Investor Day

Company Participants

- Andrew D. Baglino, Senior Vice President, Powertrain and Energy Engineering
- Brandon Ehrhart, General Counsel and Corporate Secretary
- Colin Campbell, VP, Powertrain Engineering
- David Lau, VP Software Engineering
- Elon R. Musk, Chief Executive Officer
- Franz von Holzhausen, Chief Designer
- KarnBudhiraj, Vice President, Supply Chain
- Lars Moravy, Vice President, Vehicle Engineering
- Laurie Shelby, Vice President, Environmental Health and Safety, Security And Sustainability
- Michael Snyder, Director, Megapack
- Peter Bannon, VP, Low Voltage & Silicon Engineering
- Rebecca Tinucci, Senior Director, Charging Infrastructure
- Roshan Thomas, Vice President, Supply Chain
- Tom Zhu, Vice President, Global Production and Sales and Delivery
- Unidentified Speaker
- Zachary Kirkhorn, Chief Financial Officer

Other Participants

- Adam Jonas, Morgan Stanley
- Alex Potter, Piper
- Analyst
- Ashok Elluswamy, Director, Autopilot Software
- Colin Rusch, Oppenheimer
- Dan Levy, Barclays
- Emmanuel Rosner, Deutsche Bank
- George Gianarikas, Canaccord Genuity
- Rod Lache, Wolfe Research

Presentation

Zachary Kirkhorn {BIO 20940148 <GO>}

Good afternoon, everyone. Good afternoon. My name is Zach Kirkhorn, I lead finance here at Tesla, and welcome to our Investor Day.

For those of you here in the audience, at our global headquarters in Austin, Texas, we welcome you. Thank you for being here and thank you for traveling in. For those joining us virtually, thank you for being a part of the day today.

So as we reflect back on the history of the company, there's been distinct phases of product advancement, technology innovation and rapid volume growth. The most recent of which has been the global expansion and localization of the Model Y program.

And so today, we want to talk about the future. We don't want to talk about this quarter or next quarter, we want to go further out into the future. And we've divided today's presentation into three parts. The first of which, we're going to go macro. What does it take to convert earth to sustainable energy generation and use. The second, we want to talk about Tesla's contribution to that global need. And we're going to go function by function, through the company, and you'll meet our entire leadership team, and we're going to get into the details of what those teams are doing as part of the broader goal.

And then in the third part, we're going to bring it back up and talk about what this all means for the company as a whole.

So before we get started, statements made in this presentation are forward looking statements, that are subject to risks and uncertainties. More details can be found in our written materials.

So with that, let's get started. Part one, Elon Musk and Drew Baglino.

Elon R. Musk {BIO 1954518 <GO>}

All right. Master plan Part three. So as Zach was mentioning, the thing that I think is -- we wanted to convey, probably more importantly than anything else that we're talking about here is that there is a clear path to a sustainable energy earth. It's not -- it doesn't require destroying natural habitats. It doesn't require us to be austere and stop using electricity and sort of be in the cold or anything. The story, and I think if this holds together quite well, and we will be actually publishing detailed white paper with all of our assumptions and calculations is that, there is a clear path to a fully sustainable earth with abundance. In fact, you could support a civilization much bigger than earth than -- much more than the 8 billion humans could actually be supported sustainably on earth.

And I'm, I'm just often shocked and surprised by how few people realize this. Most of the smart people I know actually don't see a -- this clear path. They think that's, there's not a path to a sustainable energy future or at least there's not one that is sustainable at our current population, or that we have to resort to extreme measures. None of this is true. So we're going to walk through the calculations for how to create a sustainable energy civilization. Yes.

Andrew D. Baglino {BIO 21161872 <GO>}

And to set the stage, today, our energy economy, it's -- let's be honest, it's dirty and it's wasteful. Over 80% of global energy, primary energy comes from fossil fuels and only one-third of that global energy actually ends up delivering useful work or heat. This is the problem statement, but we're here to talk about the solution.

Elon R. Musk {BIO 1954518 <GO>}

Yes. It's like if -- for -- on some of this I'm going to elaborate because there's a very wide range of technical expertise out there from people who are like, whatever, Level 9 Wizards in this subject, to people who do not do engineering at all.

So, like when you -- if you have a gasoline car, you're converting less than a third of and maybe only 25% of the energy and the gasoline is converted into motion, the rest is turned into waste heat. That doesn't know -- doesn't do any good role. And there's a lot of energy required even to get the oil out of the ground, to refine the oil and to transport the gasoline to the gas station.

So when you look at all that for a typical gasoline car is -- it is actually going to be using less than 20%, fully considered, of the energy from the oil actually goes into motion. So this is a -- when I see people -- when we see people doing calculations for what does it take to create a sustainable energy earth. They assume that the same energy amount is required for an electrified civilization versus a combustion civilization. This is not true. Because most of the energy of combustion is waste heat.

Andrew D. Baglino {BIO 21161872 <GO>}

And even to get the fuel to combust in the first place and get it to the end use, there's a lot lost along the way. I mean, this is the primary energy consumption, 165 petawatt hours a year. Petawatt hour is a trillion terawatt -- trillion kilowatt hour. So it's a -- large amount of energy. But the nice thing about electrified economy, there's a better way, we're going to talk about it, is that through end-use efficiency and through efficiency along every step of the way. Actually, the total energy use, it halves. So this is one of the most enabling aspects of electrifying everything, is that the sustainable energy economy is that much easier to accomplish. It's actually half the problem statement of the fossil fuel economy.

Elon R. Musk {BIO 1954518 <GO>}

Yes. And we're being conservative here. So it could be better than the half. But we're trying to have assumptions that are reasonable and not overly optimistic, in fact, slightly pessimistic. So it's really better than half, but just say, for -- it's easy to make the argument that we need half as much energy with an electric economy versus a combustion economy.

Andrew D. Baglino {BIO 21161872 <GO>}

Yes. So how the Master Plan works? You want to talk about --

Elon R. Musk {BIO 1954518 <GO>}

Yes. So the thing that is needed in -- at very large scale, that is not currently present, is a vast amount of battery energy storage. Our rough calculations are that this is about 240 terawatt hours or 240,000 gigawatt hours. This is a lot of batteries, but it is actually a very achievable amount, we'll go into details on that.

Andrew D. Baglino {BIO 21161872 <GO>}

Yes.

Elon R. Musk {BIO 1954518 <GO>}

So that's a combination of electric vehicles and stationary storage. So if you got solar or wind, you got to store the energy when the wind is not blowing, when the sun is not shining and -- so we're assuming sort of an 8 to 1 ratio of stored energy to power. So 30 terawatt hours of power -- that's -- so 30 terawatts of power. Our actual capital expenditure calculation for manufacturing investment is more like $6 trillion, but we should made it higher to make it $10 trillion.

Andrew D. Baglino {BIO 21161872 <GO>}

And this is across mining, refining, battery factories, recycling, vehicle factories, all the things that we're going to talk about, needing to invest in to build this sustainable energy economy.

Elon R. Musk {BIO 1954518 <GO>}

Yes. Now if you look at the total world economy, it's just under $100 trillion. So if this was spread out, say, over 10 years, it would be 1% of the global economy, over 20 years, it would be 0.5% --

Andrew D. Baglino {BIO 21161872 <GO>}

Very doable.

Elon R. Musk {BIO 1954518 <GO>}

-- of the global economy. So this is, yes, not a big number relative to the global economy. As Drew mentioned, you need about half as much energy with an electric economy versus a combustion economy. And in terms of wind and solar, how much land would be used? It's less than 0.2% of the land area of earth. I think, generally, people don't realize quite how much energy is reaching us from the sun. It's roughly a gigawatt per square kilometer. And sun doesn't shine all the time, but it's -- if you multiply that by, say, four, for you to get the continuous power, four or five, then that gives you the land area of solar. And you can put wind and solar often in the same place. So a lot of places that currently have wind, you could have solar there and you double your energy.

Andrew D. Baglino {BIO 21161872 <GO>}

You can also put wind offshore. It doesn't even --

Elon R. Musk {BIO 1954518 <GO>}

Yes.

Andrew D. Baglino {BIO 21161872 <GO>}

-- need to be on land. So wind is even more flexible.

Elon R. Musk {BIO 1954518 <GO>}

You can put solar offshore too.

Andrew D. Baglino {BIO 21161872 <GO>}

Yes.

Elon R. Musk {BIO 1954518 <GO>}

So Earth is 70% water. Anyway the point is that, with a pretty -- really, remarkably small amount of earth's land area, we can go fully sustainable. Yes.

Andrew D. Baglino {BIO 21161872 <GO>}

And from a -- do the resources and raw materials exist to support this transition? We'll go through that in detail, but we do not see any insurmountable resource challenges at all. In fact, in the end, we should be mining less ore to accomplish this economy than we currently do with the fossil fuel economy, and we're going to talk through that.

