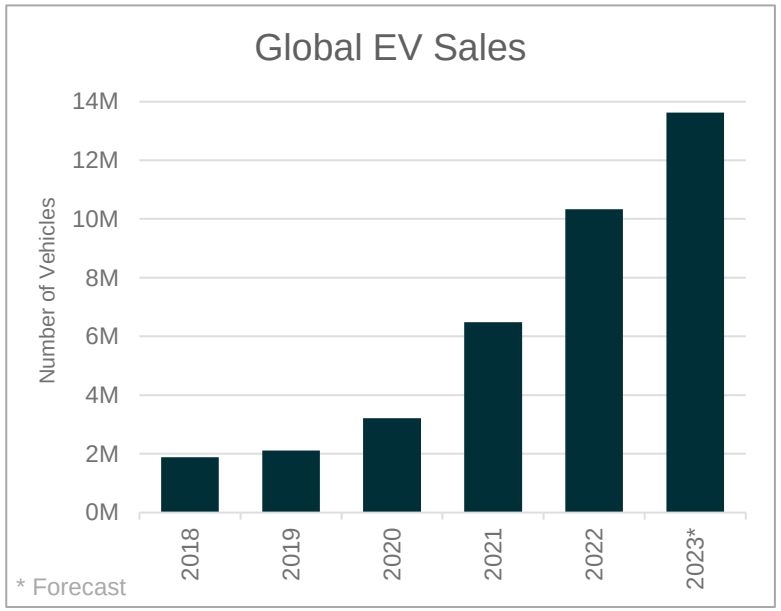
The Electric Vehicle (EV) Revolution Is Reaching an Inflection Point

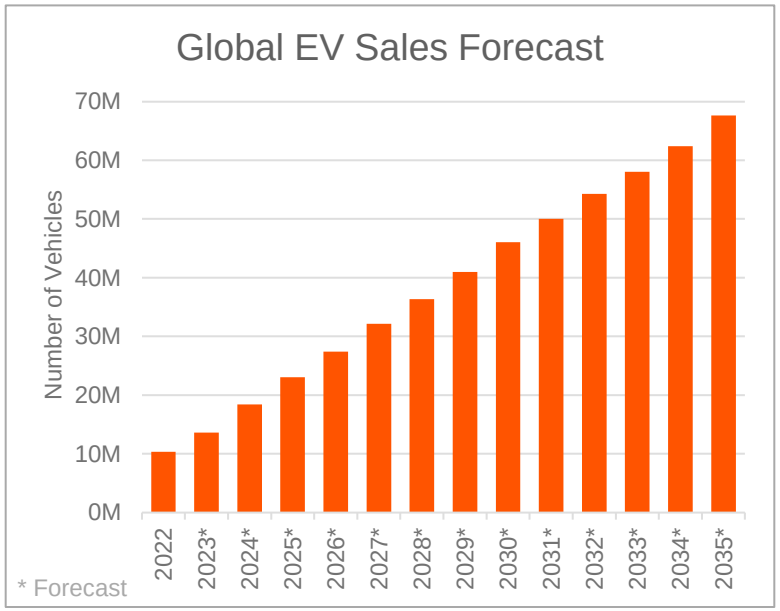
Factors such as accommodative government policy, technological improvement, traditional automaker commitments, and increasing buy-in from consumers are combining to support rapidly increasing rates of adoption for EVs.

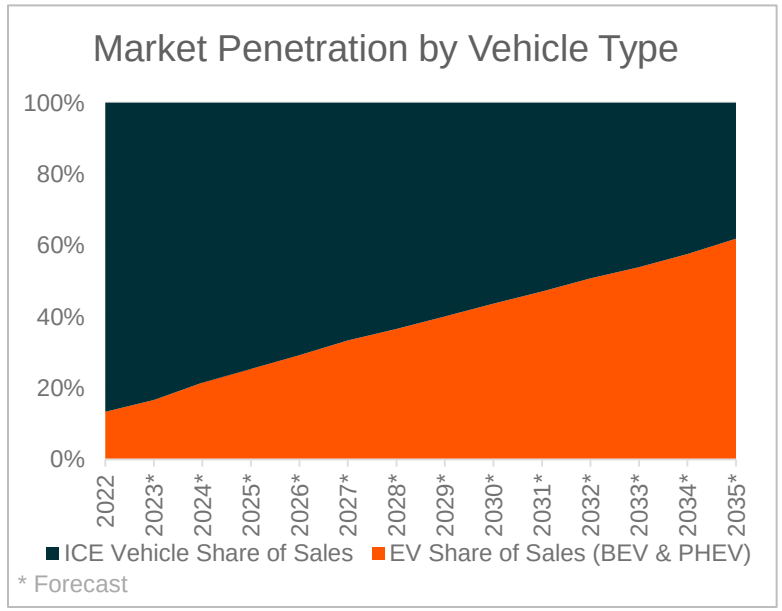
A true turning point for the EV industry came in 2021 when global sales doubled year over year. Global EV sales increased another 58% between 2021 and 2022.[1]

Starting from a base of about 10 million units in 2022, global EV sales could grow at a CAGR of 15.5% to approach 70 million units by 2035.[2]

Market share for EVs in light-duty vehicle segment could grow from 13% in 2022 to more than 60% in 2035.[3] EV sales could cross the 50% threshold as soon as 2032.[4]





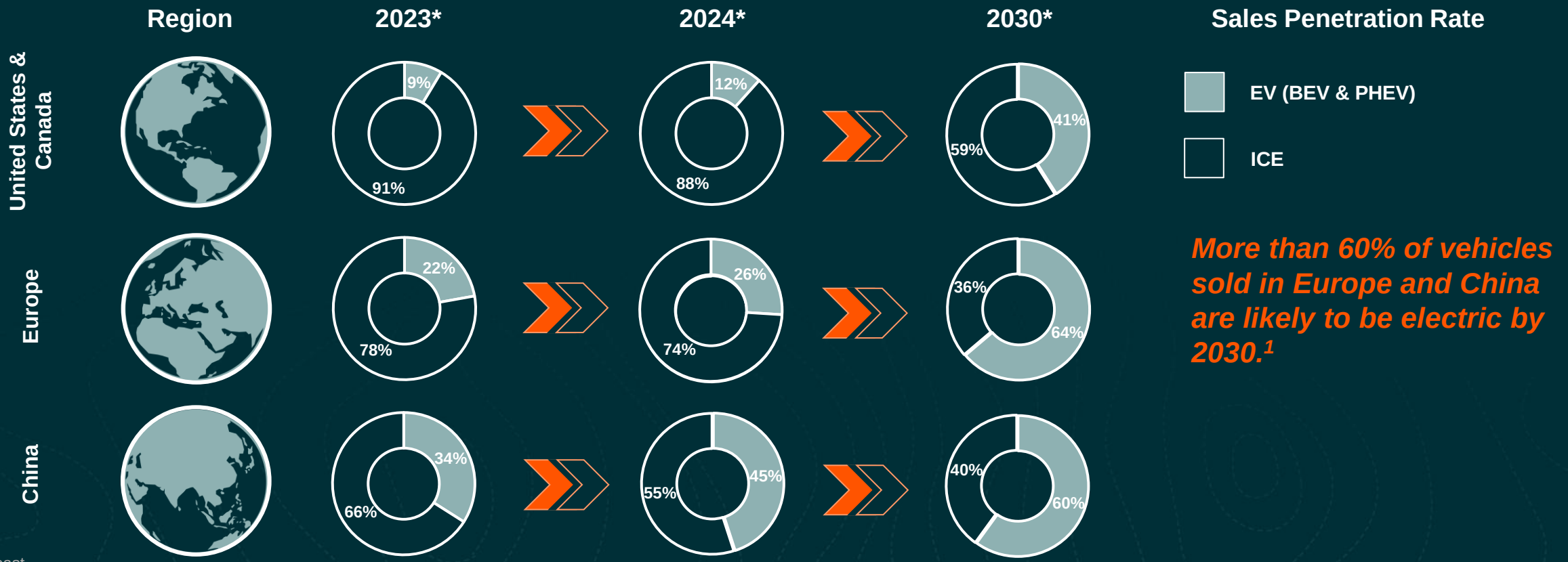


Note: Battery Electric Vehicle or pure electric (BEV), Plug-in Hybrid Electric Vehicle (PHEV)

Sources: Text: 1. Rho Motion, 2023; 2. Ibid.; 3. Ibid.; 4. Ibid.; Charts: Rho Motion, 2023

Fleet Electrification Is a Global Trend

Adoption of electric vehicles has sharply increased across all classes in recent years. Despite an uncertain macro backdrop and contraction in the broader automobile industry, EV penetration is expected to increase in 2023.



More than 60% of vehicles sold in Europe and China are likely to be electric by 2030.[1]

*Forecast.

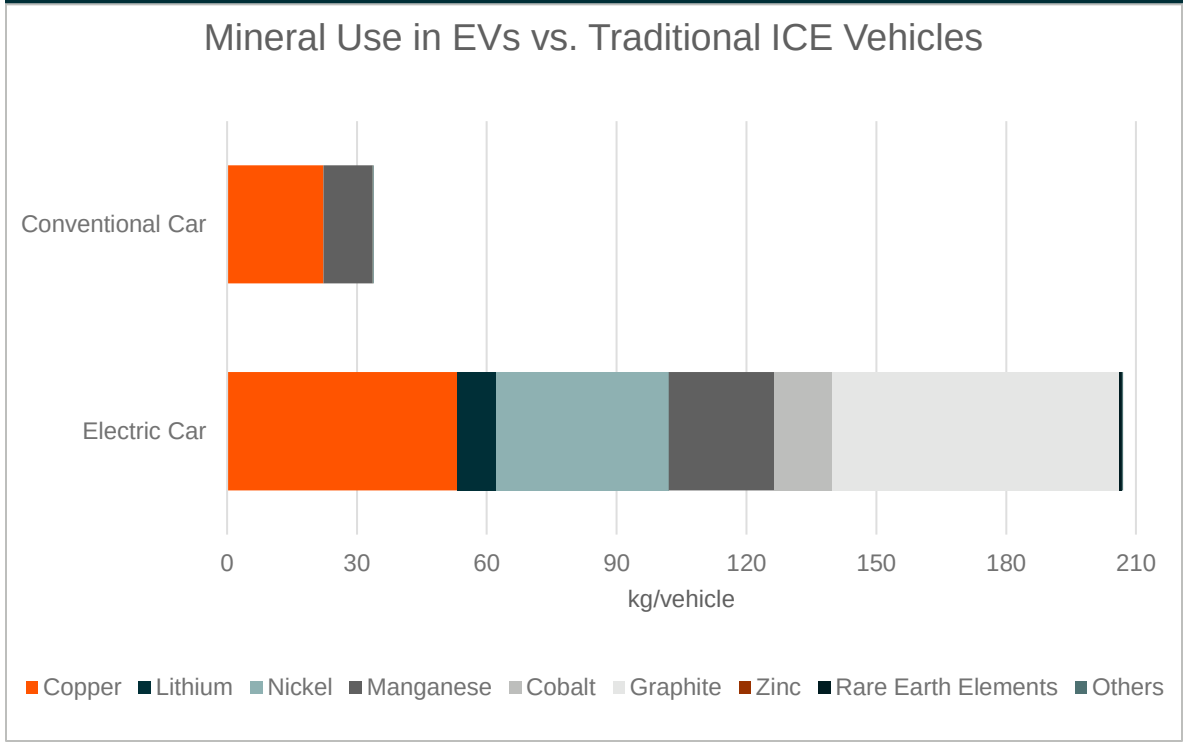
Notes: Internal Combustion Engine Vehicle (ICE). Data includes BEVs, PHEVs, and all classes of EVs.

