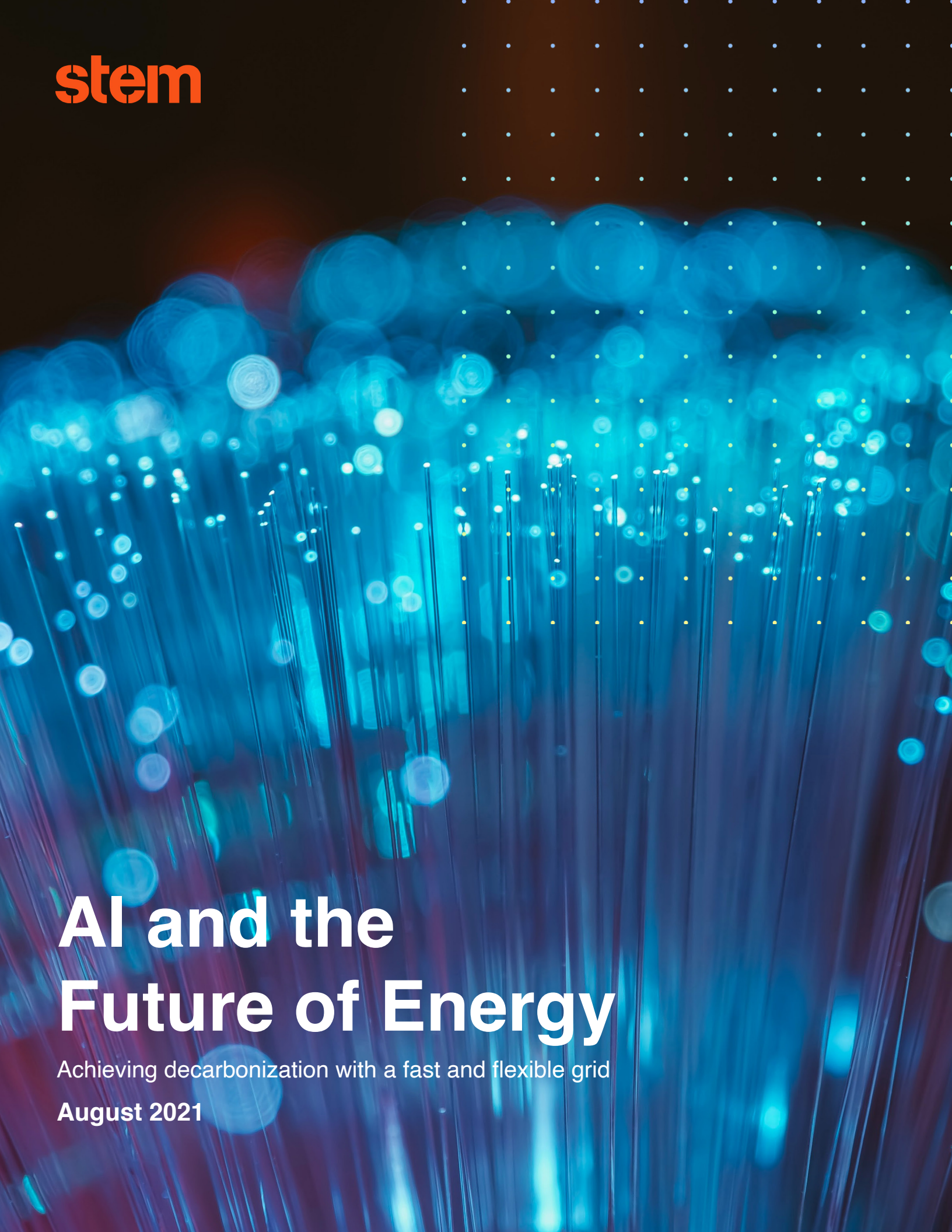

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AI and the Future of Energy

Achieving decarbonization with a fast and flexible grid

August 2021

The global clean energy transformation has begun

The world's energy systems are changing. Driven by strong demand for clean energy and mounting impacts from climate-driven extreme weather, entities around the world are setting ambitious goals to reduce emissions from the fossil fuels that have powered economic growth for over a century.