Elon R. Musk {BIO 1954518 <GO>}

Yes. Just to emphasize that again, the electrified economy will require less mining than the current economy does.

Andrew D. Baglino {BIO 21161872 <GO>}

Less.

Elon R. Musk {BIO 1954518 <GO>}

Less, not more. Okay.

Andrew D. Baglino {BIO 21161872 <GO>}

So this is the plan and now we get into a little more of the details of the plan. Basically, five areas of work: first, renewable power, the existing grid; second, switch to electric vehicles; third, switch homes, businesses and industry heating to heat pumps; fourth, high temp heat delivery and storage for high temp industrial and chemical processes, and a little bit of green hydrogen in there for chemical processes that need hydrogen; and finally, sustainable -- sustainably fuel planes and boats. These are the five areas and we're going to go into detail on all of them.

Elon R. Musk {BIO 1954518 <GO>}

Yes. I mean, my personal opinion is that, as we improve the energy density of batteries, you'll see all transportation go fully electric, with the exception of rockets, that's awkward. But you can make the fuel with CO2 and water. So you can make methane with CO2 and water. So -- and in fact that's --

Andrew D. Baglino {BIO 21161872 <GO>}

And you could do that with just electricity.

Elon R. Musk {BIO 1954518 <GO>}

Yes, exactly. So -- in fact, on Mars, if we hopefully get there some point, the atmosphere is CO2 and there's water ice throughout Mars. You can take the CO2 and H2O and turn that into CH4, which is methane and oxygen. So ultimately, even rockets can be electrified.

Andrew D. Baglino {BIO 21161872 <GO>}

So first, repowering the existing grid with renewables. And this is going to be a consistent theme. You'll see our estimates for the number of terawatt-hours, terawatts and trillions of investment at the bottom of the page. This is already actively occurring in front of us. 60% of the generation added to the U.S. grid was solar in 2022. And actually, on a year-on-year basis solar deployment is growing 50% year-on-year, as of 2022. So this is a serious upswing. And if we continue this trend, this is going to be behind us before we even know it.

Elon R. Musk {BIO 1954518 <GO>}

Yes.

Andrew D. Baglino {BIO 21161872 <GO>}

Second, switching to electric vehicles. Again, 21% reduction in fossil fuel use by doing this alone. Obviously, Tesla is heavily engaged in this activity as -- along with many others. Overall, EV production grew 59% year-on-year in 2022 and EV's hit an amazing 10% market share. I mean, it's an awesome milestone. I'm super excited to see that. And like --

Elon R. Musk {BIO 1954518 <GO>}

Yes. Right, this is, obviously, happening very rapidly. And, I mean, I think really all cars will go to fully-electric and autonomous. And so riding a non-autonomous gasoline car is going to be analogous to riding a horse using a flip phone, that's basically going to be the situation.

Andrew D. Baglino {BIO 21161872 <GO>}

And we actually took somewhat conservative assumption here in terms of how many batteries are required. Because the more the fleet is autonomous, the fewer -- the smaller the fleet needs to be, just from a utility basis. So we're not accounting for all of those benefits, really much of those benefits at all in this number. And what does this fleet look like? Just rough view from our perspective. Of course, we could be wrong, but you can see the sort of breakdown of the fleet by millions of vehicles. Our goal is to do 20 million electric vehicles a year.

Elon R. Musk {BIO 1954518 <GO>}

Yes. Fewer vehicles will be needed, at least passenger vehicles with autonomy. So there's some debate as to what that number is, but it's some number less than the number of vehicles needed today. There's roughly 2 billion cars and trucks in operation in the world today. And --

Andrew D. Baglino {BIO 21161872 <GO>}

Yes. So what we show here is actually, I think, only 1.4 million or so. So --

Elon R. Musk {BIO 1954518 <GO>}

Yes.

Andrew D. Baglino {BIO 21161872 <GO>}

-- we represent 1.4 billion, I mean, or so. So a smaller fleet. And the numbers around -- here in this presentation are around 85 million vehicles a year produced. Just to give you a sense how we're thinking about this. Again, we're going to put all these assumptions up online and encourage people's thought.

Elon R. Musk {BIO 1954518 <GO>}

Yes. So, yes. So we're basically heading rapidly towards an electric or autonomous future.

Andrew D. Baglino {BIO 21161872 <GO>}

Exciting.

Elon R. Musk {BIO 1954518 <GO>}

Yes.

Andrew D. Baglino {BIO 21161872 <GO>}

And one other reasons why EV's are so enabling is this end-use efficiency point. Tesla Model 3, it's 4x more efficient from the well to wheel than a Toyota Corolla. And that's all about the efficiency of getting the electricity to the -- into the car in a sustainable energy economy, and that how efficient the car is in transferring that stored energy to motion on the road. When compared to the engine in the Toyota Corolla and all the extraction, refining, transmission, distribution of the gasoline to the Toyota Corolla.

And just for -- this is a fun reference. Model 3 can drive over a mile on the energy it takes to boil a pot of water for pasta, and then it can drive another mile on the energy it took to cook the pasta. And that pasta is one pound and Model 3 is like 4,000 pounds. Just give you a sense of just like what -- like, it really doesn't use a lot of energy to move a Model 3, a 4,000-pound object down the road.

Elon R. Musk {BIO 1954518 <GO>}

Also, heat is lot more energy than motion.

Andrew D. Baglino {BIO 21161872 <GO>}

Yes. But people, you just boil a pot of water then you think about it. Yes. It's just interesting, how efficient these cars are.

Next, switching to heat pumps in homes, businesses and industry. Right now heat pumps meet 10% of building heating needs, install rates growing 10% year-on-year, really needs to accelerate. Heat pumps can serve heat applications up to 200 C in businesses and industry. And from an investment perspective, as you can see on this page, it's actually the lowest hanging fruit in terms of displacing fossil fuels.

You might be saying, what exactly is a heat pump? So heat pumps don't move heat, don't create heat, they move heat. When you think about, like, the natural gas furnace in your house, like, it's -- it is generating heat itself. But what the heat pump is doing is actually moving heat from outside of your house into your house. They're just an air conditioner or a refrigerator in reverse.

So we're surrounded by heat pumps. There's like -- they're all over this factory, they are in your house and all this really is about bringing them to displace all the fossil fuel heating in all of the homes, businesses and in the industry that we can. And from the end-use efficiency perspective it's a 3x reduction in the total energy required to heat these buildings. So a real obvious thing to do.

Elon R. Musk {BIO 1954518 <GO>}

Yes, heat pumps. They are in our cars, yes, as default.

Andrew D. Baglino {BIO 21161872 <GO>}

Yes.

Elon R. Musk {BIO 1954518 <GO>}

And at some point, we might make heat pump for our home.

Andrew D. Baglino {BIO 21161872 <GO>}

Yes. Maybe, maybe.

Elon R. Musk {BIO 1954518 <GO>}

Maybe.

Andrew D. Baglino {BIO 21161872 <GO>}

Next, a little bit more detail on electrifying high temp, sort of, industrial and chemical processes. So over 50% of industrial heat is greater than 400 C. Where cement, steel, fertilizers, chemicals, plastics, metals refining all need like 1500 C. So we need a solution here.

Ultimately, it's purpose-built equipment that enables electrification. Carbon graphite is stable up to 2000 -- 2,800 C. There's other options in the 1500 C range like silicon carbide, other materials. So the idea here is, you create and store heat when renewable power is available. If this is a sustainable energy economy, renewable energy is intermittent, peak of the day, you've got more generation than you need, you make a bunch of heat then and then you transfer that heat into the industrial process 24 hours a day using the stored heat you created, when the sun or the wind was blowing. That's the concept here.

And then on the hydrogen side, we also need green hydrogen to decarbonize metals and chemical refining processes. This is things like ammonia, making steel. There's roughly 120 million tons of hydrogen sourced from fossil fuel today to do these things. And hydrogen can also directly replace coal, which is currently used in a ton of steel production, through a process called directly reducing iron. You can replace blast furnaces with a hydrogen reducing direct reduced iron furnace. And this is the way to eliminate fossil fuels from these aspects of the economy, and the CO_2 associated with them.

Elon R. Musk {BIO 1954518 <GO>}

Yes. And so, I mean, some of this, there's like room to disagree, but some amount of hydrogen is needed for industrial processes. My personal opinion is that hydrogen will not be used meaningfully in transport, but -- and shouldn't be. If you're going to use a chemical fuel, you should use CH4 not H2. But unless it is needed for industrial processes and can be produced just by splitting water essentially.

Andrew D. Baglino {BIO 21161872 <GO>}

I mean, some of that's been done for decades and decades.