Sources: Text: 1.Rho Motion, 2023; Charts: Rho Motion, 2023

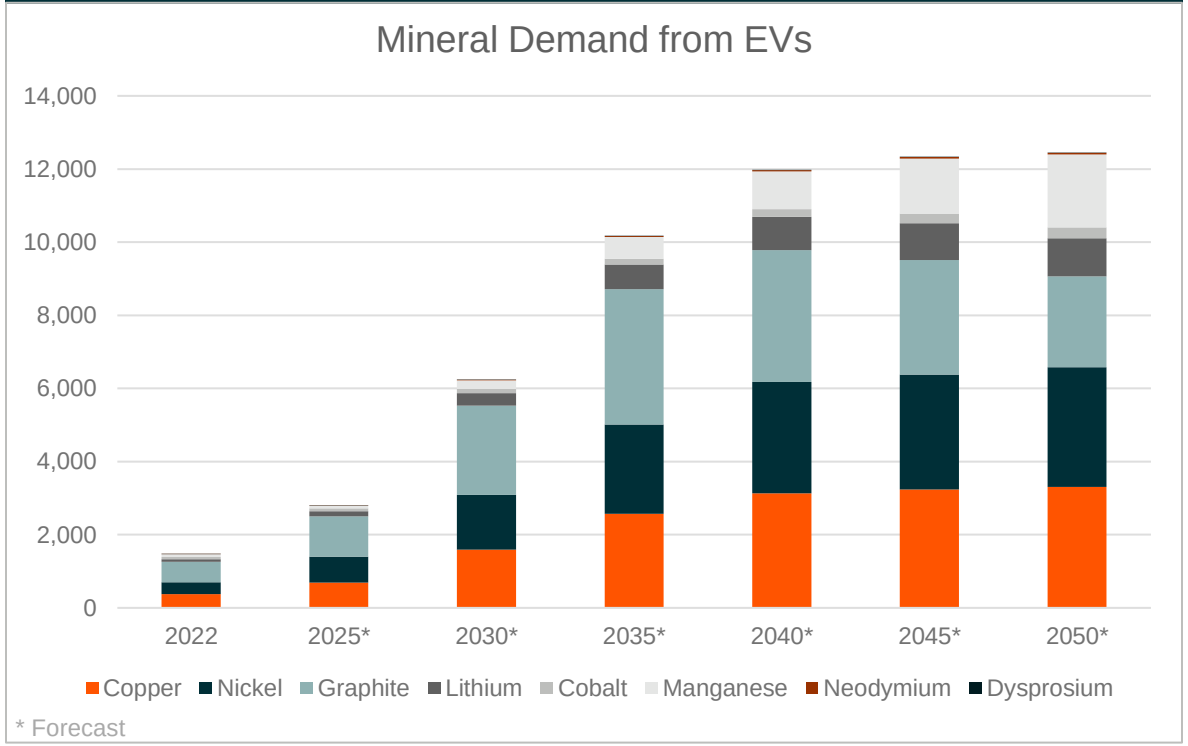
The Transition to EVs Could Magnify Demand for Disruptive Materials

An EV requires six times more disruptive materials than a traditional ICE vehicle.[1] As a result, EVs are expected to become a significant driver of demand for several minerals, including graphite and lithium.

EVs Require More Minerals Than Conventional Cars[2]



Mineral Demand from EVs Could Be 4x Higher by 2030[3]

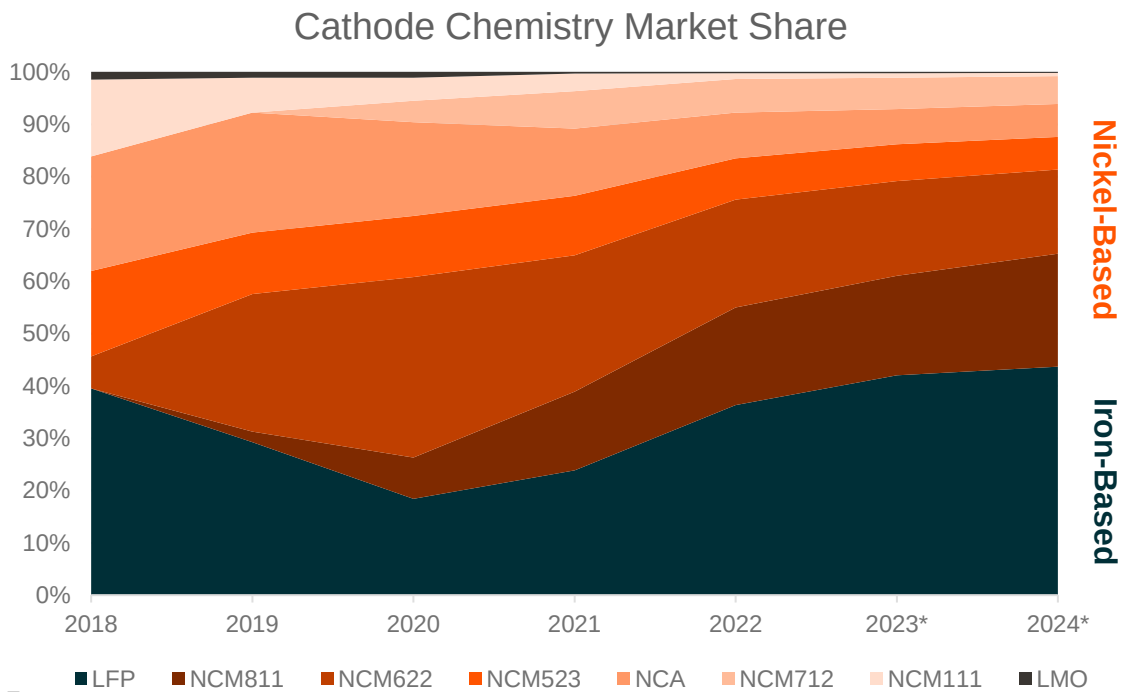


Sources: Text: 1. International Energy Agency (IEA), 2021; 2. Ibid; 3. IEA, 2023; Charts: Left: IEA, 2021; Right: IEA, 2023

Lithium-Ion Batteries Will Power the EV Revolution

Lithium-ion chemistries vary widely, and battery makers continue to experiment with different combinations. Lithium is a shared input across the two most common cathode architectures, lithium iron phosphate (LFP) and nickel-based.

LFPs and Nickel-Based Cathodes Dominate the EV Market



* Forecast

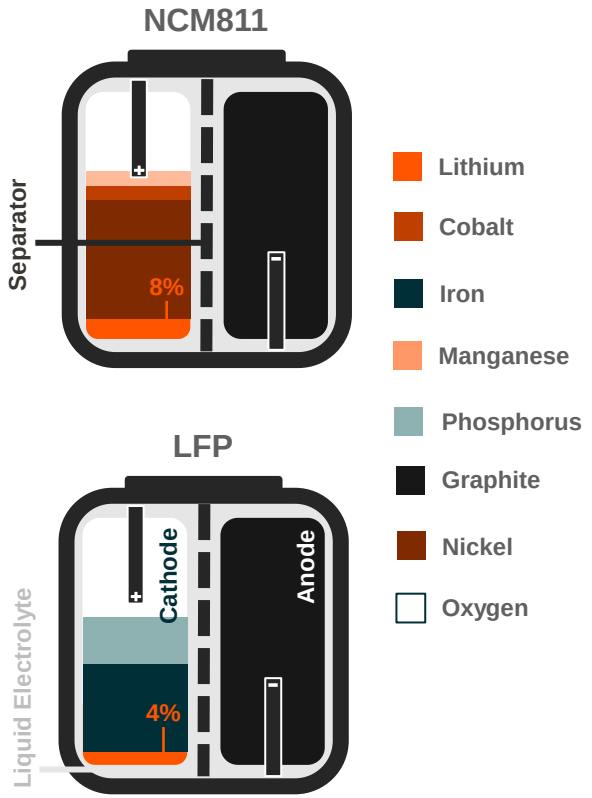
Note: Lithium nickel cobalt aluminum oxides (NCA), lithium-ion manganese oxide (LMO)

Nickel-Based (NCMs & NCAs)

Nickel-based batteries support higher range and acceleration at a premium. Various iterations of nickel, cobalt, manganese (NCM) batteries are on the market, with NCM811 being the most advanced.

Iron-Based Phosphates (LFPs)

LFPs are a class of legacy battery tech that has reclaimed market share in recent years due to lower costs and longer lifespans. Charging station buildout has made lower-range tech more viable.



Note: Not an exhaustive list of materials and elemental inputs. Lithium content expressed as a percent weight of cathode.

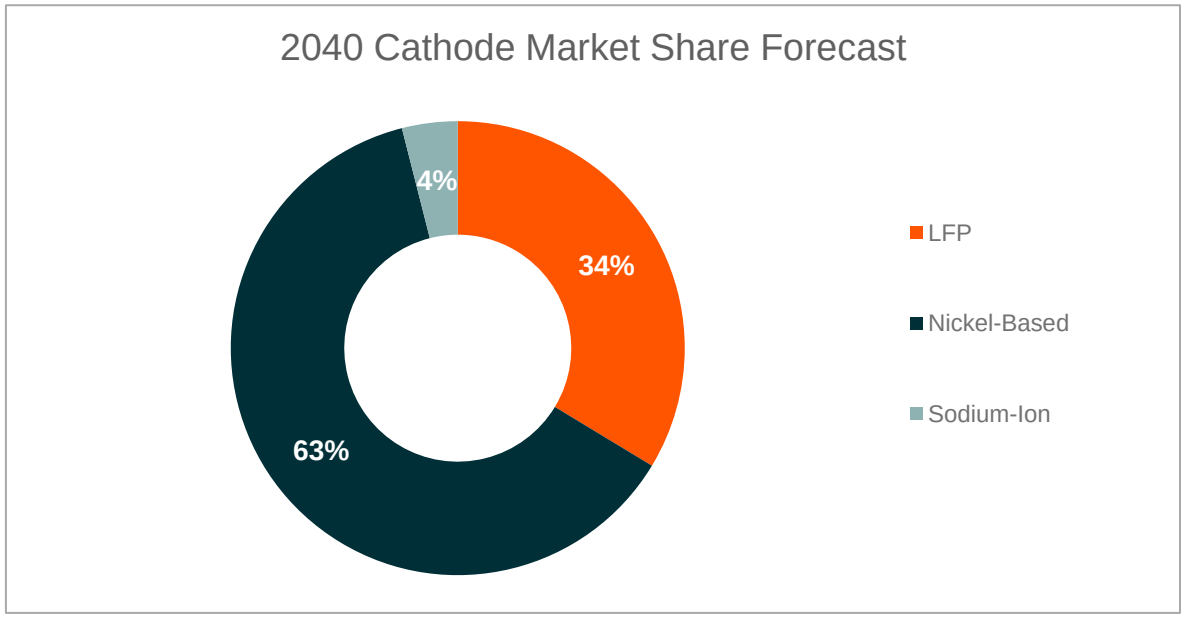
Sources: Charts: Left: Rho Motion, 2023; Right: Gaines, Richa, & Spangenberger, 2018

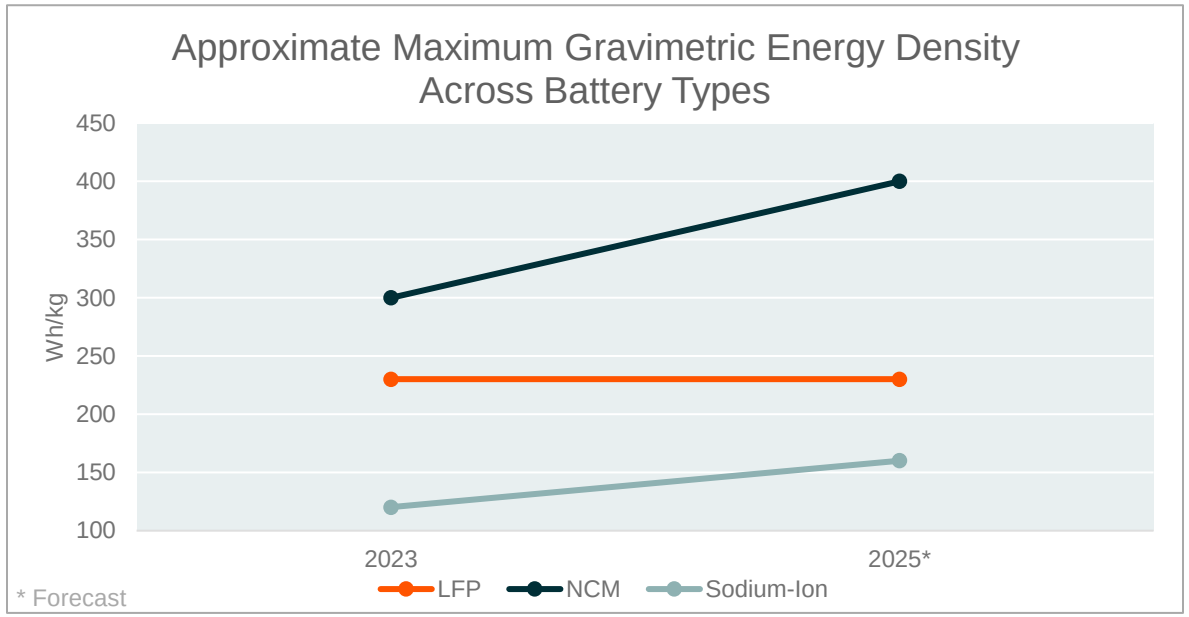
Sodium-Ion Could Have a Niche Role in Future Battery Mixes

Sodium-ion (Na-ion) batteries grabbed headlines in 2023 as a potential low-cost substitute to lithium-ion. The chemistry can help electrify various segments, but likely as a niche complement to lithium-based architectures.