More than 250 global businesses have committed to 100% renewable energy, while nearly 200 countries have pledged, via the Paris Agreement, to limit global temperature rise. In the U.S., President Biden, two dozen states and the District of Columbia have set economy-wide emissions targets.

Electricity will drive global decarbonization. Steep increases in renewables will both reduce electric sector emissions and power new loads from transportation and buildings. But the grid must undergo profound changes for this to occur. Unlike today, the future grid must be clean, resilient, dynamic, and smart – what we call the "fast and flexible" grid.

Artificial intelligence (AI) will be key to this transformation. On an increasingly complex and decentralized clean energy grid, the sheer number of decisions will far exceed both human and conventional digital automation capabilities. This piece takes a first look at the future of energy, and how AI will enable a fast, flexible, zero-emissions grid.

How will the grid evolve?

If it weren't for climate change, the top priority for the grid might be up for debate. But given the climate threat, the future grid must first and foremost be *clean.*

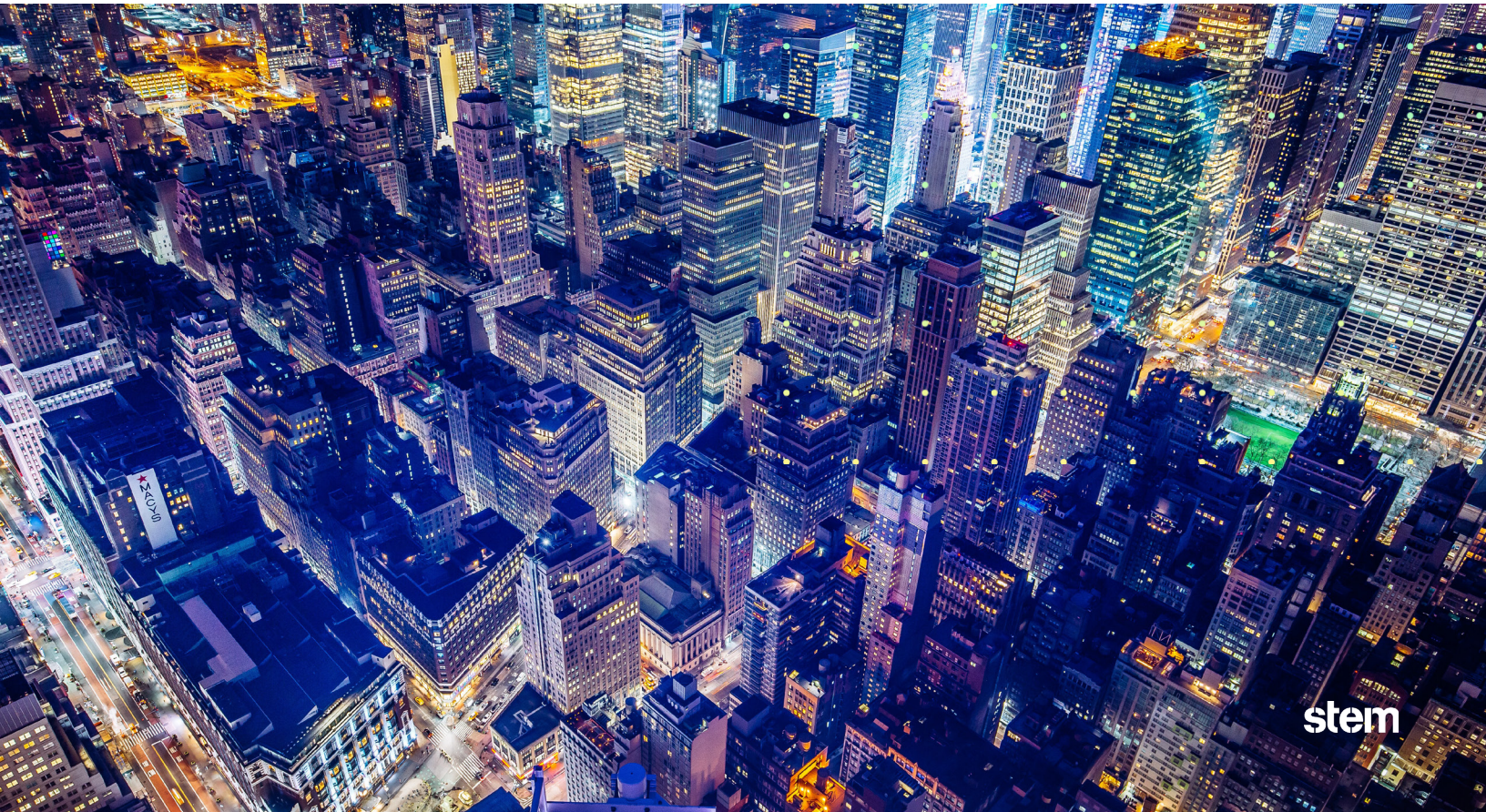
The vast majority of emissions come from just three sectors: electricity generation, transportation, and buildings. No feasible, affordable path exists to replace gasoline with a carbon-free liquid fuel for vehicles, nor natural gas with a carbon-free alternative for cooking and heating. No path, that is, apart from electrifying vehicles and buildings, which is broadly recognized as the lowest-cost, lowest-risk decarbonization strategy.

