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Big Ideas is meant to enlighten investors on the long-term impact of innovation.
This annual research report seeks to highlight the technological breakthroughs evolving today and creating the potential for super-exponential growth tomorrow.
We believe that innovation is taking off now, corroborating our original research and boosting our confidence that our strategies are on the right side of change.
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Hi everyone, my name is Sam Kors and I'm ARC's Director of Research for Autonomous Technology and Robotics.
And today we're going to go through our electric vehicle section of Big Ideas 2023.
Now of course, before we dive in, there are risks of investing in innovation.
And one of those risks, you know, is this rapid pace of change.
Things are changing quickly all the time.
And so, you know, this is an annual presentation, but obviously things change throughout the year quite quickly.
There's different competitive landscapes, political impacts.
So all of these are things to keep in mind while investing in innovation.
And now we're going to dive into it.
Electric vehicles and electric vehicles have really defied the skeptics with the exponential growth they've seen.
If you went back, you know, to 2015, the consensus view was that electric vehicles were going to be a niche part of the ecosystem.
Maybe they'd sell a few hundred thousand units globally, but really battery costs were not going to decline enough where they'd really take share.
But now the conversation has shifted to is this rapid growth going to be linear growth or exponential?
And we believe it will be exponential.
And this is largely based on Wright's law.
And so that's for every cumulative doubling of production, you get a fixed percent cost decline.
And that's really driving a huge shift in demand for electric vehicles.
So we believe that electric vehicles are going to increase sales more than sevenfold or a 50% annual rate from 7.8 million units in 2022 to roughly 60 million units in 2027.

And one of the biggest downside risks to our forecast are supply constraints, though we think the market is signaling price signaling for those to be resolved.
But also whether or not traditional automakers can successfully transition quickly enough.
And so just to give some context here, electric vehicle sales, even though we're in the early days, have been taking share over the past five years.
And so, you know, you can say that internal combustion engine vehicle sales really peaked in 2017.
And you can see they've come down pretty dramatically just one year of growth in 2021 with 1.7% increase
there.
And at the same time, you have electric vehicles that have just been consistently growing extremely strongly, you know, in 2021, over 100%, this past year, over 60%.
So you know, you get the stage set there with the backdrop of this declining sales base of gas powered vehicles and this accelerating pace for electric vehicles.
And one of the big questions out there is, you know, are people going to invest?
You need to invest in manufacturing, you need to invest in battery plants, in, you know, material development, all of these things.
And in just the past four years, we've seen a real transformation in the amount of investment money going towards EVs and batteries.
So if you look in 2018, there was roughly $100 billion of investment planned over the next 10 years for electrification.
That's increased 10 fold.
So as of 2022, there was $1.2 trillion earmarked over the next 10 years for electric vehicle and battery investment.
And roughly half of that is for electric vehicles themselves.
And so what does this convert to when it comes to annual EV production capacity?
So the historical auto industry capital efficiency is roughly $14,000 per unit capacity, which means that if you took $600 billion and you converted that all into factories at that efficiency rate, you'd be able to produce roughly 43 million units annually.
But what we're seeing is that electric vehicles are actually more capital efficient and roughly, you know, twice as capital efficient.
So just $7,000 per unit capacity, which means that that $600 billion earmarked for electric vehicles would accommodate 86 million units, which is close to all of auto production.
So you have the backdrop and now you've got the financial backdrop.
The investment dollars are there.
They're being committed.
So really, you know, what do we have standing in the way between us and in all electric vehicles in the future?
It's making the vehicles that are actually priced in the right way.
And this comes down to that battery cost.
And why is the battery so important?
It's the single largest cost component of an electric vehicle.
So getting those prices down are what make these vehicles affordable and compelling to consumers.

And so this dives into Wright's law, which is really at the crux of all of our electric vehicle modeling and all of our cost decline work.
And so Wright's law, as I stated earlier, states that for every cumulative doubling of production here measured by kilowatt hours, you get a fixed percent cost decline.
And for batteries, that's 28%.
And what we're seeing in the battery space is actually something pretty interesting.
So there's really two big camps of battery chemistry out there.
You have nickel and you have lithium iron phosphate.
And for a while, everything was shifting towards nickel because it was higher energy density.
So more energy per unit of mass.
And people were doing this because the electric vehicle drivetrain systems were not that efficient.
And so you needed more energy to get an acceptable range.
But as the rest of the drivetrain and the power electronics have become more efficient, we're actually able to shift to less energy-dense cells, these lithium iron phosphate cells, which are cheaper as well.
And so these cells are declining at the same rate, same Wright's law curve.
But they're starting at a cheaper price point.
And there's been fewer of them cumulatively produced, which means if we look at this chart on the right, you can reach a cumulative doubling faster, which should lead to accelerated cost declines.
And so this is really big.
And it's driving a lot of these cost declines that we're seeing in vehicles today.
Another common question when it comes to electric vehicles is, you know, it takes too long to charge.
How long will it take to charge?
Are charging rates getting better?
Well, Wright's law also captures this and successfully models where the future is going.
And so you can see that, you know, as of today, the best vehicle out there is charging 200 miles in 15 minutes.
So already, I would argue that that's a pretty compelling offering.
But if this trend continues, you could get to 2027, where you'd be able to charge 200 miles in four minutes.
But I think a bigger point here is that, you know, EV charging is going to continue to get faster, but really this metric is a good proxy for overall performance.
And the reason for that is that it captures the efficiency, the range, the power capabilities of the vehicle and how that tracks over time.
And what we're seeing is that at a certain point, it doesn't matter if your car charges in, you know, seven minutes or six minutes, but you'll start to optimize for different things.
And then instead of investing in incremental faster charging, you start investing more in the autonomous driving capability, the safety features or the entertainment.
So this chart, though it's capturing EV charging rate, it really speaks to the performance metrics of the vehicle overall.
And in 2022, we hit a pretty profound point that has often been talked about in LERD.