Forecasts place Na-ion manufacturing capacity at around 150 gigawatt-hours by the end of 2030.[1] In contrast, global lithium-ion production is expected to pass 1 terawatt-hours in 2023, more than six times the entire Na-ion pipeline through the end of 2030.[2]

Na-ion could eventually result in substantial cost savings, but it sacrifices energy density. Energy density, which determines the range and power available to an EV, is likely to limit Na-ion adoption for energy storage, electric equipment, and lower-end EVs.





Sources: Text: 1. Benchmark Mineral Intelligence, 2023-May; 2. Benchmark Mineral Intelligence, 2023-Feb; Charts: Left: Rho Motion, 2023-Sep; Right: Electrive, 2022; InsideEVs. 2022; Rho Motion, 2023-Jun

Lithium Is Key to Current and Next-Generation Battery Tech

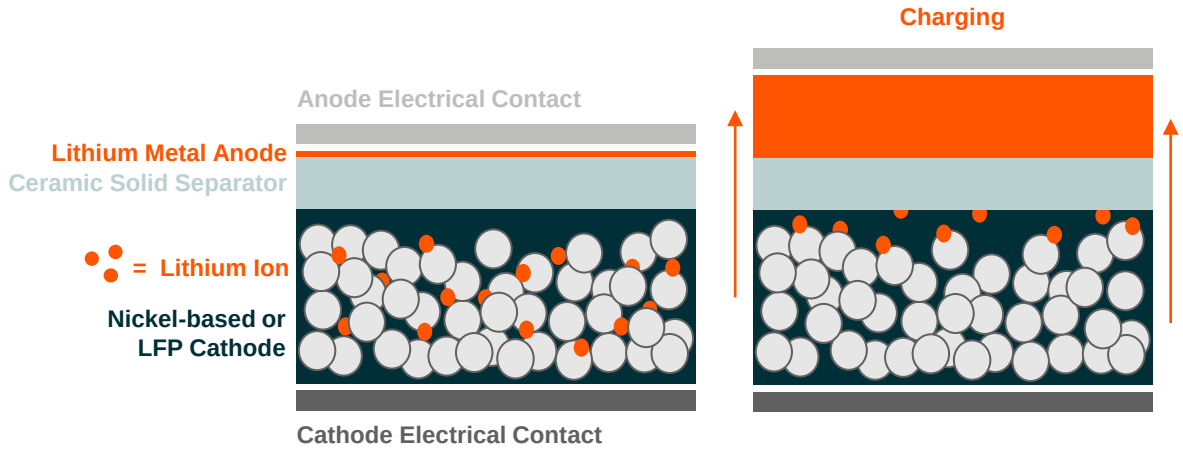
The race is on to develop solid-state battery technology, the often-heralded next generation of EV battery technology. Nearly every solid-state prototype leverages legacy cathode technology and expands usage of lithium to the anode.

Solid-state battery tech could bring more range and faster charging at a lower cost. Broad commercialization is likely years away, although several key developers are already working on semi-solid-state prototypes (see table).

QuantumScape is developing a battery that may support a 400-mile range and 15-minute charge.[1] The design is "anodeless," where lithium deposits during charging. Other solid-state designs have permanent anodes, often a blend of lithium metal and graphite.

Company	Cathode Type	Anode Inputs	Time Frame
QuantumScape	NCM, LFP	Lithium, Copper	Production prototypes by 2025
Samsung SDI	NCM, NCA	Lithium, Steel	Commercial production by 2027
Ganfeng	NCM, LFP, LCO	Lithium, Graphite	In production as of May 2023
SES	NCM	Lithium, Copper	Expected in vehicles by 2025
Solid Power	NCM	Lithium, Silicon, Copper	Expected in vehicles by 2028
ProLogium	NCM811	Lithium, Silicon, Graphite, Copper	Commercial production by 2026

QuantumScape Proposed Solid-State Battery Design

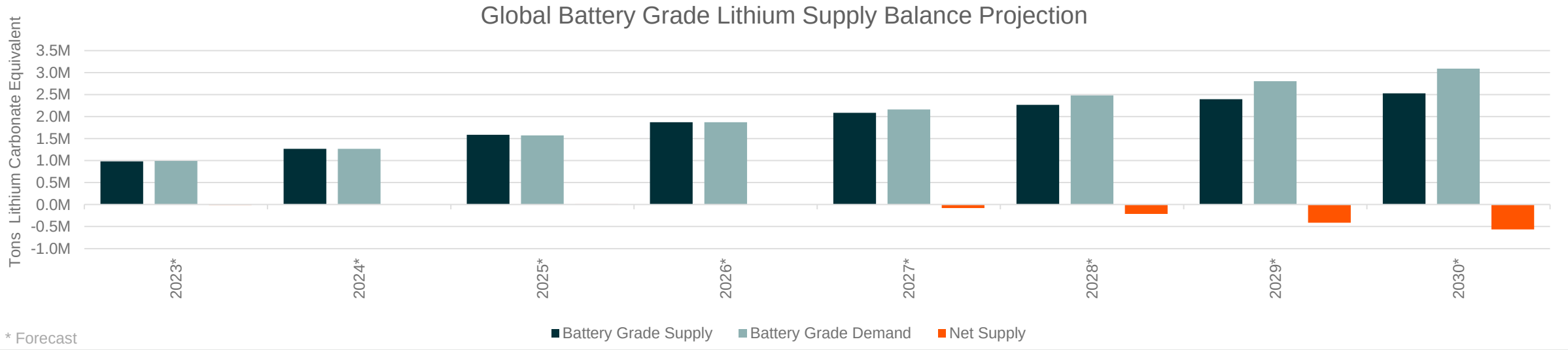


Sources: Text: 1. QuantumScape, n.d.; Charts: Left: CNBC, 2022; CnEVPost, 2023; Green Car Congress, 2023; Rho Motion, 2023; Tech Brew, 2021; TechCrunch, 2022; Yonhap News Agency, 2023; Right: QuantumScape, 2021

Elevated Lithium Pricing Could Be Here to Stay

The inelastic nature of lithium supply combined with growth in EV demand supports structurally high lithium prices. Even as more mining capacity comes online, we expect lithium pricing to remain elevated.

Tight Lithium Markets Are Likely to Persist Through the End of the Decade, Potentially Supporting Elevated Pricing



Approximate Production Ramp Timelines for Components of the Lithium Supply Chain

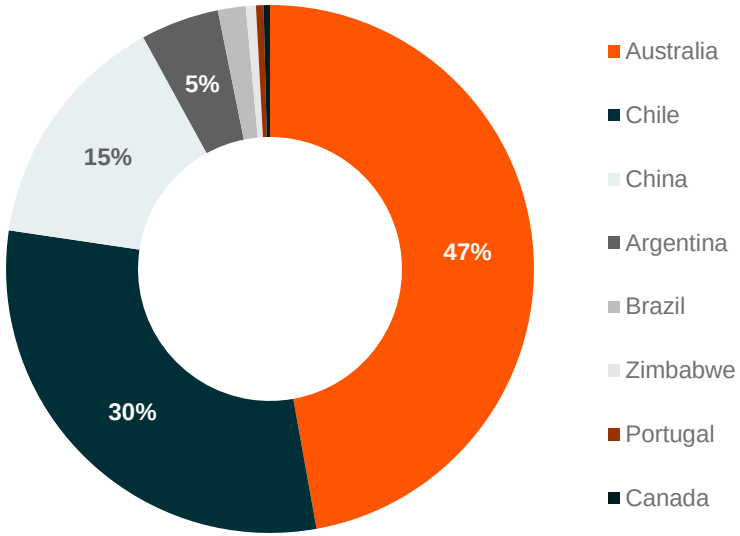
Sources: Charts: Top: AMG Critical Materials, 2023; Benchmark Mineral Intelligence, 2023; Bottom: Benchmark Mineral Intelligence, 2023.

Lithium Production Does Not Align with Resource Distribution

Lithium is an abundant resource found all over the world. However, lithium production is concentrated in only a handful of countries. This concentration is part of the challenge and opportunity in bringing lithium to market.

Australia and Chile Lead in Lithium Production While the "Lithium Triangle" Contains More Than Half of Known Resources

Lithium Production by Country

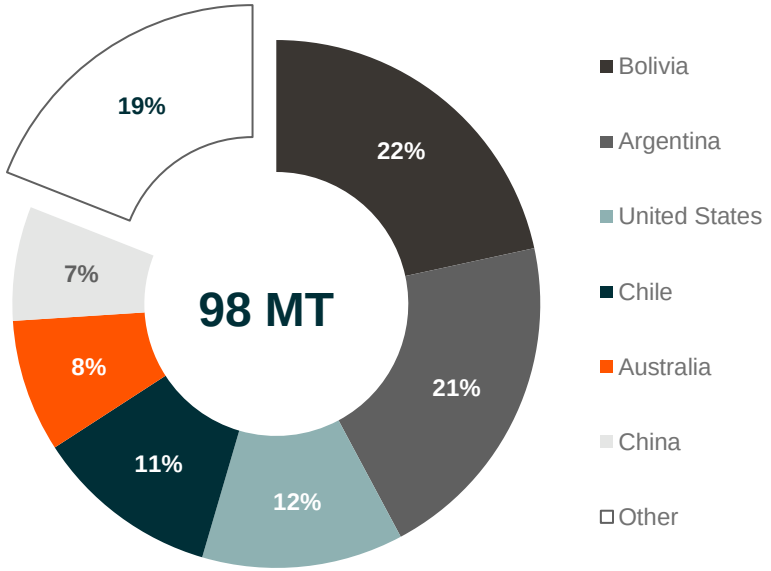


Hard rock and brine are the two main types of lithium deposits. Hard rock deposits can be found in Australia and Canada and are extracted in a process akin to traditional mining.

Brine deposits are metallic solutions that are most abundant in the "Lithium Triangle" of Argentina, Bolivia, and Chile. Brine deposits are pumped to the surface where evaporation gradually yields a lithium concentrate.

Lithium brine resource viability varies. Bolivia has the largest reserves, but also lower evaporation rates and more rainfall than Chile. Regulations also determine if a resource is developed.

Identified Lithium Resources

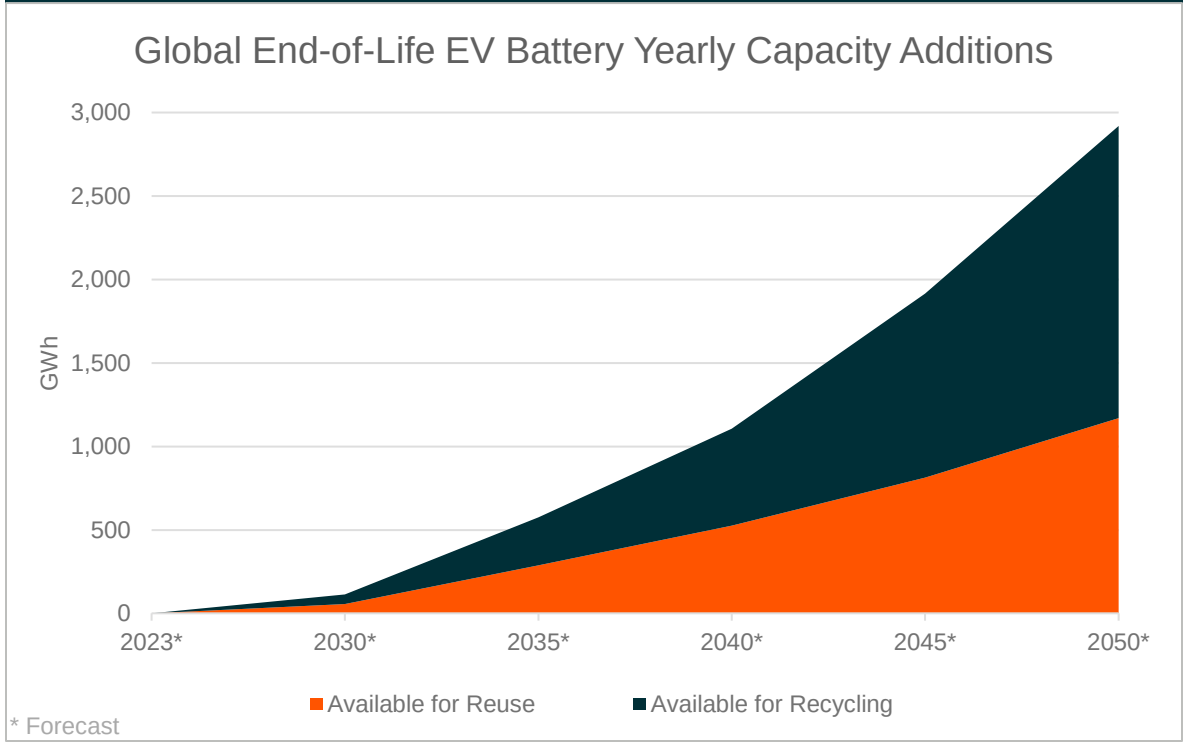


Source: U.S. Geological Survey, 2023.