Clean electricity will therefore drive emissions reductions across the economy. Where will all that renewable energy come from? Some will no doubt still come from large power plants. But those can be difficult or impossible to build, as can be the long transmission lines that bring power to users. By contrast, local solar can provide clean, affordable power directly to many customers, and ultimately almost everyone, much more easily. So in addition to being clean, the future grid will be more *decentralized*.

Having a clean, decentralized grid will address a key challenge: power outages and economic losses from extreme weather. With these events becoming more frequent and severe, maintaining the grid's century-old, centralized architecture is a costly proposition. A clean, decentralized grid will also be more *resilient*.

What else will be true of the future grid? With new large- and small-scale renewables, huge growth and variation in electricity services, and significant unpredictability in both supply and demand, the grid must become much more *flexible* and *dynamic*. And in order for that grid to function, it must also be *smart*.

That's where AI comes in.



AI in the Fast, Flexible Grid

For simplicity, let's compress all of those attributes and say the future grid will be *fast and flexible*. The need for software automation is obvious – there's already automation on today's grid – but automation can only go so far. Fully enabling a fast, flexible future grid and maximizing its benefits will require AI.

AI refers to the ability of computers to learn, solve problems, and make decisions based on huge amounts of data with minimal human oversight. AI also adapts to dynamic conditions, enabling insights, efficiencies, and real-time optimization that otherwise would be impossible.

Machine learning AI generates the most accurate forecasts possible, while AI-based anomaly detection responds instantly when new automation strategies are needed. AI is distinct from conventional digital automation, whose rigidity is ill-suited to unpredictability and change. Orchestrating a fully decarbonized economy – with hundreds of millions of vehicles and devices, all powered by variable renewables – is exactly the kind of challenge AI is uniquely equipped to solve.

Ultimately, AI will transform the grid from an aging supplier of commodity electricity to an intelligent "system of systems" that produces optimized outcomes. Maximizing emissions reductions, time-matching clean energy generation, and optimizing costs will depend as much on distributed intelligence as it will on clean distributed energy resources (DERs).

How will AI enable the fast, flexible grid? What will it look like? We consider the three key sectors – electricity, buildings, and transportation – and show how AI will decarbonize each.

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Electricity

Powering a decarbonized U.S. economy will involve not just replacing fossil-fueled plants with clean renewables, but also roughly tripling the amount of electricity that's delivered. Because the fast, flexible grid will be decentralized, the sources of energy supply will increase by an order of magnitude – from tens of thousands of plants today to a network of millions of resources. And because most of these resources will be wind and solar, weather will profoundly affect electricity supply. Collectively, these changes will transform both the structure and operation of the electricity grid.