Elon R. Musk {BIO 1954518 <GO>}

Yes.

Andrew D. Baglino {BIO 21161872 <GO>}

This is not rocket technology.

Elon R. Musk {BIO 1954518 <GO>}

Yes.

Andrew D. Baglino {BIO 21161872 <GO>}

And lastly, a small part of the pie, but a necessary part of the pie, is sustainably fueling planes and boats. Shipping accounts for 3% of global CO2. It's right for electrification. Even with a lithium iron phosphate, long-haul ships can be fully battery powered. So that's a great opportunity to electrify. Energy density is a little bit harder for planes, but short-haul is doable today, with some improvements we'll get long-haul underway. But even in the meantime, we can leverage sustainable aviation fuels produced and stored using excess renewable electricity. There's a lot of work going on in this space. And it's, yes.

Elon R. Musk {BIO 1954518 <GO>}

I mean to really get a long-range aircraft and long-range shipping to use lithium-ion, you need to redesign the ship and not just --

Andrew D. Baglino {BIO 21161872 <GO>}

Or the plane.

Elon R. Musk {BIO 1954518 <GO>}

-- and the plane. To take advantage of the fact that it is a new source of energy. It's -- that's -- it's a different architecture. So just like with an electric car, you wouldn't just take a gasoline car and stick a battery in it. That's very suboptimal. It's much more efficient to have the battery be the structure of the car and make it as -- make it mass efficient and optimize for batteries. To say, if that's done with aircraft, that you can get long-range aircraft at around -- with cells at around 450-watt hours per kilogram, which you can buy it right now actually. They are expensive, but I think that price will come down.

Andrew D. Baglino {BIO 21161872 <GO>}

So when we stack up all of these efforts, we end up with the numbers we shared at the beginning of the presentation, 30 terawatts, 240 terawatt-hours, $10 trillion. And you're -- you may be saying like, I need some context. Is this feasible? Spoiler alert, it's entirely feasible.

Just looking at it from a growth rate perspective. How much do we need to grow the deployment of these technologies? We're talking about only a 3x to growth rate in solar and wind deployment. Solar is already growing at a breakneck pace, as is wind. This gap is going to be closed really quickly. When we look at the electric vehicles, they have to grow 11x. Well, they grew 60% year-on-year last year. That growth rate is also going to close, pretty darn -- that gap is going to close pretty quickly as well.

And lastly, storage. Tesla's energy storage business has grown at 65% CAGR, since 2016. The global energy storage business is accelerating pace as well. I mean, all these gaps are going to close. Especially as this momentum of the transition to sustainable energy accelerates.

And of course, our goal on this page is 20 million EVs per year and 1 terawatt hour of stationary storage per year, basically as soon as we can. And then, what about this investment? How do I have a reference point on this investment? Elon mentioned it's 10% of one year's world GDP. Another way of thinking about it is, how does it compare to what we're investing? Like, what we invested last year in the fossil fuel infrastructure, and it's 60% of that investment. So actually, building this sustainable energy economy is less than extending the fossil fuel economy from year-over-year investment basis. So very doable.

When we look towards, does this fit on the planet? Absolutely. Less than 0.2% of land, as a reference point. The total land area intensively farmed today is 12.5% of all land. So, I mean, you drive around, you see some farms, but you don't see them everywhere, this is an order of magnitude, more than an order of magnitude difference between farming and what we're talking about for sustainable energy land.

Elon R. Musk {BIO 1954518 <GO>}

And it doesn't need to displace farmland or --

Andrew D. Baglino {BIO 21161872 <GO>}

Of course, not. Yes.

Elon R. Musk {BIO 1954518 <GO>}

-- forests or jungle, or any kind of ecological preserve. It can be used in very sparsely populated desert regions.

Andrew D. Baglino {BIO 21161872 <GO>}

Barren areas.

Elon R. Musk {BIO 1954518 <GO>}

Yes.

Andrew D. Baglino {BIO 21161872 <GO>}

Areas that are just not really fit for development or otherwise use, so.

Elon R. Musk {BIO 1954518 <GO>}

Yes.

Andrew D. Baglino {BIO 21161872 <GO>}

I mean, 0.2% can fit into a lot of places.

Elon R. Musk {BIO 1954518 <GO>}

Yes. It's -- there's essentially no meaningful ecological impact. In fact, transition to a sustainable energy economy would result in a substantial reduction in current ecological impact.

Andrew D. Baglino {BIO 21161872 <GO>}

It's a great way to put it.

Elon R. Musk {BIO 1954518 <GO>}

Yes.

Andrew D. Baglino {BIO 21161872 <GO>}

And what about on the mineral extraction side? So this is a cartoon that sort of gives you a sense for all the ore and the, like, extracted minerals that are coming out of the earth every year. It's about 68 gigatons. So each truck is a gigaton.

What does this look like when we're in a sustainable energy economy? Looks like that. Fossil fuel extraction disappears. We replace it with the materials required to fulfill the sustainable energy economy, actually reduces. Now it's not to say that we don't need to continue to explore, bring on mining and refining for the, sort of, specific materials for the sustainable energy economy? We do. But the investment in mass flows are all very achievable, just looking at what is already happening on the planet. Like, this is nothing out of scale of what has been done and is already being done.

And then, we calculated on a sort of element-by-element basis. The resources are there to support the transition. This is cumulative demand to move in the sustainable energy economy direction until 2050 relative to USGS resources today. We're not breaking the resource bank for any of these materials. And then when we look at what really happens as we move forward. History teaches, the more we look, the more we find. What people think happens is, oh, there's this many resources, next year there's going to be less because we're going to extract them. What actually happens is, as we extract resources we find more. And you can see on the right what has actually occurred with the key materials to the sustainable energy economy. Since 2000, the sustainable energy economy has been growing and Tesla has been growing and all the industries around us have been growing. The actual resource availability has increased, not decreased.

Elon R. Musk {BIO 1954518 <GO>}

Yes. This is -- all seems to be quite a bit of confusion about the -- about lithium. Lithium is extremely common. It's one of the most common elements on earth. There is no country that has monopoly on lithium or even close to it. There's enough lithium ore in the United States to electrify all of earth. If the United States was the only place producing lithium. There's enough domestic material to electrify earth. It's very common. The limiting factor is the refining of the lithium into battery-grade lithium hydroxide or lithium carbonate. That's the actual limiting factor.

Andrew D. Baglino {BIO 21161872 <GO>}

And the same is true for these other materials.

Elon R. Musk {BIO 1954518 <GO>}

Yes.

Andrew D. Baglino {BIO 21161872 <GO>}

And this is -- again, these are not like crazy technologies. It's just the investments need to be made. And the investments, they're not gigantic, they just need to happen.

Elon R. Musk {BIO 1954518 <GO>}

Right. Nickel is maybe the -- of them all, the trickiest one to solve. But as we showed with the graph there, maybe need like 30% of the world's nickel -- known nickel reserves. So --

Andrew D. Baglino {BIO 21161872 <GO>}

And the nickel reserves have actually grown since (Multiple Speakers)

Elon R. Musk {BIO 1954518 <GO>}

Yes. There is more -- yes, exactly. So -- and you only need nickel for basically aircraft, long-range boats and very long-range cars or trucks. But's -- the vast majority of the heavy lifting for electrification will be iron-based cells. And earth is -- iron is actually -- literally, the most common elements on Earth. So a little trivia point. If you say like, what is earth made of? By mass, it is most -- it is made of iron more than anything else. And second, oxygen, and then everything else after that. So basically, we're a muddy rushed ball, is what Earth is. So an iron cathode is sort of -- we're definitely not going to run out of iron. There's so much iron, it's insane. So that's it. Yes.

Andrew D. Baglino {BIO 21161872 <GO>}

Yes. And ultimately, there's resource extraction. We go through this effort. We built these batteries and then we recycle these batteries. So ultimately, we're doing this to build this sustainable energy economy, but the maintenance amount of ore that we require is really in order of magnitude more -- less because of recycling.

So in the end, a sustainable energy economy is within our reach, and we should accelerate it.

Elon R. Musk {BIO 1954518 <GO>}

Yes. I mean -- so this is really the main message of today. And I really wanted today to be not just about Tesla investors who own stock, but really anyone who is an investor on Earth. And what we're trying to convey is a message of hope and optimism. And hope -- optimism that is based on, on actual physics and real calculations, it's not virtual thinking. Earth can and will move to a sustainable energy economy, and we do so in your lifetime. Thank you.

Andrew D. Baglino {BIO 21161872 <GO>}

Yes. Thank you. And I just want to welcome up Lars and Franz to the stage.

Lars Moravy {BIO 22525342 <GO>}

Hi.

Franz von Holzhausen {BIO 7162520 <GO>}

Hi. I'm Franz. I lead Design at Tesla.