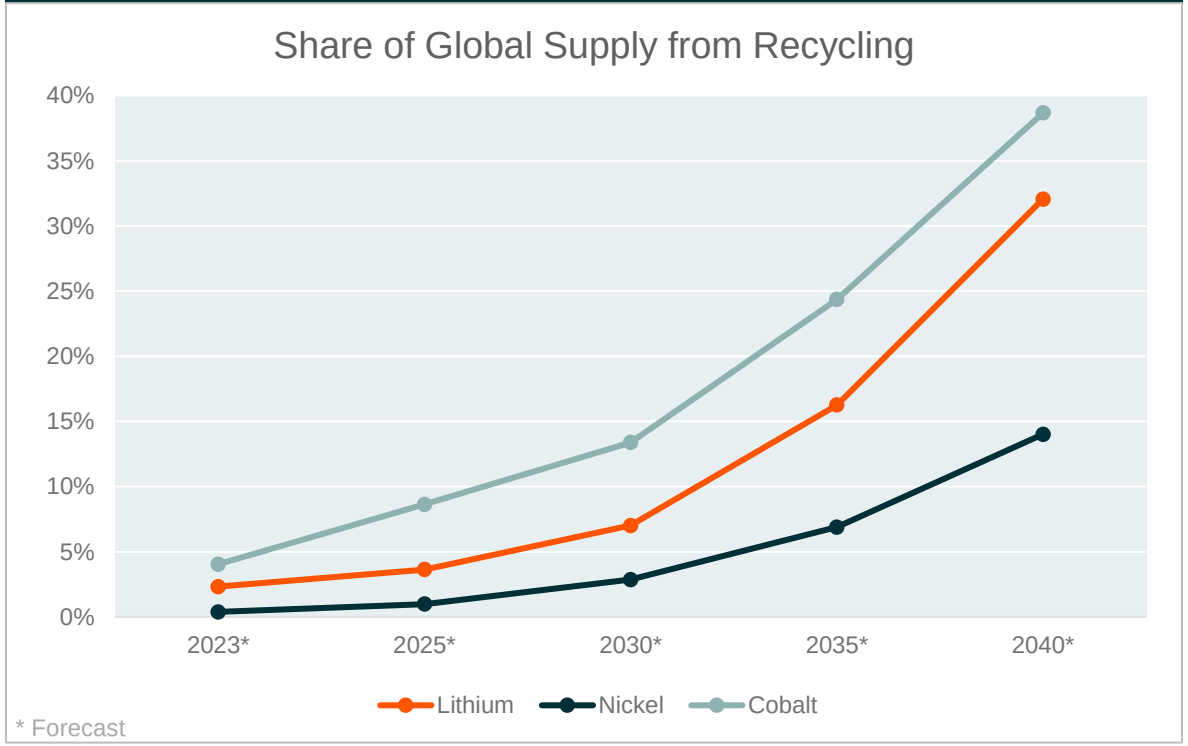
Circular Battery Economics Could Secure Supplies for Key Materials

Limited EV battery recycling capacity exists today, but this is set to change in the coming decades as vehicles start to age out of use. Recycling efforts are likely to help bridge the gap between raw material supply and battery demand.

Spent EV Battery Capacity Is Likely to Grow Substantially



Recycling Could Help Supply Key Battery Inputs



Sources: Charts: Left: International Council on Clean Transportation, 2023; Right: Benchmark Mineral Intelligence, 2022.

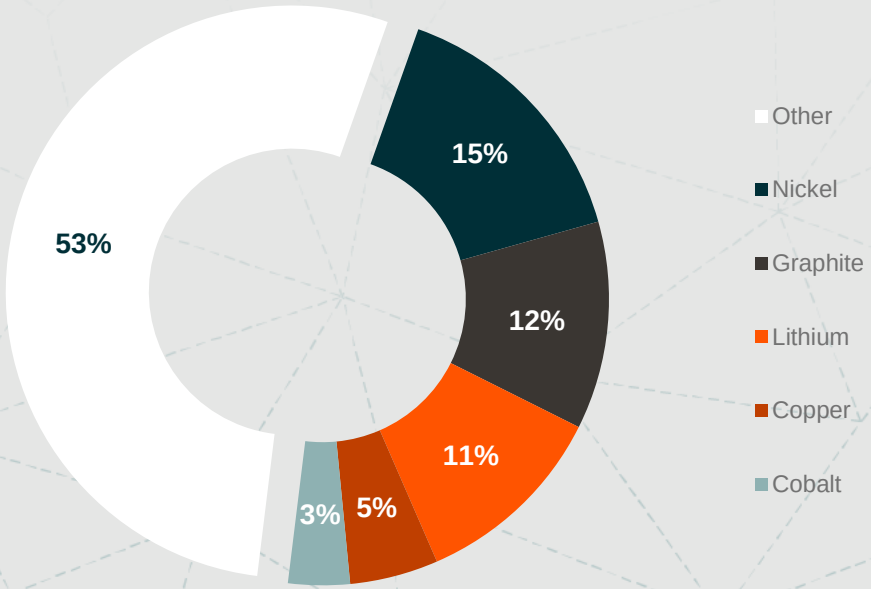
Batteries Contain Recoverable Value

Mike O'Kronley

EV batteries contain valuable metals such as lithium and nickel. Elevated lithium prices in recent years improved the value proposition for battery recycling and could contribute to industry growth alongside EV adoption.

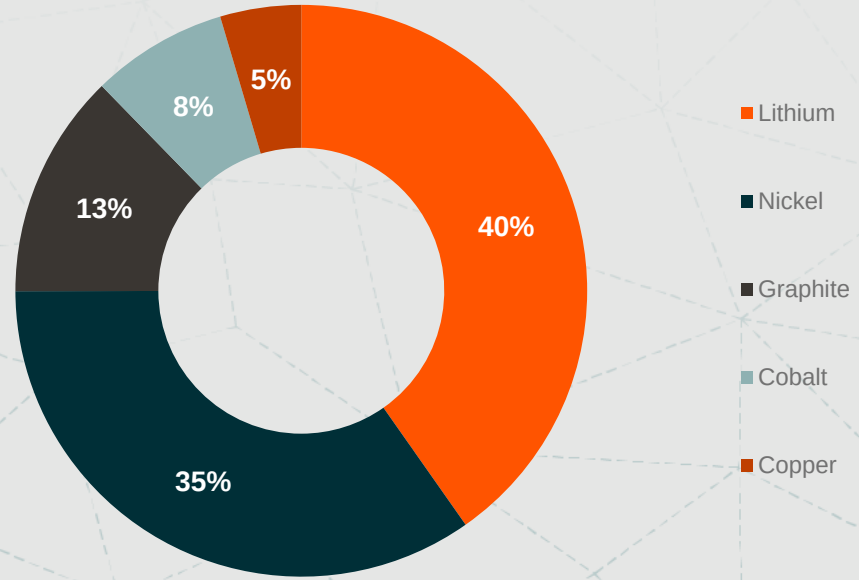
Nearly Half the Weight of a Battery Pack Is Valuable Material

Average 100 KWh Battery Pack Weight Breakdown



Lithium and Nickel Represent the Majority of Recoverable Value

Average 100 KWh Battery Pack Value Breakdown



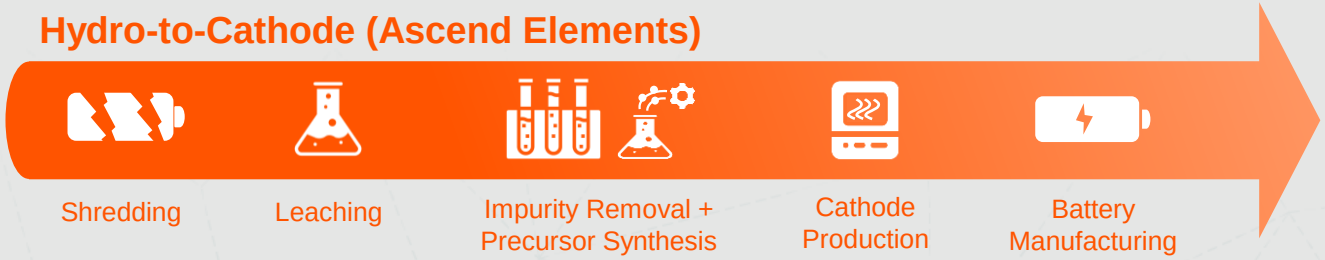
Sources: Charts: O'Kronley, 2023

Processes Exist to Recycle EV Batteries

Mike O'Kronley

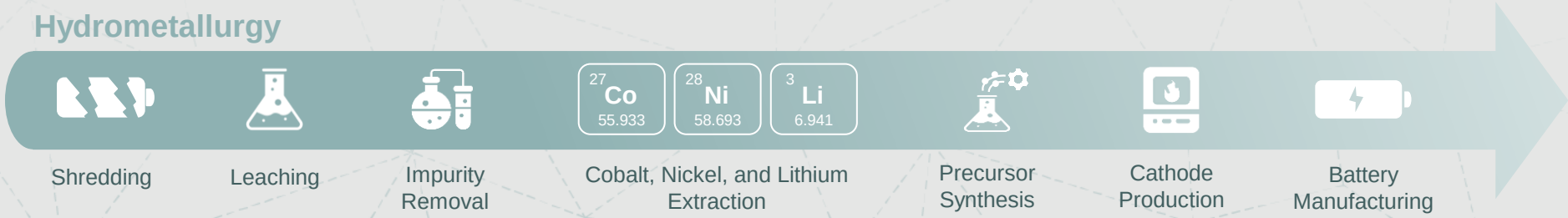
Better recycling economics and greater spent battery volumes are drawing automakers, battery producers, and startups to the space. Several techniques are already in use and we expect major innovation as capacity expands.

Hydro-to-Cathode (Ascend Elements)



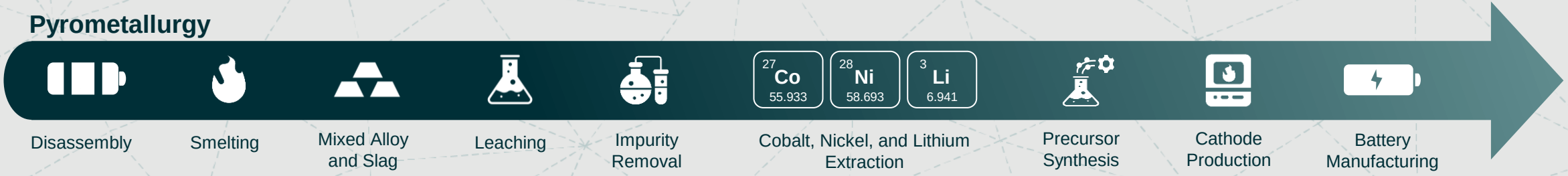
Ascend Elements' **Hydro-to-Cathode** technology improves upon traditional hydrometallurgy techniques and aims to produce a customizable cathode input. This technology contrasts with traditional recycling techniques that produce usable metal content by refining black mass.

Hydrometallurgy



Hydrometallurgy uses aqueous solutions and **pyrometallurgy** uses high temperatures to extract metals from batteries.

Pyrometallurgy



Direct Lithium Extraction Could Usher in a New Era of Lithium Mining

Direct lithium extraction (DLE) pulls lithium directly from metallic brines without the need for evaporation. If developed at scale, this technology could provide a host of environmental and operational benefits.