AI will be at the heart of this transformation. Its capabilities in *prediction, optimization* and *control* will allow a fast, flexible grid to function.

Leveraging years' or decades' worth of data, AI will generate forecasts for key factors including weather, renewable energy generation, customer demand, and market prices. These forecasts, and learning from predicted vs. actual outcomes, will enable AI to optimize every resource on the grid for every moment of the day. And its real-time control capabilities will both execute on forecasts and correct for anomalies, ultimately down to the sub-second level.

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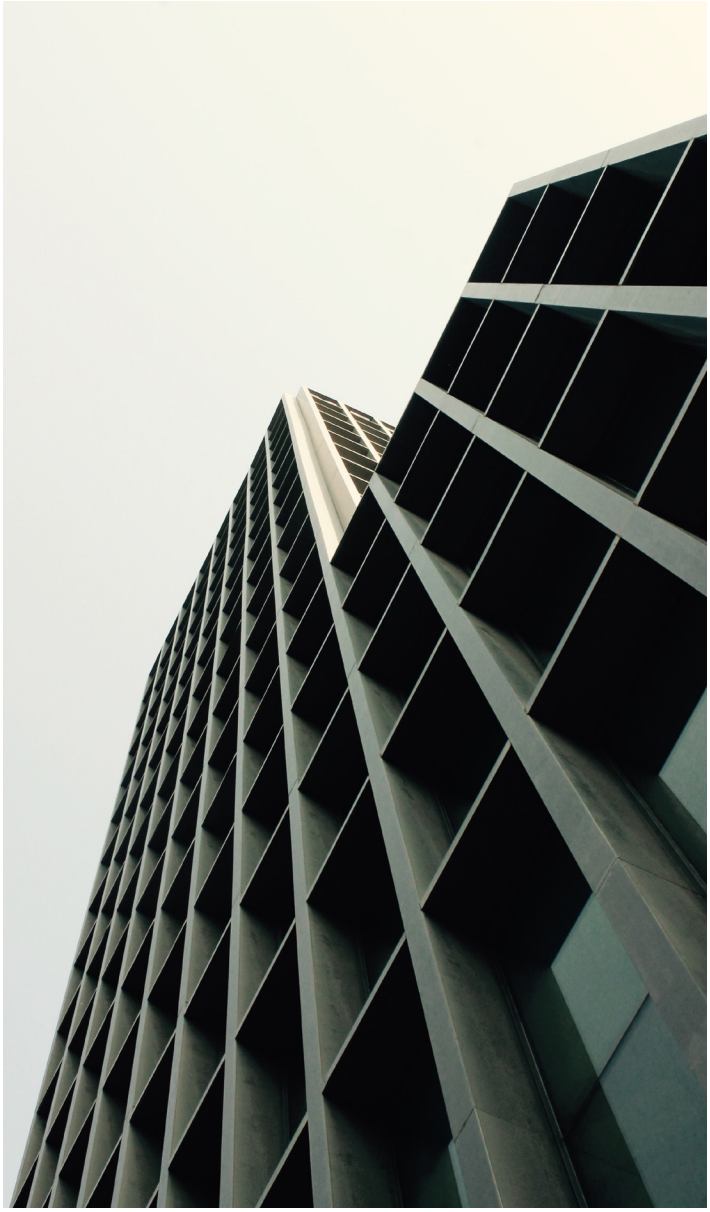

Buildings

Electrifying buildings means powering energy services such as space heating, cooking, and industrial processes with electricity rather than fossil fuels. As decarbonization efforts intensify, the amount of clean electricity buildings consume will rise dramatically, as will the amount of it they produce on-site.

But more importantly, the role of buildings on a fast, flexible grid will change: instead of a passive, predictable consumer of electricity, buildings will become an integrated, dynamic resource and active market participant. And just as important as the selling of clean, locally generated electricity into markets will be the selling of grid services, with buildings' "flexible loads" helping to maintain a balanced, reliable grid.