They say in LERD, sorry, they say price parity.
What is price parity?
That's when you have an electric vehicle that costs the exact same amount as a like for like gas powered vehicle.
And this happened in 2022.
So you can see that the least expensive EV with more than 300 miles of range was actually below the average new transaction price for a vehicle in the US.
So we hit price parity.
And the interesting thing here is that with cost declines for electric vehicles, those costs should continue to come down.
So you can see here the forecast future Tesla model, which they've spoken about.
And that's at half the cost of what they're producing today.
And so you kind of see a repeat of the cycle that we saw in 2017.
Before 2015, there were no EVs with more than 300 mile range.
And then the Model 3 comes out in 2017.
And it's this close, it's more than having the cost.
And now they're going to more than have the cost again in 2023 and beyond.
And on the right, you kind of see how Tesla really leads the pack here.
And so Tesla had the vehicle with more than 300 miles of range.
And it took until 2021 for another company to come out with a vehicle of equal range.
And then you see in 2022, you get a whole host of other companies who have entered the scene here.
And now there are more in 2023 as well.
But what we would expect is that similar to what happened in 2017 with the Tesla Model 3, what Tesla comes out with in the future at half the cost could leave a similar time lag for these other companies to catch up and offer something compelling.
And so EV growth has been strong.
But we really think that we're at this inflection point and that these battery cost declines are going to continue to drive exponential growth in electric vehicle sales.
And so what you see on this chart is this darker blue line is the global revenue share of all autos by MSRP.
And the lighter blue line is global EV market share by average MSRP.
And you can see that they track very closely.
So as EV prices come down, there is a larger addressable market.
And if you hit that price point, then people are very compelled to switch over to electric vehicles.
With that rights law cost decline, we think that in 2027, you're going to have a compelling electric vehicle at potentially the roughly $20,000 price point, which means that there is going to be a huge jump in demand for electric vehicles.
And you can see we really are at this price inflection point where you really start to see the elasticity of demand for vehicles.
And this gets into the question that we started with.
Is the growth for electric vehicles going to be linear or is it going to be exponential?
And this chart on the left shows kind of the scene in 2017.

And what you had was consensus forecast that was linear in trajectory and suggested that in 2022, there'd be roughly 2 million electric vehicles sold globally.
The reality was that there was closer to 8 million electric vehicles sold globally.
So much more exponential than linear.
And then if we look at the chart on the right, the same thing is happening again today.
The consensus forecast for electric vehicles in 2027 is a linear extrapolation of the past few years and suggests roughly 20 to 22 million electric vehicles sold globally.
Our forecast is much more exponential.
And we think that's going to be closer to the 60 million unit mark.
And so this is very different.
Historically, it has grown more exponential than linear.
But still, consensus is looking on this linear path.
Another factor at play here is what will happen to internal combustion engines as it becomes clearer and clearer that electric vehicles may be the path forward.
So then do you have a consumer who's delaying a purchase because they see electric vehicle prices maybe in the next couple of years are going to come into their price point?
And so maybe they put off buying a new gas powered car or maybe they go to the used car market and they say, I need a car now, so I'll get a used car because it's less expensive.
And then when the electric vehicle comes into my price point, I'm going to shift up.
And so what you see on this chart is a large number of those internal combustion engine units at risk as the shift to electric vehicles continues.
And then really to sum this all up here, the planned investment levels should support a sevenfold increase in electric vehicle production from the roughly 7.8 million this past year to 60 million electric vehicles in the next five years.
And again, this is a 50% unit compound annual growth rate.
So thank you for joining me on this big idea.
Our work does suggest these declining battery costs are going to lead to exponential growth for electric vehicles.
And it's going to be fairly easy to track how this is progressing because you can look at those battery costs and every year you'll be able to see those electric vehicle sales numbers.
Thanks for joining us.