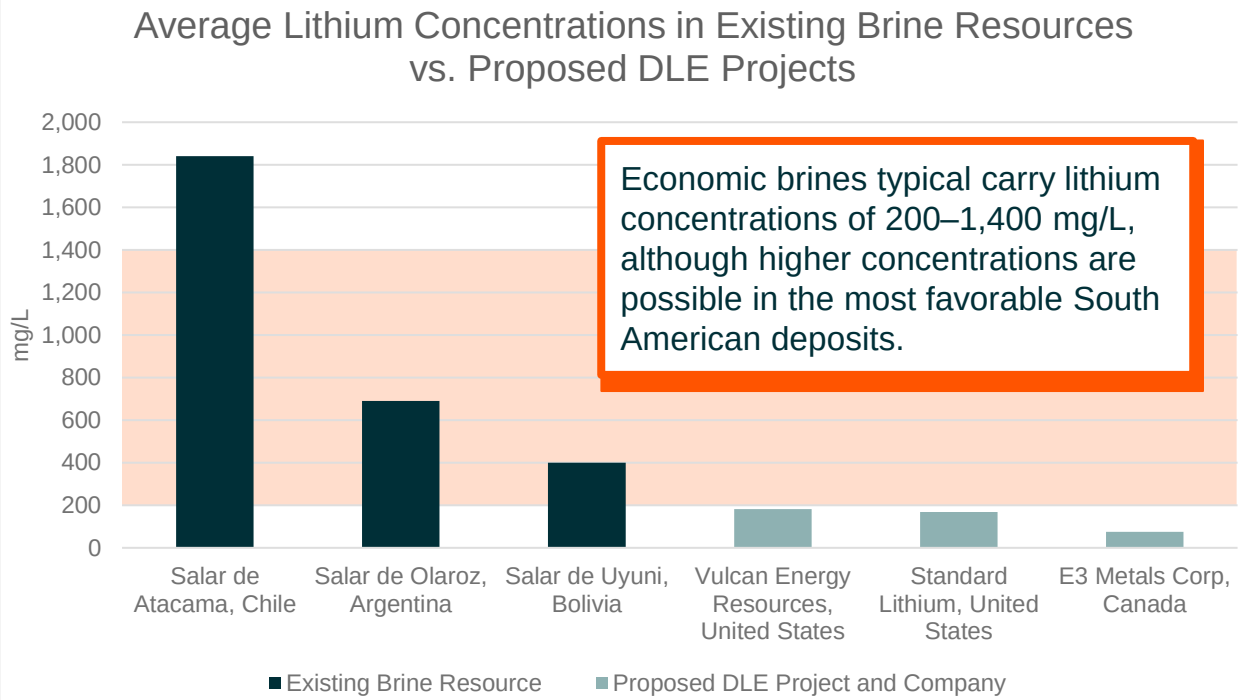
Potential DLE Benefits

Reduced Ecological Footprint: Full DLE systems could dramatically reduce land, energy, and water use. Current evaporation techniques use as much as 200 cubic meters of water to produce 1 tonne of lithium carbonate equivalent.[1] Some pilot projects produced lithium extract using about 1% the water required for brine fields.[2]

Improved Lithium Concentrations: A brine resource's viability is partially dictated by the lithium concentration, which naturally varies by region. DLE pilot projects achieved lithium yields of 70–90%, and as high as 99%, compared to a typical recovery rate of 50% for traditional evaporation projects.[3,4]

Accelerated Extraction Timelines: Currently, an evaporation pond normally takes 18–24 months to produce commercial products, depending on weather conditions.[5] Pilot tests of DLE condensed this process into a matter of days.

DLE Could Enable Projects with Lower Lithium Concentrations



Sources: Text: 1. CleanTech Lithium, n.d.; 2. Ibid; 3. Green Car Congress, 2023; 4. National Renewable Energy Laboratory, 2021; 5. Washington Post, 2023; Charts: Chemical Geology, 2020; National Renewable Energy Laboratory, 2021; PorterGeo Database, n.d.; U.S. Geological Survey, 2013

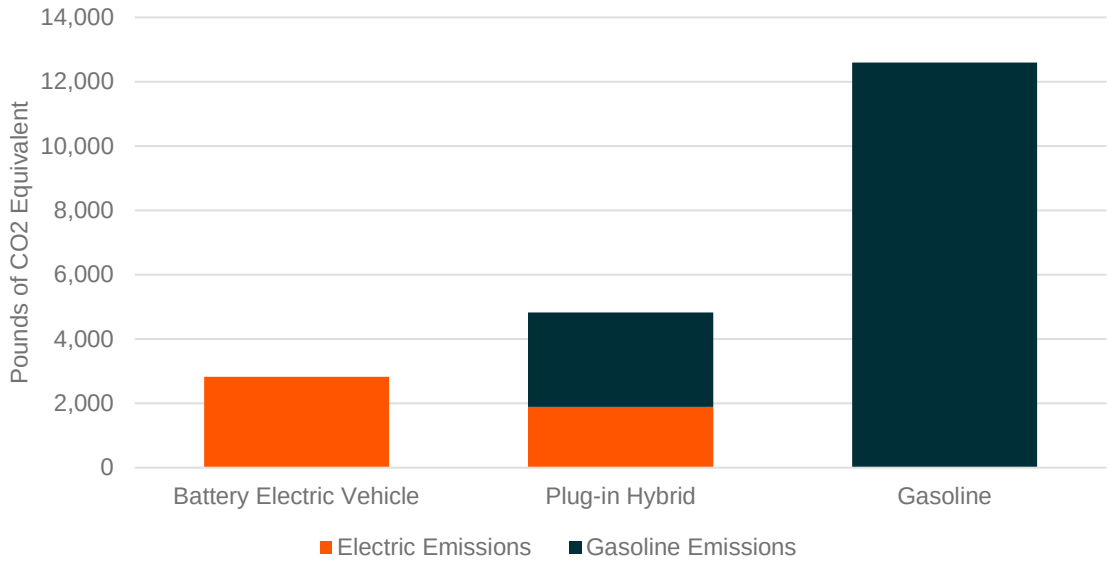
EVs Produce Fewer Lifetime Emissions Than Gasoline-Powered Vehicles

Even with higher mineral demand, EVs can produce fewer lifetime greenhouse gas emissions than comparable ICE vehicles.[1] Cleaner power grids as well as improved production and recycling methods could yield further emissions cuts.

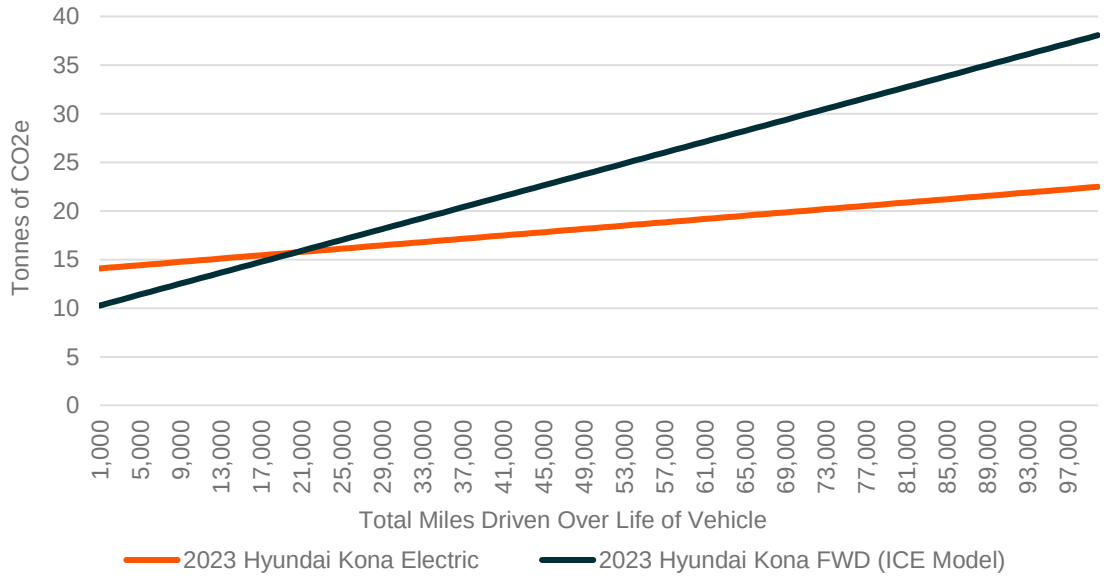
Manufacturing an EV often produces more carbon emissions than a similarly-sized ICE vehicle due to energy-intensive raw materials and manufacturing processes.[2] However, EVs produce significantly lower average annual emissions, even on fossil fuel-dominant energy grids like the United States.[3]

Considering emissions produced during manufacturing and while in use, the Hyundai Kona Electric is estimated to break even with the most efficient Kona ICE model at around 20,500 miles, even on the United States' power grid. At 100,000 miles, the EV produces an estimated 41% fewer lifetime emissions.

Average U.S. Annual Emissions per Vehicle



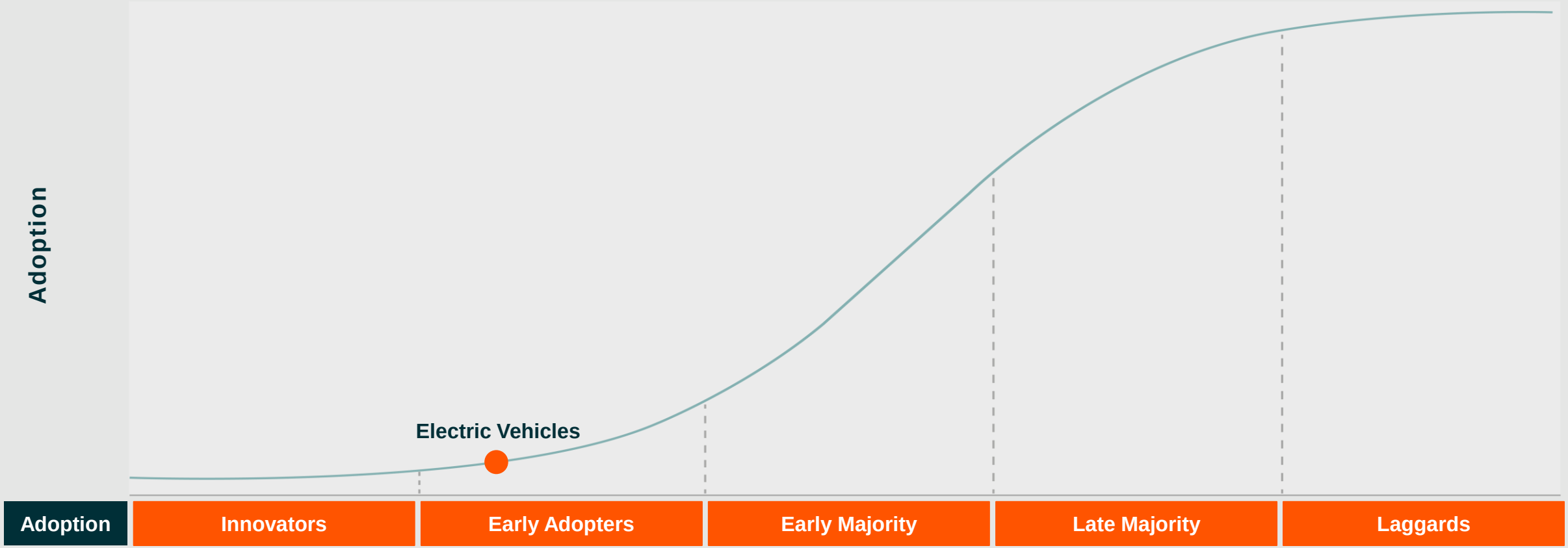
Estimated Total Emissions for 2023 Hyundai Kona, ICE vs. EV Models



Sources: Text: 1. Office of Energy Efficiency & Renewable Energy, n.d.; 2. Visual Capitalist, 2023; Charts: Left: Office of Energy Efficiency & Renewable Energy, n.d.; Right: Dominion Energy, n.d.; Visual Capitalist, 2023.

An Electric Future: S-Shaped Curve of Adoption

EVs are the primary pathway for decarbonizing the mobility segment. EVs are forecast to account for 43% of global vehicle sales by 2030, up from 16% in 2023.[1]



Note: For illustrative purposes only.
Source: Text: 1. Rho Motion, September 2023.

Earth’s Evolution

Infrastructure, Reimagined

A New Era for the U.S. Economy

American infrastructure is top of mind, as recent legislation works to rebuild deteriorating assets and positions the United States for a return to industrial growth. These bills combine to produce a generational investment in U.S. infrastructure and could add momentum to trends such as the manufacturing boom and long-standing need to overhaul the grid.