AI will be the link between electrified buildings and the future grid, ensuring each benefits and complements the other. Again, this will be a matter of forecasting, optimization and control: site-specific forecasts combined with local and regional ones, along with the ability to automate optimized, real-time transactions, even down to specific devices. AI-enabled buildings will also allow users to match consumption with on-site and off-site renewable generation to achieve "24/7 clean energy" objectives.

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Transportation

Electrifying U.S. vehicles – currently over 250 million passenger cars and 10 million medium and heavy duty trucks – will transform the U.S. energy landscape as much as anything we've considered so far. In place of existing gasoline supply infrastructure will be EV charging stations, and far more of them – at former filling stations; at hotels, office buildings, and supermarkets; and at homes and apartment complexes.

EVs, and specifically the batteries that power them, can provide tremendous value to the grid. They are also the most complex grid resource to predict and manage. Mobile sources of both supply and demand, EVs can theoretically appear anywhere on the grid at any time; and their primary obligation, for both convenience and safety, is to fulfill the driver's mobility needs, and not the needs of the grid.

AI will be crucial to powering EVs with zero-emissions electricity and maximizing their value to both consumers and society. Its benefit will be felt as both the number of EVs and their impact on the grid become increasingly material, and as more data becomes available to understand how EVs behave and how they can be optimized.

In the short term, smart charging can address grid integration challenges and keep costs down for consumers and utilities; in the longer term, fully leveraging EVs in a decarbonized economy will require AI.

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Energy storage completes the picture

We've referenced energy storage only briefly, as batteries in electric vehicles. In reality, storage will be as important as renewables and AI in achieving global decarbonization.

On the grid and at homes and businesses, storage will solve the challenge of intermittent renewable generation so that clean energy is available when it's needed. Storage will also enable buildings to act as fully flexible grid resources, making up for shortfalls in on-site generation and providing grid services when devices can't.

Building a massive grid that instantaneously balances supply and demand while providing power to millions has been called the greatest engineering feat of the 20th century. Powering a fully decarbonized economy with AI-driven renewables and energy storage may prove to be the greatest achievement of the 21st.

How do we get there?

Renewables, energy storage, and early-stage AI all play a role on today's grid. But much needs to change if AI is to enable a fully decarbonized economy.

First and foremost, electricity markets must transform completely. Today's markets bear very little resemblance to those that will underpin a fast, flexible grid. The range and value of AI-enabled clean energy services haven't been contemplated in many jurisdictions, let alone the means of incorporating and compensating them in real time.

Every barrier that prevents a customer from buying or selling the clean energy services they want, and that the grid needs, at any point in time, must be removed. In its place must be an efficient, transparent market mechanism. These mechanisms will be animated by AI, which will allow customers and utilities to realize their desired outcomes with as little human involvement as they wish.

Policy drives markets. With appropriate action starting now, policy makers can bring about many needed changes over the next decade. Doing so could enable full electric sector decarbonization by 2035, a pillar of many long-term emissions reduction strategies.

AI technology itself must continue to evolve and respond to priorities around cybersecurity, data privacy, and other areas. But by far the biggest barrier isn't technical – it's political and regulatory.

Meaningful action towards mid-century decarbonization must occur in this decade, and the costs and risks of inaction increase with each passing year. As a leading provider of AI-driven energy storage solutions, Stem is committed to supporting customers, partners, and policy makers in realizing the fast, flexible grid society needs.

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About Stem, Inc.

A global leader in artificial intelligence (AI)-driven energy storage systems

Stem delivers and operates smart battery storage solutions that maximize renewable energy generation and help build a cleaner, more resilient grid. Our customers include Fortune 500 corporate energy users, project developers and installers, and utilities and independent power producers.

Stem's market-leading Athena® software uses advanced artificial intelligence and machine learning to automatically switch between battery power, on-site generation and grid power. Athena® helps lower energy costs, stabilize the grid, reduce carbon emissions, and solve renewable intermittency across the world's largest network of distributed energy storage systems.

For more information, visit www.stem.com.

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