Lars Moravy {BIO 22525342 <GO>}

And I'm Lars. I've been doing Vehicles with Franz for almost 13 years now.

Franz von Holzhausen {BIO 7162520 <GO>}

So I joined Tesla in 2008 to vertically integrate design into the company, that didn't exist before, it was a pretty small team. I was tasked with designing most beautiful, innovative and well-engineered vehicles on the planet. No small task, in 2008. There is not a lot going on in the EV sector then. Since then, we focused on constant improvement on cost, efficiency, innovation, things that you'll continue to hear about today, while continuing to design the most desirable cars.

Today, we produce cars differently than we did 10 years ago. But the end result is always an exciting, futuristic and desirable set of vehicles.

Lars Moravy {BIO 22525342 <GO>}

Back then, we only had a handful of designers and engineers like myself, but we had a great vision to radically change transportation.

Franz von Holzhausen {BIO 7162520 <GO>}

So back in 2008, where we're designing Model S, we didn't have a factory. In fact, we had a really small engineering team and a tiny design team. But that allowed design to lead all the conversations. It led us to innovate forward-thinking ideas like, how do you fit seven people into a sedan? Or how do you make door handles disappear into the doors? Or putting a huge touchscreen into the center of the vehicle, something that had never been done before.

Lars Moravy {BIO 22525342 <GO>}

And then we won MotorTrend Car of the Year.

Franz von Holzhausen {BIO 7162520 <GO>}

Yes. And we won MotorTrend Car of the Year in 2013. Our first great award, first car. Pretty good start. Kind of a home run, I think. But that whole process resulted in a linear process that you see on the screen. We designed first, then we engineered, and then we figure out how to manufacture it.

Lars Moravy {BIO 22525342 <GO>}

Yes. I mean, I think that's really important. When we were designing the car together, we didn't even know where we're going to build it, and so we came up with many --

Franz von Holzhausen {BIO 7162520 <GO>}

I didn't even know Larz (Inaudible)

Lars Moravy {BIO 22525342 <GO>}

That's true. We didn't -- so once we got Fremont, we were very fortunate and we figured out the manufacturing solutions, sort of, like we were flying a plane and putting the wings and building the engine at the same time. So we knew we had to do better.

Franz von Holzhausen {BIO 7162520 <GO>}

Yes. We knew we had to be better in order to scale. And as part of the Master Plan that you've read, Model 3 needed to be a smaller, more efficient and more affordable version of Model S, but had to be equally great, it had all the things that people loved in their Model S or Model X and -- but be much more affordable. And so we approached the process a little bit differently than the first time around. Now we had teams that we all work together. So we're able to combine design, engineering and manufacturing process all at the same time.

But, somewhere along the way, we changed the manufacturing process to be fully automated. And so we leaned into this whole new way of manufacturing a car, but we had already engineered it. So things didn't quite go as well as planned.

Lars Moravy {BIO 22525342 <GO>}

It was an amazing product, but it landed us in production hell. Many of us who lived through that carry those battle scars. It was a great idea, but it wasn't the right timing.

Like Franz said, automating something that we designed to be built manually is super hard. And we have many, many failed examples of that at the Fremont factory that we ripped out. But some of them eventually still work. This is the one, I actually worked on with a small team of engineers. It's still running today. And some of the engineers that came by said, we couldn't do it or no longer with the company, but it's running and it's running faster than ever.

So we kind of self-imposed constraints on the design when we were doing it to be built manually, and we really didn't think about it. But despite all that, Model 3 is the best-selling EV ever.

Franz von Holzhausen {BIO 7162520 <GO>}

Yes. And Model Y, which is derived from Model 3 is about to pass that. But we knew we had to improve the process further. And with Cybertruck, we designed a vehicle around a vision, that actually started with the manufacturing process. And in this case, the materials dictated the design.

Lars Moravy {BIO 22525342 <GO>}

Forming full-hard stainless steel isn't rocket science, but it sure isn't easy and it limited the way we could do it.

Franz von Holzhausen {BIO 7162520 <GO>}

Yes. Absolutely. It really forces to think about designing something in a way that you couldn't normally stamp pan holes, you couldn't form them in a traditional way. So you ended up with very linear bending processes that are just not in automotive, kind of, language of manufacturing today. But it actually created a very efficient end process and one of the most dynamic designs ever, I believe. It's definitely something that's going to change the road landscape.

Lars Moravy {BIO 22525342 <GO>}

Hopefully, you guys saw it down there and you experienced it. It's definitely real. Those are real trucks. We're on our way to build them. But what that stainless steel opportunity did for us? It has led us rethink the factory footprint. We don't stamp those. That's a huge part of it. We don't even paint them. So our footprint got smaller and we started to think about innovative ways to take those constraints and make great products.

Franz von Holzhausen {BIO 7162520 <GO>}

But that constraint didn't really change the end result of the truck. It's a super dynamic truck and it has all the functionality you would expect out of any of the other competitive trucks. And the best thing about it, it's coming this year.

Lars Moravy {BIO 22525342 <GO>}

So ideally, after all that, we would design, engineer, manufacture, and plan for automation happening together. It gives us the opportunity to question requirements. This is something that is fundamentally only available at Tesla. The places I used to work in the top manufacturing companies in the world, they don't sit together.

Franz von Holzhausen {BIO 7162520 <GO>}

Yes, I (Multiple Speakers)

Lars Moravy {BIO 22525342 <GO>}

We're one team.

Franz von Holzhausen {BIO 7162520 <GO>}

-- where I know has all these teams together, thinking about these processes from the very beginning.

Lars Moravy {BIO 22525342 <GO>}

In fact, all of those engineering teams, manufacturing, design, automation, they're all in one work. They all report to one person. We can't point fingers at each other. So we have to solve them together, which is the best way to innovate. The traditional way of making a vehicle is this, you stamp it, you do -- build a body in white, you paint it and you do final assembly. And what's interesting is, these shops are dictated by the organizational structures that exist and they are dictated by the boundaries that exist in the factories that are laid out. If something goes wrong in final assembly, you block the whole line, and you end up with buffering in between. This is at the tail end of its manufacturing optimization.

Henry Ford, first invented this assembly line in 1922. It's been 100 years and it's really hard to make a change after 100 years. And when you watch it happen, it's actually really silly to a guy like me. You take all these stamped panels, you put them together, then you put them in a framing station, you build a body that looks something like a car, you put the doors on and then you paint them. Once you get the color, you take the doors off and then you start putting the interior inside the car. It comes in through the openings that already exists. I wish it went in like this, big piece like this, but there's actually people coming in and out of the car. There's awkward movements. Then we lift the car up. We put stuff from underneath it. We put it down. Then we put the seats in the car. And finally, we close it all out with glass and we bring those doors and went away for a trip and we put them back in the car.

Most of the time, we're doing this with a big giant car and moving it and doing really nothing to it at all.

Franz von Holzhausen {BIO 7162520 <GO>}

What's funny though in this kind of whole process is that, just recently, Toyota had just called this, "an engineering work of art."

Lars Moravy {BIO 22525342 <GO>}

True.

Franz von Holzhausen {BIO 7162520 <GO>}

The Model Y.

Lars Moravy {BIO 22525342 <GO>}

That was humbling. But at Tesla, it's not good enough. If we're going to scale the way we want to do, we have to rethink manufacturing again. It's part of the Master Plan. We have to make another step change in cost. We started this on Model Y, when we made these huge giga castings, and we deleted hundreds of parts. We simplified assembly with the Model Y structural battery, where we decided the floor should be a part of the car. The battery is the floor. We put the seats in the interior on the battery and we bring it up through a big open hole and we assemble it. And this allowed us to do things in parallel. Fully rethinking the process and reducing the final assembly line by about 10%. And we thought maybe we could do this other places.

Franz von Holzhausen {BIO 7162520 <GO>}

Yes. I mean, in a way the constraints become part of the solution, rather than a problem.

Lars Moravy {BIO 22525342 <GO>}

So when you think about what I'm trying to say, I really want to hammer this home. When you have a car that's about 5 meters long and you have people working around it, like we did in Model 3. And we change that to this process where we take different parts of the car and we can do more at the same time, like we did with the Model Y structural battery pack. What you see here is us doing that on the front part of the vehicle or the rear part of the vehicle. That means, we can get more people working on the car or robots, working on it at the same time. That means, we have better operator density, less time doing nothing. I call that space-time efficiency. It has nothing to do with quantum mechanics. We can have that conversation later. But we get 44% more operator density, which means more work, less time walking back to the station, 30% improvement in space-time efficiency. And because we're not building it in and out of the car with those slow movements of those robots, I showed you from production hell. When we go to automated, it's going to be a lot easier.