Mobilization of the Infrastructure Investment and Jobs Act (IIJA) Continues Across the Country

Rollout of the IIJA remains in its early stages, yet nearly $400 billion in funding has been announced at the state level that will be directed toward over 40,000 IIJA-related projects.[1]

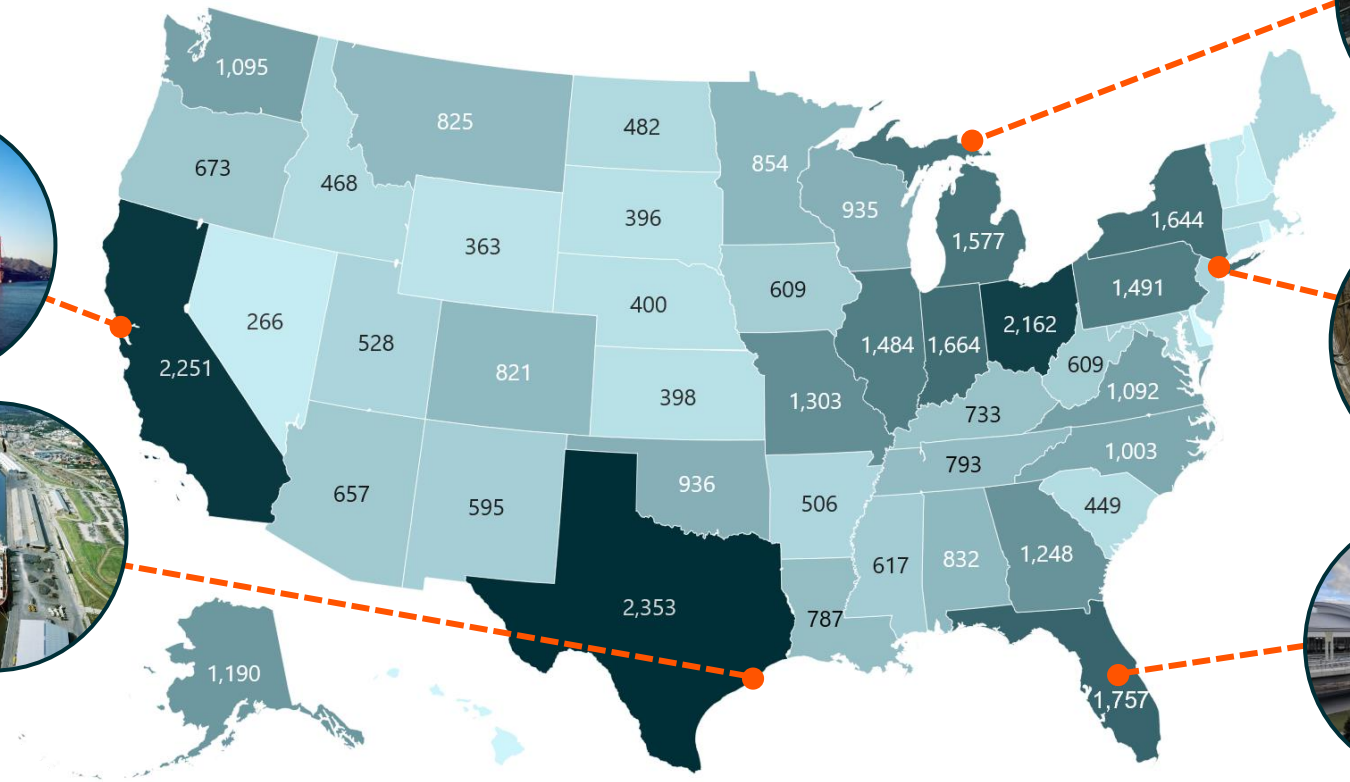
Golden Gate Bridge

$400 million awarded from competitive Bridge Investment Program to renovate and retrofit the bridge and boost resilience against earthquakes.[2]

Port of Houston

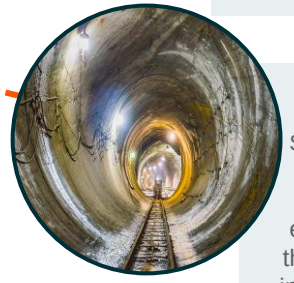
$143 million provided by the Army Corps of Engineers from the IIJA to help expand a segment of the Houston Ship Channel.[3]

Number of Announced IIJA Projects by State*



Soo Locks

$650 million through various IIJA programs will help repair and expand this critical connection between Lake Superior and the lower Great Lakes.[4]



Hudson River Tunnel

$6.9 billion in federal funding, the most ever secured for a mass-transit project, is for an effort to expand and renovate the Northeast Corridor rail line in New Jersey and New York.[5]

Orlando International Airport

$69 million will go towards two terminal expansion projects, including construction of new gates and expansion of a connector bridge.[6]

Sources: Text: 1. The White House, 2023-9; 2. The White House, 2023-September; 3. Business & Industry Connection, 2022; 4. Center for American Progress, 2023; 5. ENRMidAtlantic, 2023; 6. The White House, 2023-May; Charts: The White House, 2023

Inflation Reduction Act (IRA) and CHIPS Act Are Already Driving Investment in Disruptive Tech

By incentivizing the buildout of domestic supply chains for disruptive technologies, the IRA and CHIPS Act are driving private investment and boosting outlooks for construction companies that could make these projects a reality.

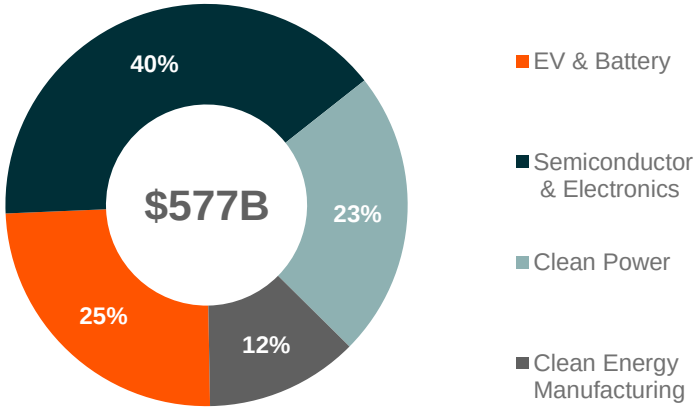
The IRA and CHIPS Act are designed to boost U.S. competitiveness in disruptive technologies like renewable energy, EV batteries, and semiconductors. Since passage of the bills in August 2022, private commitment in these areas total $577 billion.[1]

The U.S. gigafactory project pipeline exceeded Europe's for the first time in May 2023.[2] To put this in context, in August 2022, Europe's pipeline capacity was roughly 50% larger than the United States'.[3] This major shift is largely attributable to the IRA.

Private Investments Made Since August 2022 in the United States*

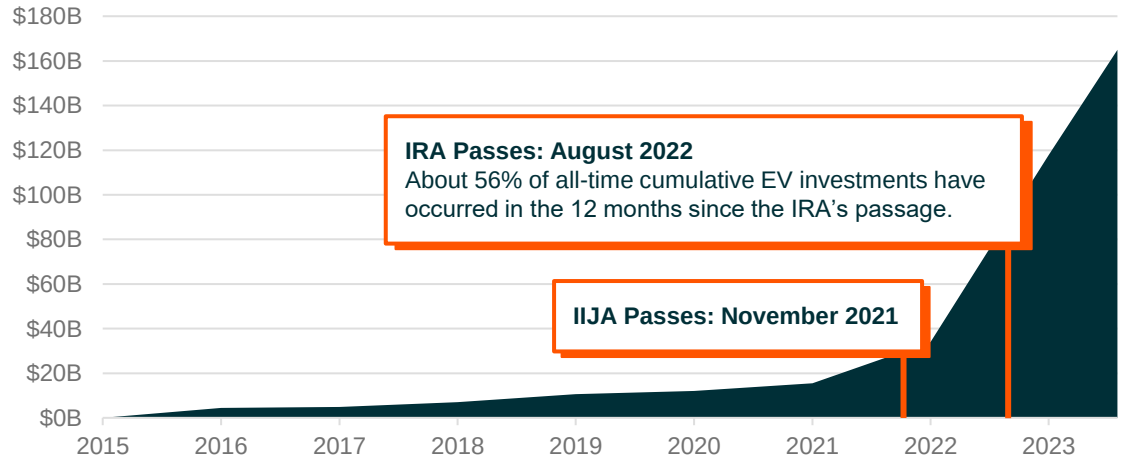
EV & Battery
Top States:
1. Georgia: $24B
2. Michigan: $19B
3. Tennessee: $16B

Semiconductor & Electronics
Top States:
1. Arizona: $61B
2. Texas: $52B
3. New York: $41B



*As of November 2023

Cumulative Private EV & Battery Tech Investments in the United States



Sources: Text: 1. The White House, 2023; 2. Benchmark Mineral Intelligence, 2023; 3. Ibid.; Charts: Left: The White House, 2023; Right: Environmental Defense Fund, 2023.

Inflation Reduction Act and CHIPS Act Project Highlights

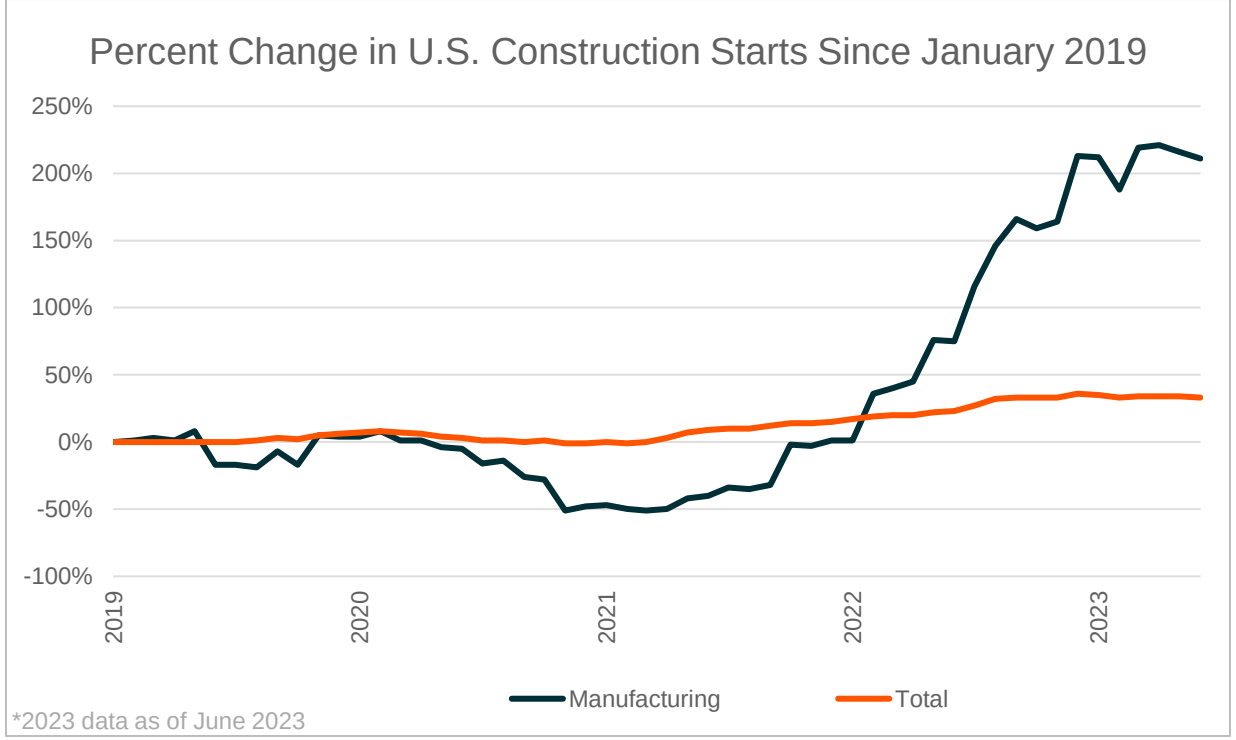
The IRA and CHIPS Act changed the equation for U.S. CleanTech and semiconductor projects, ushering in a wave of new investment. Projects at various stages of construction are racing ahead to take advantage of the new incentives.

TSMC – Arizona Semiconductor Fabs: In response to the CHIPS Act, semiconductor giant TSMC announced a second chip factory in Arizona, upping total investments in the state to $40 billion.[1]

LG Energy Solution – Ohio Battery Plant: Honda and LG Energy Solution committed $3.5 billion toward a joint venture EV battery plant in Ohio.[2] LG Energy Solution is also working on major factories in Arizona and Georgia.