In the end that will probably look something like this, where we balance parallel and series manufacturing in a way where we only do things that are necessary. With a much shorter final line blocking a lot less of the entire rest of the factory, so we can optimize material flow using the best practices. And what that means, it's going to look something like this. Where we build all the sides of the cars independently. We only paint what we need to. And then we assemble the parts of the car once and only once. We put them where they need to go. The interior is attached from a bottom-up or a top-down strategy, so there's more access for those robots and people. We aren't moving heavy objects around and doing nothing to it. And it means, we're doing more work on the car, more of the time.

And then when we take it, all of these tested sub-assemblies and we put them together, we finally assemble the car, only one time, putting the sides on with all of their parts to a front and rear that was already assembled, carrying the floor in with the seats, and finally boxing it out with the doors one time. Just like Cybertruck. So in the end, you get the same car, but it's not going to be a Model Y.

Franz von Holzhausen {BIO 7162520 <GO>}

Yes. This is not -- this is a Model Y for illustration, not the next-gen vehicle.

Lars Moravy {BIO 22525342 <GO>}

In the end, what does that mean? To increase the scale and adoption of electric vehicles on the orders of magnitude that we just showed you, we have to make constraints part of the solution. It leads us to greater than 40% reduction in footprint, which means, we can build factories faster with less CapEx and more output per unit. Faster, less CapEx, more output per unit dollar. Zacks going to go into more details on this later, but it also means through this innovation and some of what my other engineering colleagues are going to talk to you about in the future, we'll reduce cost as much as 50%. This is the two-for-one concept, you hear me and Elon talking about on earnings calls.

Franz von Holzhausen {BIO 7162520 <GO>}

Yes. So I think our track record approves that we can deliver the best cars. And we deliver the best cars in spite of, because of these constraints. And I'd love to really show you what I mean and unveil the next-gen car. But you're going to have to trust me on that until later date. Just -- and I promise we'll always be delivering exciting, compelling and desirable vehicles like as we always have.

Lars Moravy {BIO 22525342 <GO>}

Have we ever not? We always do.

Franz von Holzhausen {BIO 7162520 <GO>}

Yes. But what else is Tesla known for?

Lars Moravy {BIO 22525342 <GO>}

Speed. So with that, I want to bring on Colin, who's in charge of making our cars go fast.

Colin Campbell {BIO 17382259 <GO>}

Thank you, Lars. Thank you, Franz. My name is Colin Campbell and I have the real privilege of leading Powertrain Engineering here at Tesla. We make the fastest cars that you can buy for the money, whether they're electric or gas. And the Model S flat that we're looking at here, it has more than 1,000 horsepower and pound-per-pound the motors in that car are as powerful as jet engines. Our cars are super fun, people absolutely love driving in them.

And the other thing that you probably all know about our powertrains is that they're efficient, our cars would go 25% to 30% further than other EVs in our class for the same amount of efficiency. But at Tesla efficiency means more than just reducing how much energy the cars use. It's about how we develop, how we manufacture, how we refine, and how we scale the powertrain.

Now the Model 3 and Y powertrain is a great example of this broader meaning of efficiency. So since we launched it back in 2017, we've continuously improved that powertrain and the factory that builds it. So the drive unit, the engine of the car is 20% lighter for the same power. We use 25% less heavy rare-earths than when we started. And the flower train -- the powertrain factory, which is behind me today, is 75% smaller and 65% cheaper than the one that we originally built.

And what I really want to emphasize is that, we did all of this without compromise. Our cars are just as powerful, they go just as far, they cost the same or less, and the factories have the same output. So, how did we do that? We did it by designing the entire vehicle and the entire factory together as one company. And this sets Tesla apart. We have small and highly-capable teams and to make a critical decision, we can have the battery cell chemists, the mechanical engineers, the manufacturing engineers, the supply chain team, the automation designers, the software programmers, all in one room, working together in real time. And that allows us to make decisions that are best for the whole car and to make them really fast. And that approach is unlike traditional automotive engineering, which is really fractured. And if you were to go buy like a premium German Electric Car, the engineers who designed the drive inverter in that car, they did not work for that car company. They worked for a contractor. And in Tesla, we design the entire car and the factory that builds it.

I want to highlight a few examples of what we've been able to do in-house. Thanks to that unique approach. So inside the charge of your Tesla are transistor packages, and that's at the top of your screen here. And every electron that moves you down the road flows through one of these packages. We designed our own custom package, which is what you're seeing here. And we can extract twice as much heat out of that package as what we could buy off the shelf. And so what does that mean? It means that the silicon carbide wafer that's inside those packages can be much smaller. And silicon carbide is an amazing semiconductor, but it's also expensive and it's really hard to scale. So using less of it is a big win for us.

And then on top of that, orchestrating all of these transistors and making them switch in the right ways is computationally extremely intensive. It used to require four microprocessors, which are shown here in the bottom left. We have developed our own custom microprocessor. It's purpose built for high power electronics. It's half the cost and it does in just one the job of all those four. And these are just two examples of many, that I could use, to showcase our expertise in high power electronics, and that expertise has allowed us to take the cost of the chargers. They were in our Model S, when we launched it in 2012, both the cost and the mass and cut both of those in half.

And even more important, the power electronics, they are central not just to our cars. They are central to our superchargers, into our energy storage products, and Rebecca and Mike will be talking more about that.

So in addition to the work that we've done is software and hardware, we've also done a lot of work in-house on software. So this is the drive unit from Model 3 and Model Y. And if we take a cross section, we see the stator and the rotor and they're responsible for the core function of the drive unit, which is converting electricity into motion. And our custom software lets us simulate the rotating magnetic field that is responsible for that conversion. And getting that simulation exactly right, it's central to the cost, the weight, the size, and even the sound of the drive unit.

Now, you can buy software that will do all of this, but our tools are faster and they are more accurate and that was not easy to do, and that allows us to quickly iterate through millions of possible drive unit designs to find the best one.

I want to highlight one more area where Tesla really excels, because we integrate work that is often farmed out. So when you are making a new product, it's not enough to think about the product itself, you have to think about how you're going to make it at scale. So Tesla, our powertrain and our powertrain manufacturing equipment is both designed under one roof. Engineers were designing the motor, they are in the same room as the engineers who are designing the machine, that's going to put that motor together. And that collaboration pushes us from Day 1 to design products that are not only high performance, but are really easy to assemble.

So, all of this expertise that we have in the powertrain team and hardware, and software, and manufacturing, it's going to have a major impact on our next platform. In our next powertrain. So the silicon carbide transistors that I mentioned that are key component, but expensive. We figured out a way to use 75% less without compromising the performance or the efficiency of the car. And, of course, we know the battery cells supplies one of the constraints on the scalability of EVs right now. Our new powertrain is compatible with any battery chemistry and that will give us great flexibility in battery sourcing.

If we want to make EVs more accessible to people, they have to be cheaper. We've reduced the drive unit cost to about $1,000, and we don't think any other automaker is even close to that number.

Finally, the bigger factor is, the longer it takes to build. If we can build the same number of cars from a smaller factory, we are going to be able to scale EV production faster. Our next powertrain factory is 50% smaller than the one that's behind me today, even though it has the same capacity. All of these improvements, I think, are going to be transformative for the adoption of EVs and our ability to scale them.

There's one more thing that I want to highlight. So I talked about how we had reduced the amount of rare earth in our powertrains. And as the world transitions to clean energy, demand for rare earth is really increasing dramatically. And not only is it going to be a little hard to meet that demand, but mining that rare earth, it has environmental and health risks. So we want to do even better than this. We have designed our next drive unit, which uses a permanent magnet motor, which do not use any rare earth materials at all.

So how does all this fit into the Master Plan? We can make lower cost products that are still efficient and compelling and we can make them at scale. We're going to use less of constrained commodities, silicon carbide, rare earths. We're going to build them all in compact and high-output factories that are easy for us to build quickly. We're going to make that easy-to-scale powertrains, all the way up to the levels that Drew and Elon mentioned at the beginning.

And this achievement, like all of the achievements that I mentioned today, it's only possible because of the incredible people on our powertrain teams. They are absolutely committed to the cause of sustainable energy and that is why we can do what no other company can do. Thank you.

So next, I'd like to welcome my colleagues Pete Bannon and David Lau.

Peter Bannon

Thanks, Colin. Good afternoon, everybody, and welcome to Texas. Picture here is the low voltage system of a Model S from 2012. This car was primarily designed with vendor source controllers integrated by Tesla. There are over 300 low voltage devices that encompass everything from the mundane, like the light in the glove box, to the complicated, like the infotainment computer, to the safety-critical like the airbags, steer-by-wire, and break-by-wire.

The low voltage harness is built from individual wires, cut to length, crimped and inserted into connectors. A manual process that is tedious, error-prone, and doesn't scale well. Going forward, we want to reduce the size and complexity of the harness and enable automated manufacturing.

David Lau {BIO 19018580 <GO>}

These wire harnesses introduced extraordinary complications, especially in the early stages of development in bring up a vehicle, because when we're trying to bring up this entire system and we see that it's not working properly, we don't know whether it's a problem with the software, with the controller, the processor, any of the endpoints in this entanglement of wires, and so we have to go and debug everything, all at once, and Pete's going to tell us about how we're going to make it better.

Peter Bannon

So I'm going to talk briefly about a few things that we've changed over the years since the Model S. With the Model 3 (Inaudible) Tesla started designing and increasing share of our controllers by merging controllers together. And we were able to simplify the design with a significant reduction in wire count and weight, going from as to three, we reduced the wire harness by 17 kgs compared to Model S. And this is a pretty big deal. And just to put that into context, our VP of Engineering, Lars, will deliver a bottle of your favorite spirit to your desk, if you've managed to save a kilogram of weight from our car. So this improvement cost him quite a lot.

Did we skip one? Yes. The original Model 3 controllers were enhanced and then built into Model Y. Those improved controllers were then moved back into Model 3, when we introduced the heat pump. At that point, we had a shared controllers across both cars which helps simplify our supply chain.

Those Model 3 and Y controller designs were then updated and enhanced for the new versions of Model S and X that we introduced in 2021. For Cybertruck, we are now designing 85% of the controllers in the car. For the next-gen platform, we're going to finish the job and be designing 100% of the controllers to give us full control of the design and the supply chain at the component level. Having full control of the supply chain at the component level has been critical to Tesla over the last few years, as the supply constraints have hampered our ability to build cars.

David Lau {BIO 19018580 <GO>}

And with that control comes control over all the software, which enables us to develop features and functionality that we never even dreamed of at the time we designed the hardware. So that's why you see software in your car is getting better and better over time, in ways that we didn't even think of when we designed the hardware in the first place.

Peter Bannon

Yes. Sentry Mode is one of my favorite, last minute changes. With the introduction of Model 3 in 2017, we deleted relays and fuses from the car in favor of e-fuses. E-fuses replace moving parts with solid state transistors, that provide fine-grained control of the power system to software, and allow software to do advanced things like load shedding in the car under adverse conditions. E-fuses also allow for software-controlled retries for transient faults and they all allow for detailed monitoring of the power system over time.

David Lau {BIO 19018580 <GO>}

Yes. The theme you hear a lot about today is software-controlled hardware. And when I think about that in my team, software-controlled hardware is fundamentally about being able to sidestep, what otherwise would have been static trade-offs between one attribute or another in a piece of hardware. We are able with software to instill intelligence, context awareness, and context-specific behavior into what otherwise would have been a piece of hardware that had to get optimized for one type of scenario. We get more of everything.

Peter Bannon

In 2022, we completed the transition of the lead-acid batteries to lithium-ion batteries and -- which use a new tool as connector. We expect lithium-ion batteries to last for the life of the car, so we don't expect anyone to wake up to a dead battery ever again. This eliminates a major source of failures for our car. And the tool as connector makes it easier to service the car and it also includes a software feature to allow validation that the connector has been properly installed at the end of a service event, which removes another source of failures in our cars. Obviously, the mass and volume savings are also significant, which is super helpful.

At Tesla, we're always trying to improve every single component in the car and a nice example of that is the 15-inch display that was originally shipped in the 2017 Model 3. Over time, the cost of the display has gone down 24%. We've been able to reduce the weight by 12% and we've reduced the power by 33%. At the same time, we've increased the brightness of the display by 50% and improved the color accuracy. So this is one of our favorite things at Tesla just to make a component cheaper and better.

At Tesla, the drive to improve efficiency in the car is never ending. I think of it as like peeling a carrot, you just take a swipe at it, a little bit falls off, doesn't really make much of a difference. But if you just keep at it over time, it accumulates into a pretty significant improvement.

One of the changes that we're looking to make right now is to change something that's been steady for the last 60 years, 12 volts. 12 volts has been, as I said, for 60 years. The demand for power in the car has been steadily increasing to the point where we now have to have pretty large wires to drive over 200 amps of current around the car, which increases the mass and cost. With Cybertruck and all future Tesla platforms, we will be moving to 48 volts. This reduces the current needed by a factor of four. And since power loss in the harness is resistance times the square of the current, a 4x reduction in current leads to a 16x reduction in lost power, while distributing energy in the car. That allows for smaller wires, smaller e-fuses and smaller controllers. It also allows us to make the heat sinks smaller, or in many cases remove it completely, all benefiting the car in terms of mass and weight. 48 volts is the future for (Inaudible) voltage design at Tesla and likely the rest of the industry in due course.

David Lau {BIO 19018580 <GO>}

We welcome and encourage other OEMs and the entire supplier network to join us on this evolution.

Peter Bannon

You bet. As the number of wires in the car is driven by the number of end points that need to be powered and controlled. In the past, centralized control has led for wires spanning the entire car. For Cybertruck design, we have moved to a local controller, where the wire is connected to the nearest controller and those controllers are connected over Ethernet. Wires are routed to the nearest controller, where the data is converted into a network packet for transmission to the correct location on the car. To be effective, the network must be reliable, have low latency and low jitter, and these are all attributes that we've been able to achieve with the current design. The design is delimited most of the cross-work car wires in Cybertruck. And with the next-gen platform, we're going to finish the job and eliminate all of them.

David Lau {BIO 19018580 <GO>}

There's some -- consolidated vehicle network allows us also to make a whole lot more dynamic changes on the fly to how components in the vehicle talk to each other, rather than the traditional approach of separate CAN buses that are spread throughout the vehicle and (Multiple Speakers) in hardware.

Peter Bannon

And one of the nice things is that, you can see the entire vehicle through a single connection, which wasn't possible in the past for debug.

For the next-gen platform, we're looking to optimize the controller design across the entire car and across all of the organizations, not just for a given subsystem. Simplifying the wire harness will enable automation; 48 volts will allow us to reduce the size, mass and cost of the low-voltage system, and those are one of the key things to enabling us to scale production of the low-voltage systems to -- for the Master Plan three. David?

David Lau {BIO 19018580 <GO>}

Cool. So I joined Tesla to 2012. And even in those very early days of the Model S, we already have the ability to update software over the air in all the controllers throughout the entire vehicle. At that time when other cars were just starting to update software in only their infotainment units. And furthermore, we've had sophisticated, anonymized data logging and telemetry capabilities that allow us to understand how the fleet is doing, what customers are doing with it, and how it's responding in the field to that usage.

These two capabilities combined, OTA updates, and data insights, give us the ability to iterate quickly on our software and to maximize the amount that we learn and proceed, and the progress that we make in every one of those iterations. We've used these capabilities to inform countless design decisions, in both software and hardware.

Zachary Kirkhorn {BIO 20940148 <GO>}

Yes, one example is that, we were able to monitor and track the use of the sunroof in our cars, and found that our customers never use their sunroof. So we've made it easy decision to remove it.

David Lau {BIO 19018580 <GO>}

Very barely. Yes, I've had some rest for a while. As another example, we are able to use our collision data to design our crash safety systems for what happens in the real world far beyond what regulatory and consumer ratings test prescribed. And then furthermore, we're able to use that data to recreate in simulation all of those crashes, every single time we make a change to the vehicle's design, or to the software that controls the air bags and other restraint systems.

Here, on this graph, the gray dots that show up first. Our specific crash tests that are prescribed by regulatory and consumer ratings agencies throughout the whole world. And the rest of the color that fills in around and on top of it, those represent the crashes that we've seen happen in the real world. Those are what we design for and what we test to.

Peter Bannon

Right. And last year, this data was used to change the algorithm for seat belt tensioning to reduce injuries in the field, which was OTA-ed to all of our cars.

David Lau {BIO 19018580 <GO>}

Here are a few statistics that demonstrate how staggeringly quickly we gain new insights from the anonymized data that we've received from the fleet, every day. Everyday 123 million miles driven, 1.9 million charge sessions, and those rates are only increasing as we deliver more and more cars into the world.

As another example, we've analyzed patterns in the way the fleet drives and charges to optimally size battery packs for our next generations of vehicles. And you'll hear lots of other examples throughout the rest of the day about how we're using data to inform decisions in the products and in manufacturing.

So you've heard a lot from Pete, Colin and others about how important vertical integration is for us in hardware, but it's especially important for us in software. And this is extremely difficult from the way the rest of the traditional automotive supply chain is set up. In most situations, all the controllers in the car are delivered by different Tier 1 suppliers, whose software is written by Tier 2 suppliers, who farm some of that software out to different Tier 3 suppliers and so on and so on.

Making a change that spans multiple components takes months of coordination, before any work can even start. And furthermore, integration of software in the server side with what's happening in our vehicles has always been a core part of our DNA, and enables us to do things that nobody else can.