Hanwha Qcells – Georgia Solar Factory: Korean solar company Hanwha Qcells plans to invest $2.5 billion to build a cell and panel manufacturing complex in Georgia and increase capacity in the region to 60,000 panels per day.[3]

Manufacturing Spending Fueled Growth in Construction Starts

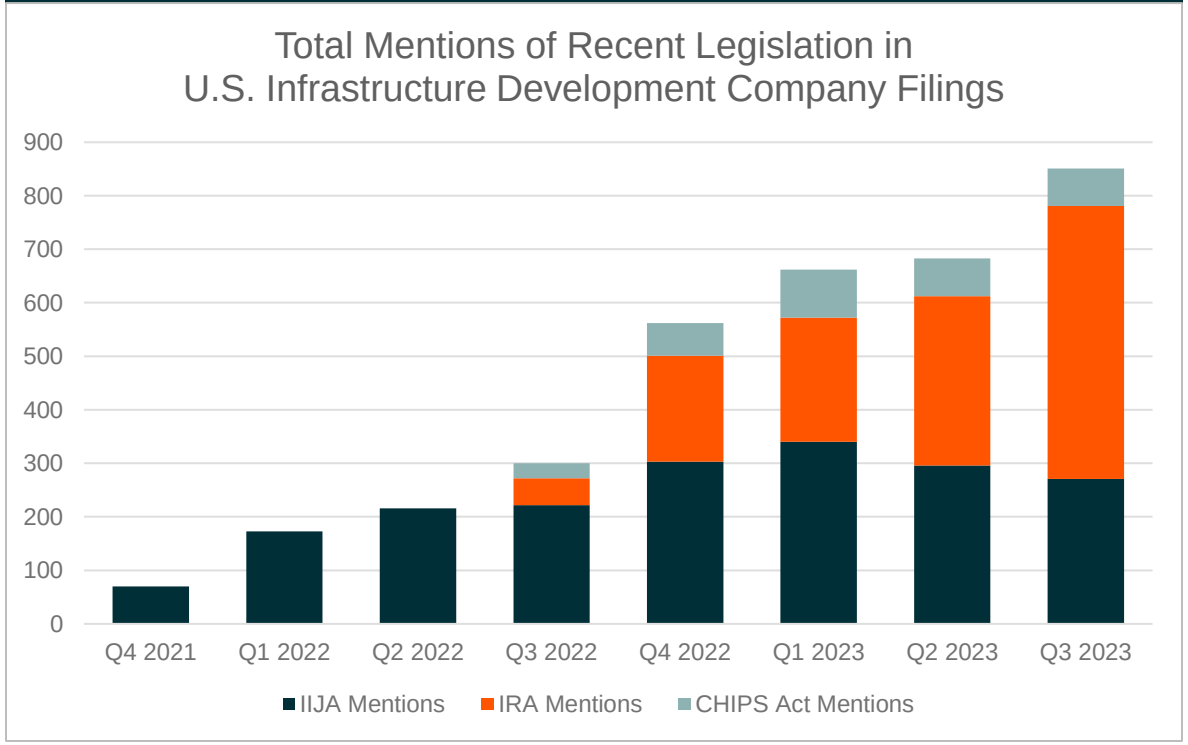


Sources: Text: 1. Taiwan Semiconductor Manufacturing Company (TSMC), 2022; 2. Honda, 2023; 3. Canary Media, 2023; Charts: Construction Dive, 2023

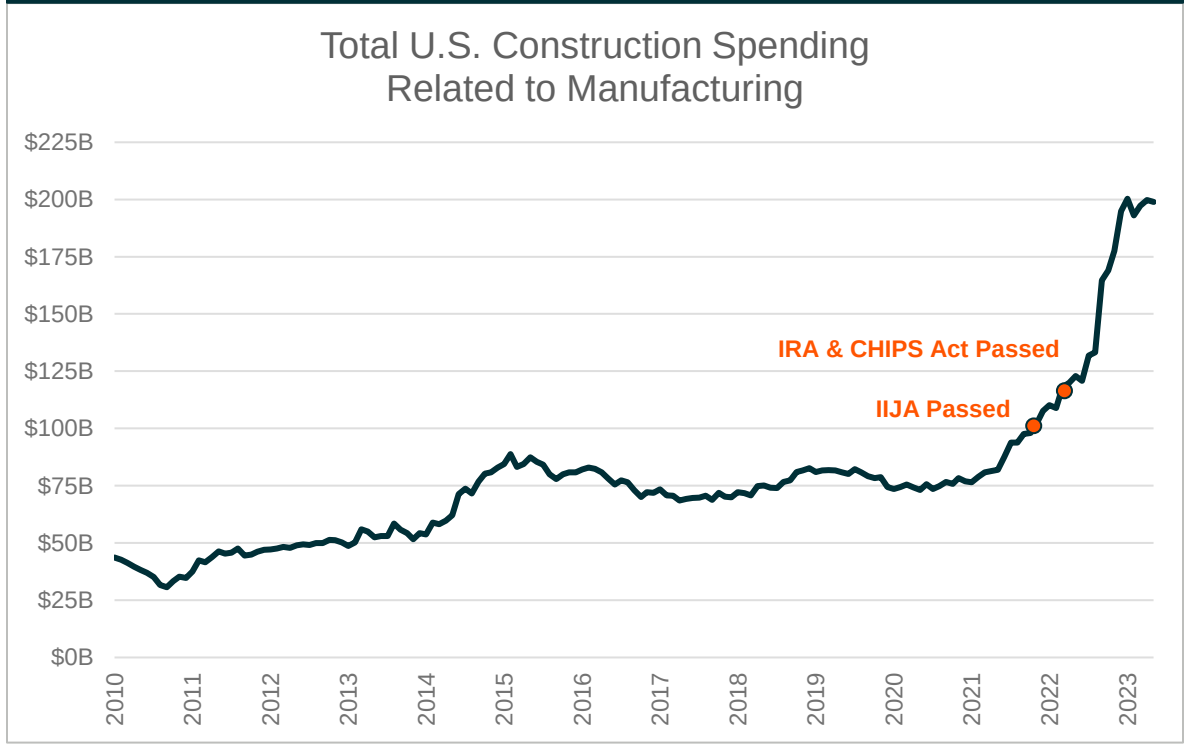
Recent Legislation Is Likely to Build More Momentum for U.S. Infrastructure

Management guidance from U.S. infrastructure companies continues to indicate that the benefits from the IIJA, IRA, and CHIPS Act are likely to begin in earnest in late 2023 and early 2024.

Mentions of Infrastructure Bills Rising on Earnings Calls



Legislation Already Boosting Manufacturing Construction



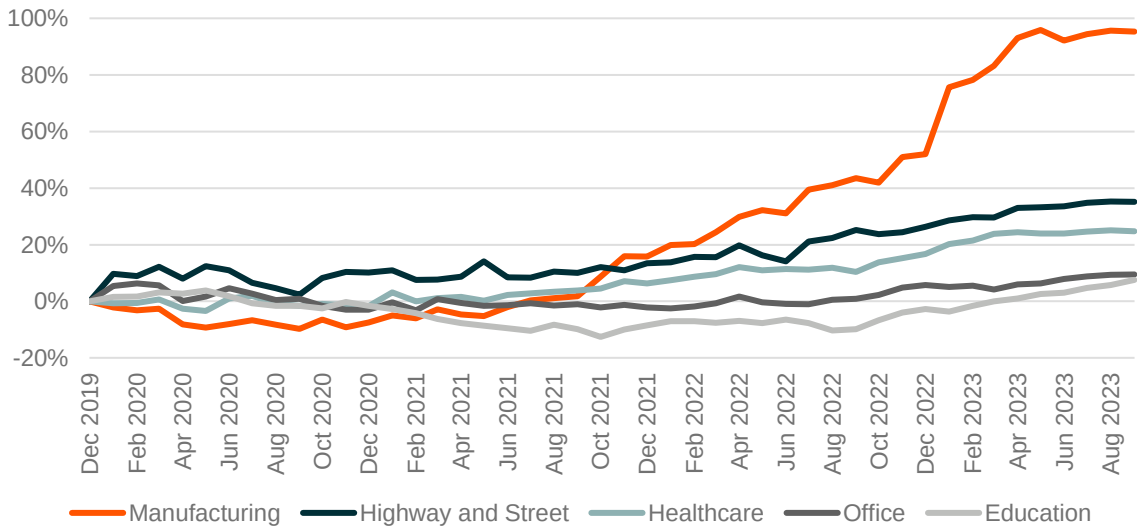
Sources: Charts: Left: FactSet, 2023; Right: U.S. Census Bureau, 2023

Onshoring Trend Tied to U.S. Industrial Production's New Path

After years of stagnation, a new era of U.S. industrial production growth is materializing, spurred by deglobalization and historic investments. Domestic reshoring is a multi-year trend that could boost demand for infrastructure development.

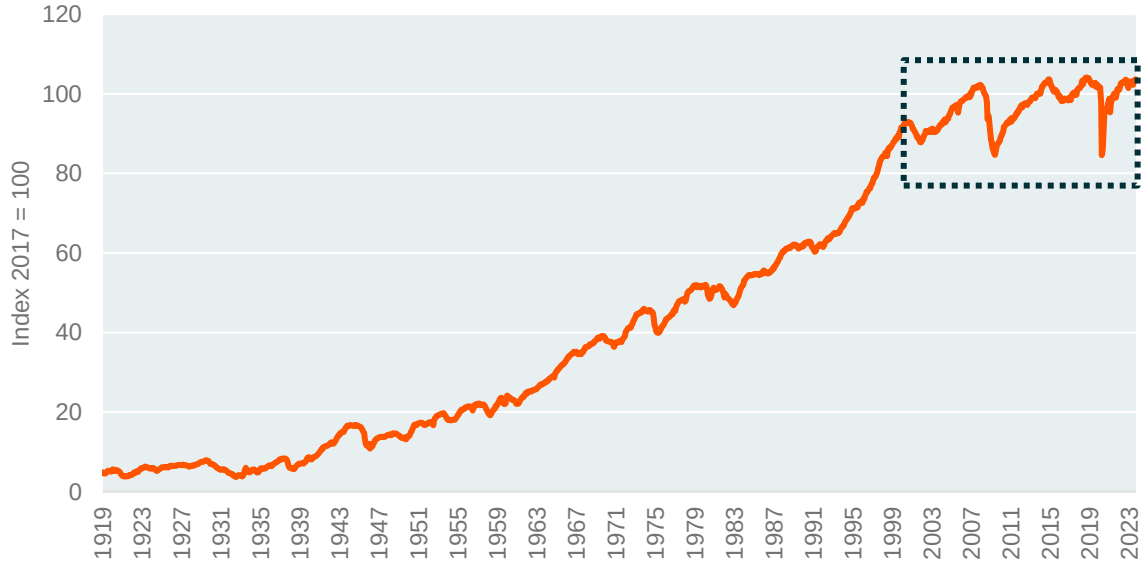
U.S. spending on manufacturing construction is elevated compared to history and has outpaced growth in other segments since the beginning of the COVID-19 pandemic. U.S. construction spending on manufacturing reached a record $108 billion in 2022.[1]

Cumulative Percentage Change in U.S. Construction Spending Levels by Category Since December 2019



For 80 years, rapid industrial production growth defined the U.S. economy. Starting in the early 2000s, though, the U.S. industrial production machine began a two-decade stagnation. This dynamic could change if deglobalization continues to gain momentum.

U.S. Industrial Production: Total Index



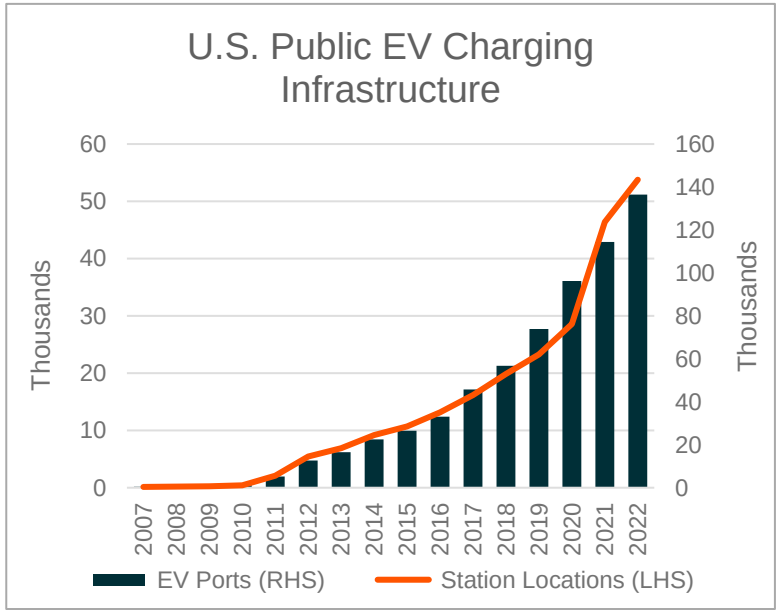
Sources: Text: 1. The Wall Street Journal, 2023; Charts: Left: U.S. Census Bureau, 2023-Sep; Right: U.S. Census Bureau, 2023-Sep

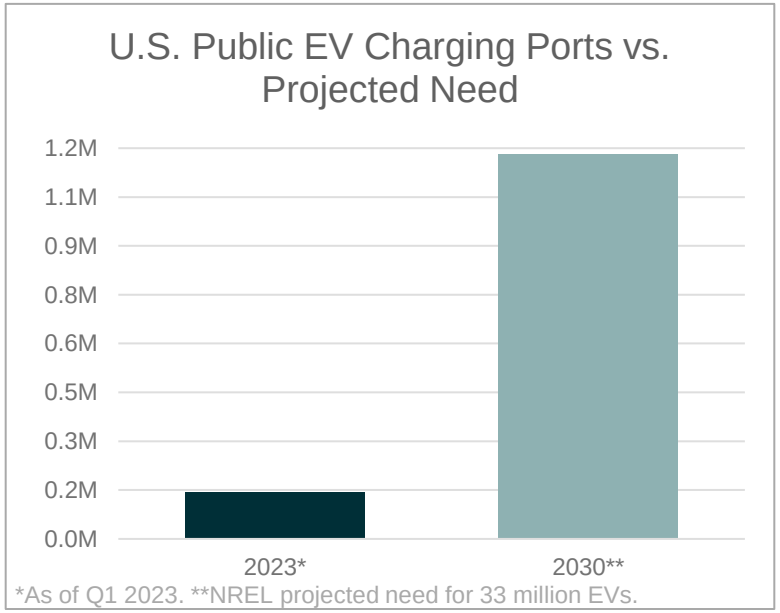
U.S. Charging Network Buildout Creates Opportunities for Infrastructure Companies

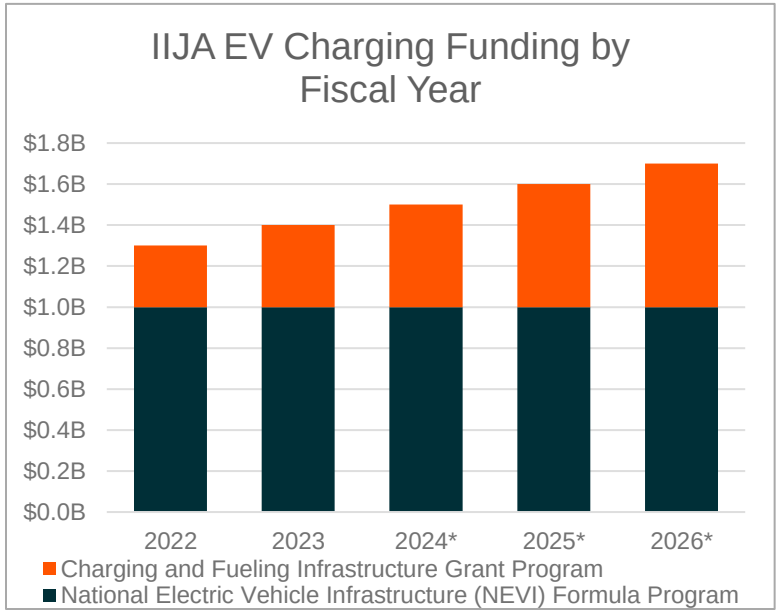
The United States boasts one of the largest EV charging systems in the world, but many more chargers are needed for full-scale adoption. Progress on a national network could benefit companies that offer relevant equipment and services.