Most engineers think about the vehicle as a complete consolidated fully contained system, but in the software team, we think about the system as including the vehicle, as well as all of our back-end, server-side applications and infrastructure, and the resultant feedback loop from the entire fleet that informs all the decisions we make as an engineering team.

For example, we recently released a feature in Model S and Model X that automatically, predicatively adjusts and raises the suspension for ride comfort, before the car hits a section of rough road. We do that by leveraging the fleet to generate a map of road roughness everywhere our cars drive. Sounds pretty simple, but requires coordination of software across a number of different components inside and outside of the car. The restraint control module, whose inertial measurement unit senses the road roughness the autopilot computer whose GPS module and localizer figure out where the car is in the world, our navigation server, which aggregates the anonymize telemetry from the fleet and annotates our map with things like updated speed limits, lane topology and now road roughness. The onboard navigation engine, which looks ahead of the route that the car is traveling on and determines whether things are about to get rough. And finally, the air suspension controller, which takes all of those factors into account and decides continuously, whether it is appropriate to adjust the suspension for ride comfort.

And before we release this feature to the world, we sent prototype versions of it to the entire fleet that ran passively in the background, sending us anonymous data about every time it would have engaged, which taught us exactly how it was going to behave in the wild, in every environment, in every circumstance.

Peter Bannon

Being able to test new algorithms in the background without impacting the car is really critical ability for us, especially for safety critical things like automatic emergency breaking.

David Lau {BIO 19018580 <GO>}

And we've used it to iterate on early versions of our stability control algorithms, which were introduced to the entire Model 3 fleet in 2017 with extreme -- extremely high confidence, even on a very foundational and safety critical function.

Okay. So far, you've heard me talk a lot about how we leverage our software systems to iterate quickly on the customer-facing product. But what I haven't talked about and what we haven't said much about publicly in general, is how we leverage these capabilities in our own internal operations. So for example, in the early days of manufacturing Model S, we very quickly realized that there are a lot of different ways you could miss assemble a car. You could forget to plug in a wire, you could not fully set a connector, you could pull apart from the wrong bin. So when we designed our manufacturing processes for Model 3, and all of our other vehicles going forward.

We took a page from the software playbook, which says, test early and test often. And we applied that mantra to every single car that we build at every step of the assembly line. So now, when a production associate plug something into the car, the central car computer sees that connection, confirms that it's the correct part for the type of car that supposed to be built, installs a software update, if necessary, checks configurations and calibrations, and runs a barrage of tests on that thing and all the other things that are connected to it. And if it finds an anomaly that can't be fixed purely with software, it throws an alert immediately, that is displayed prominently on the vehicles display as well as sent to back-end command and control systems, so that a human can come over and fix the problem, before the rest of the car gets built on top of it.

And we're taking a similar approach in service through a combination of onboard vehicle diagnostics, natural language processing applied to customer narratives, when a customer schedules a service appointment and the suite of internally developed tools. We are successfully diagnosing, scheduling and ordering parts for over 33% of customer concerns in service.

Peter Bannon

Yes. And we also use testers built around our own controllers to test subassemblies before they get to the car, which will be even more important as we go to Larz's unboxed assembly strategy.

David Lau {BIO 19018580 <GO>}

100%. We'll know, with extremely high confidence that before those boxes get put together, that they are assembled -- they themselves are assembled correctly.

Okay You've heard at lots of other events about all the awesome things that our autopilot and AI teams are doing to make the car drive itself, bringing us into the future of autonomy. But we've also been thinking for years about all of the other pieces that we are going to need to manage a network of autonomous vehicles. A lot of this has been happening behind the scenes in the form of platform level functionality, that will leverage later. But you've seen some of it surface already in terms of features that our customers and our internal operations teams can benefit from.

Like in 2021, we built on top of our mobile app Phone Key and gave our customers the ability to share their car with anyone by sending them an invitation in a text message or an email. Last year, we introduced profile synchronization, which synchronizes your seat, steering and mirror positions, as well as your settings, media favorites, and stored navigation locations across all vehicles in your account.

Internally, we have an app that allows our personnel and engineering, manufacturing, delivery and logistics to view, locate and drive all Tesla owned vehicles at their site. And when customers bring their car into service, when they receive a Tesla's own service-loner vehicle, we are starting at some locations to automatically add that vehicle to the customers mobile app account, so that combined with cloud synchronized profiles and Phone Key, it's a completely seamless experience. As soon as the customer walks up to that loner, it behaves and feels exactly like their own car.

And all this is built on top of end-to-end encryption and cryptographically signed commands. So that customer data remains private and obscure, and the fleet only trust commands from authorized parties. So that's a bit of a preview of all the pieces that we're building, looking ahead to our future of autonomous fleets: synchronization, permissions management, security and privacy.

And that has been a whirlwind tour through some of the things that we're doing behind the scenes to enable the efficiency, cost reduction and speed that we are going to need for our next phase of growth and for the next phase of the Master Plan.

And so now, to tell us about the latest in full self-driving, I'd like to introduce, Ashok.

Ashok Elluswamy {BIO 22648673 <GO>}

Thanks, David and Pete. Hey, everyone. My name is Ashok Elluswamy. I work on Autopilot and Self-Driving at Tesla. I joined Tesla back in 2014. So I've been working on this problem for almost nine years now.

Yeah. Some of you might be wondering, hey, what's the Self-Driving got to do with the plan to a sustainable future? But it's actually a critical part of this plan and here is why? Currently, when the car is not being used, it is sitting idly in parking lots, not doing anything. But when autonomy is truly unlocked, this car, instead of being idle, can go serve other customers. This fundamentally reduces the need to scale manufacturing to extreme levels because each car is being used way more.

But this is no trivial problem. Building a scalable, self-driving system is I think one of the hardest real-world AI problems out there right now. Nonetheless, we at Tesla, have made significant strides in making one of the most general systems at solving this problem.

There are three main parts to get right to build a scalable problem. First is the architecture, the architecture of AI system. Second is the data and third is the compute. We'll start with the architecture.

At Tesla, we are betting on AI machine learning neural networks to help us build a general vision and planning system. In the early days, we used to have single camera, single frame neural networks that produce some outputs. These were stitched together in some post-processing steps for the planner. But this was very brittle and was not leading to great success.

So what we did in the last few years is transition most of our stack into this multi camera video neural networks. These neural networks take in live feed from the car in real time of the eight cameras in the car and produce a single unified 3D output space. There are many tasks that we produce such as the presence of obstacles, their motion, lanes, roads, traffic lights, what have you?

This is one example output that you're seeing here. This is from our occupancy network that predicts the positions of obstacles and their motion. You can see that it precisely captures the (Inaudible) violent motion of this truck next to us and this helps the planning system to avoid a collision with this object.

Some of the tasks such as lane connectivity are more complicated to model using navy methods in computer vision. So, we don't stop at the computer vision techniques, but we reach out to techniques in other areas such as language modeling, reinforcement learning to model this task. This is similar -- these networks use similar techniques such as transformers, attention modules, autoregressive modeling of tokens similar to what language models like ChatGPT do out there.

With such an end-to-end system of solving perception, we have really removed the brittle post-processing steps and produced high quality output for the planning system. Even the planning system is not stuck in the old ways; it is now starting to use more and more AI systems to solve this problem. The neural network-based planners are needed especially in complicated urban planning, when there's a lot of other objects interacting with us.

This is for example an intersection, where we have to turn left while yielding to crossing objects and to the pedestrians crossing the road. We have to do this both safely and smoothly while respecting everyone's right-of-way and preferences. If this was done naively, each configuration would take 10 milliseconds of compute and there are easily thousands of configurations to reason about. This would not be feasible using traditional compute. But using AI, we have packaged all of this into a 50 millisecond compute budget so it can run real time.

The second big piece of this puzzle is the data. This is where Tesla has a unique advantage because it can tap into the fleet to access the exact data that can fix the problems. But raw data is not sufficient. We -- in order to train these networks, you need label data, you need labels to supervise the networks. And if you only depended on the human labelers, this data would be too tiny to train these large multi camera video module. We need lots and lots of data to train these networks.

Hence, we have built a sophisticated auto-labeling pipeline that collects data from the fleet, runs computational algorithms in our data center and then produces the labels to train these networks. Here, you are seeing a 3D reconstruction that is happening by collecting various clips from different cars in the fleet and assembling them all of them together into a single unified representation of the world around the car. You can see all the lanes, the road boundaries, curb, crosswalks, even in the text on the road being accurately reconstructed by these algorithms.

We don't have to stop at this kind of reconstruction. Once we have this base reconstruction, we can build various simulations on top of it to produce an infinite variety of data to train for all the corner cases. We have a capable simulator that can synthesize adversarial weather, lighting conditions and even the motion of other objects to test all the corner cases that might even be rare in the real world.