Charging deployment could boost demand for companies like Eaton Corp or Hubbell that offer charging-aligned equipment. Construction and engineering firms also stand to benefit. In June 2022, AECOM won a contract to execute Arizona's IIJA EV charging program.[1]

The IIJA directs $7.5 billion toward public EV charging infrastructure through the National Electric Infrastructure Formula (NEVI) Program and the Charging and Fueling Grant Program.[2] Both initiatives cover up to 80% of project costs.[3]







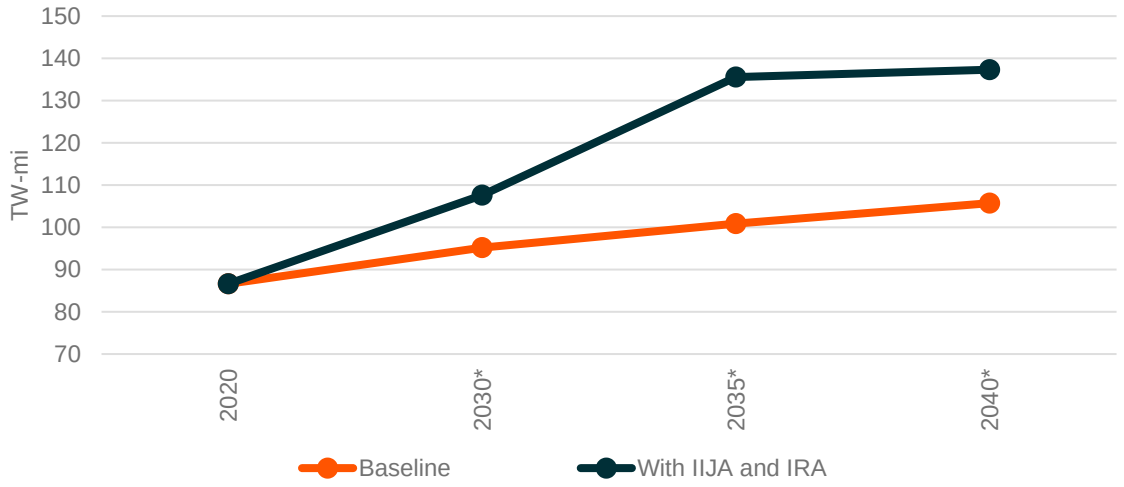
Sources: Text: 1. AECOM, 2022; 2. Bipartisan Policy Center, 2022; 3. Ibid.; Charts: Left: Alternative Fuels Data Center, 2023; Middle: Alternative Fuels Data Center, 2023; National Renewable Energy Laboratory, 2023; Right: Bipartisan Policy Center, 2022

Transmission Infrastructure Is Required for Grid Modernization

The U.S. grid needs an upgrade, given the energy transition and the fact that over 70% of transmission lines are at least 25 years old.[1] In coming decades, structurally high demand for grid expansion and improvement is possible.

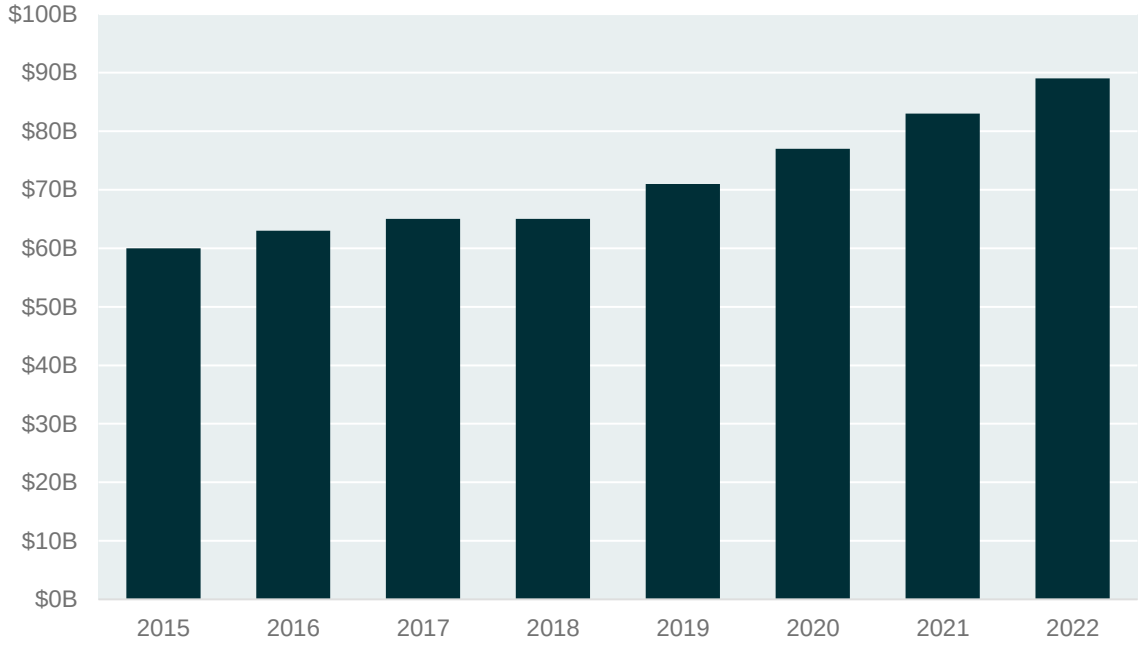
Transmission infrastructure is key for a healthy grid that can support fluctuations in electricity from renewable energy and EVs. The DOE estimates that 47,300 GW-miles of new transmission are needed by 2035 to meet clean technology goals, a 57% addition against 2023.[2]

Total Transmission Capacity in Contiguous United States Under Different Growth Scenarios



U.S. Grid Investments Are on an Upward Trajectory

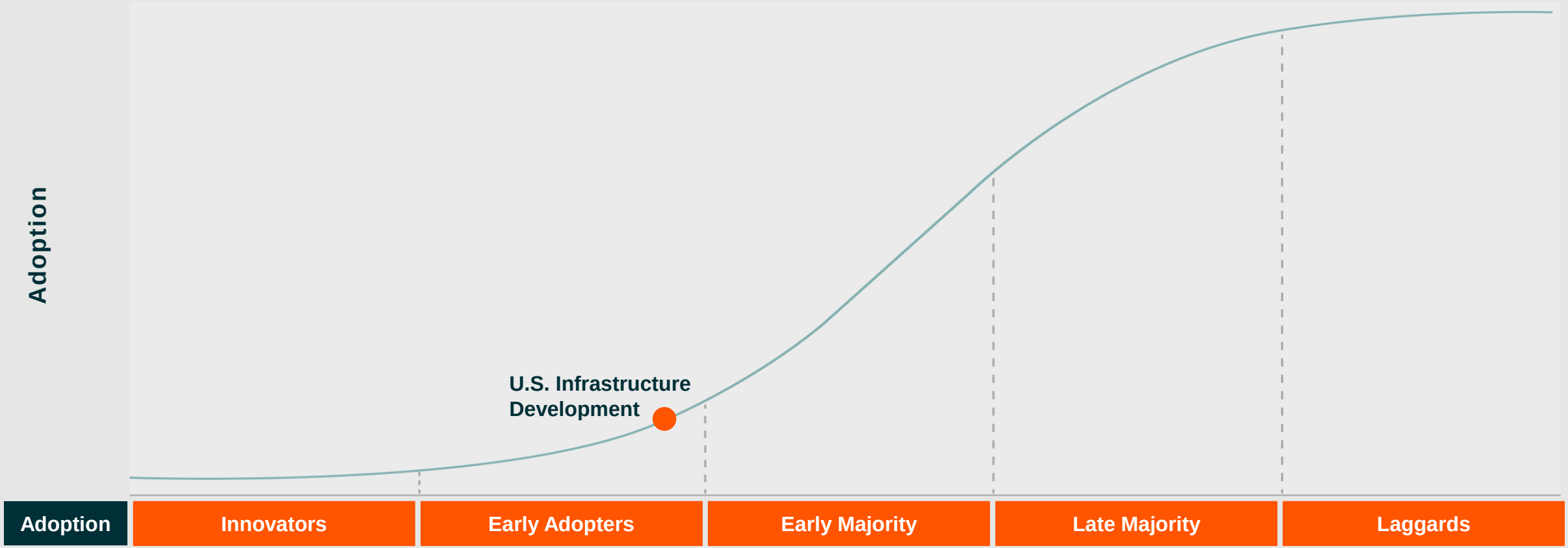
Historical U.S. Grid Investments



Sources: Text: 1. The White House, 2022; 2. U.S. Department of Energy, 2023; Charts: Left: U.S. Department of Energy, 2023; Right: International Energy Agency, 2023

Infrastructure, Reimagined: S-Shaped Curve of Adoption

A total overhaul of U.S. infrastructure is many years and trillions of dollars away. Compared to the opportunity, the theme remains in the early stages of adoption.



Note: For illustrative purposes only.

CHARTING DISRUPTION 2024

Appendix: CleanTech & Beyond

CleanTech & Beyond: Sources

Earth's Global Surface Temperature Has Increased More Than 1°C Due to Human Activities

Text

- Carbon Brief. (2023, March 23). Q&A: IPCC Wraps Up Its Most In-Depth Assessment of Climate Change.
- Etheridge, D., Steel, L., Langenfelds, R., Francey, R., Barnola, J., & Morgan, V. (1998, June). Historical CO2 Records from the Law Dome DE08, DE08-2, and DSS Ice Cores (1006 A.D.-1978). Accessed on July 28, 2023 from Lawrence Berkley Laboratory.
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Charts

- Berkley Earth. (n.d.). Global Temperature Data. Accessed on July 23, 2023.
- Etheridge, D., Steel, L., Langenfelds, R., Francey, R., Barnola, J., Morgan, V. (1998, June). Historical CO2 Records from the Law Dome DE08, DE08-2, and DSS Ice Cores (1006 A.D.-1978). Accessed on July 28, 2023 from Lawrence Berkley Laboratory.
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Current Levels of Warming Already Having Negative Effects

Text

- Carbon Brief. (2023, July 26). State of the Climate: 2023 Now Likely Hottest Year on Record After Extreme Summer.
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- Phys.org. (2023, July 29). N. Atlantic Ocean Temperature Sets Record High: US Agency.
- Phys.org. (2023, August 12). Antarctica Risks 'Cascades of Extreme Events' as Earth Warms, Study Says.

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Concerns About Climate Change Rise with More Extreme Weather Events

Text

- Carbon Brief. (2022, August 4). Mapped: How Climate Change Affects Extreme Weather Around the World.
- Carbon Brief. (2022, October 10). Climate Change Made 2022's Norther Hemisphere Droughts 'at Least 20 Times' More Likely.
- Carbon Brief. (2022, November 16). West Africa's Deadly Rainfall in 2022 Made '80 Times More Likely' by Climate Change.
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- Carbon Brief. (2023, May 5). Western-Mediterranean Heatwave 'Almost Impossible' Without Climate Change.
- De, M. (2023, July 24). July 2023 Consumer Pulse Survey: Extreme Weather Event & Economic Repercussions. Global X ETFs.

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