Here's an example of why this data is critical and how we can solve problems using data. So back in the days, for example, in this case, we had some false breaking where we thought this car that's actually parked there was going to move into our path and hence, we were precautiously braking. But it is unnecessary because the car is truly parked.

So how can we solve this? What we did was we mined the fleet for similar cases where the car is false braking due to some parked car. We added 14,000 videos to our training set. And then once we trained the networks again with this new data, it now correctly understands that okay, there is no driver in this car and so it must be parked, so then there is no need to brake. And this is a systematic way to solve problems.

And on the chart on the right side, you can see that every time we add data, the performance improves. And then we can do this for every kind of tasks that we have in our system. And this is what we call as data engine. We identify challenging cases such as the one you saw earlier and there could be other different types of challenging cases too. We mine the fleet for such data, put it through our auto labeling system and produce the labels added to the training set. And once you have the newly trained models, we deploy it onto the fleet. If we rinse and repeat this process, everything gets better and better.

The final critical piece is the compute. In order to train these large models in a reasonable amount of time, you need lots of compute. In addition, compute is also required to produce the labels automatically. This is just compute in our data centers. In addition, we also have high computers in the car, which can run up to like 150 teraOPS of compute.

On the back end, we have a 14,000 GPU cluster and roughly 30% is used for auto labeling and the remaining 70% is used for training. We also have a 30 petabyte of video cash and this is growing to 200 petabytes. All of this is going to significantly increase once we bring Dojo, which is our training computer onboard into this.

Just to give you a reference, just the occupancy networks that you saw earlier use 1.4 billion frames to train these networks. We have already shipped our FSD Beta software to pretty much everyone that has bought it in United States and Canada. This amounts to roughly 400,000 customers who can turn it on anywhere and then the car would attempt to drive to the destination, is still supervised but it can already handle turns, stop at traffic lights, yield with other objects and generally get to the destination.

We have observed that people who use FSD are already 5x to 6x safer than the U.S. national average. Like, I mentioned earlier, the solution to scalable FSD is getting the AI architecture, the data and the compute just right. And we have assembled a world-class team to execute on this. We are pushing the frontier on these three items and as we improve the safety, the reliability and the comfort of a system, we can then unlock driverless operations, which then makes the car we use way more than what is used right now.

With that, I'd like to introduce Elon back on stage to give some more updates.

Elon R. Musk {BIO 1954518 <GO>}

Is there a video?

Ashok Elluswamy {BIO 22648673 <GO>}

Yeah, next leg is video.

Elon R. Musk {BIO 1954518 <GO>}

It's been weird seeing the arms and legs just separate. We have a whole lab full of arms and legs with bearing in mind that when we did AI Day,(Inaudible) didn't work at all. So, the rate of improvement here, I think is quite significant. It's obviously not doing parkour[ph], but it is walking around and we have multiple copies, I suppose of Optimus. I think that's -- I think Tesla brings to the table that others don't have is that we have the real-world AI -- we're the most advanced in real-world AI. So the same AI that drives the car, which you can think of the car really is a robot on wheels and this is a robot on legs.

So, as we solve real-world AI, I don't think there's any -- I don't think there's anyone even close to Tesla on solving real-world AI, that same computer and software goes into Optimus. So it's not that helpful to have a humanoid robot if you have to program every individual action. It needs to be able to walk around autonomously and solve tasks. You should be able to instruct it in simple things by showing visually what you're -- what the robot needs to do or just telling it what to do.

So, I think that's a key advantage that we have and then we also are good at designing things for manufacturing and then manufacturing itself. So the actuators in Optimus are all custom design Tesla actuators. So, we design like the electric motor with the gearbox, the power electronics, obviously the battery pack and everything else that goes into Optimus.

We're actually quite -- we were quite surprised to find how little was available off the shelf because there's a lot of -- vast number of electric motors gearboxes and whatnot that are available in the world. And we found none of them were useful in a humanoid robot, virtually none. So, you have to custom design the actuators for a humanoid robot. And so, the same team that designed the ground-breaking electric motors that are in the say, the Model S Plaid designed the actuators in the robot.

So, I mean for practical purposes what this means is that we should be able to bring an actual product to market at scale that is useful far faster than anyone else. And assuming the things I'm saying are true or at least put it -- I think they are true, it's just the question of the timing, you start getting into interesting questions of like, what's the ratio of humans to humanoid robots? I think it might be greater than one-to-one. Because you can sort of see a use -- a home use for robots, certainly industrial uses for robots -- humanoid robots. I think we might exceed a one-to-one ratio of humanoid robots to humans. It's not even clear what an economy means at that point since the economy is output per person times persons, but if output is much higher and there's no limit on persons, then what's the actual limit on the economy? We're still pretty far from Kardashev Scales here, but we're getting there.

So anyway, so probably the least understood or appreciated part of what we're doing a Tesla that will probably be worth significantly more than the car side of things long term. So charge --

Unidentified Speaker

I think Rebecca is next for

Elon R. Musk {BIO 1954518 <GO>}

All right.

Unidentified Speaker

-- talking about charging.

Elon R. Musk {BIO 1954518 <GO>}

Charge.

Rebecca Tinucci

Hi, there. My name is Rebecca Tinucci, and I lead our Charging Infrastructure teams here at Tesla. And at Tesla charging, we have understood since day one that a great charging experience is the linchpin to electric vehicle adoption. And that understanding has meant that we've always taken a holistic approach to charging.

That's a word that you've heard a lot here today, but what it means for charging is that, we've considered every use case. We think a lot about what it means to charge at home, even if that home is an apartment or condo, and we spend a lot of time thinking about, what does it mean to charge away from home including if that's for daily commuting or if you're going on a road trip. And this holistic approach has led to some pretty incredible results.

In 2022, we provided 9 terawatt hours of charging across our various charging methods, over 50% of that was supplied via convenient AC home charging. And when our customers are away from home, they can visit one of our 80,000 charging points that includes 40,000 of our beloved superchargers.

Now getting here has meant that we've spent ten years building charging infrastructure when basically no one else in the industry would do it. And while, we certainly have a lot of areas that we want to improve, those 10 years have afforded us the opportunity to get pretty good at charging.

First, we have the industry's lowest deployment costs. Our costs are often 20%, if not 70% lower than alternatives and that goes for both our supercharging hardware and deployments and our AC charging product lines. A lot of reasons that we're able to achieve this. You've heard a lot of them here today, we've vertically integrated with manufacture and engineer all of our own charging equipment. We share components across our different product lines. And on the supercharger side, we also install and operate all of our own sites and that's led us to be pretty obsessed with finding new ways to innovate around installation.

As an example, we have recently extended our excellence in manufacturing to how we build supercharger sites. We are pre-building for post-supercharger units at our factory and giga -- at our factory in New York. We load them on a truck. We truck them to site and then we crane them into position. This method saves us 15% on our deployment cost and we can install a site in a matter of days. Once we install a site, we also operate at really efficiently. Over the last few years, we've been able to cut our per kilowatt-hour cost by 40%. Again, a lot of reasons for this but one of the top of the list is we've focused on increasing our site utilization. Site utilization is just how many sessions or kilowatt-hours can we push through a site or a post, and basically doing that allows us to spread our cost over more sessions, thus lower cost per kilowatt hour. But of course, that's easier said than done, because when we push up side efficiency, of course, the risk is that we have a poor customer experience and we have wait time at our sites.

This is where trip planner comes in. Trip planners are in-vehicle routing or navigation system. Other electric vehicle manufacturers or some of them have vehicle side data, other infrastructure providers have site data. But at Tesla, we have both. And what that allows us to do is to use trip planner to route vehicles towards available sites and away from congested sites so we can balance our utilization without risking wait time. And the results speak for themselves.

Over the last few years, we've been able to drive up site utilization by 30%, that means lower per kilowatt-hour cost, while also cutting our wait time in half. And we think this can get even better. Today, we're feeding trip planner with real-time site information and information about vehicles currently at sites. Going forward, we'll be moving that to projecting site occupancy based on the understanding of what vehicles are currently routing to those sites. And ultimately, our vision for trip planner is that it's the air-traffic controller for electric vehicle charging across all infrastructure on a global basis.

And the last thing we focused on to get here is quicker charge times. We're really proud of what we've been able to accomplish here. We've shaved off 30% of our charge time -- average supercharging sites time, visit time over the last few years. This has taken improvements on the hardware side, with our software on our on our vehicles and on our infrastructure and we're really excited to continue pushing this trend down.

Looking forward, the job does not get any easier. As you heard earlier, we aspire to a fully electrified global fleet. That fleet from an industry standpoint needs 9 petawatt hours of charging on an annual basis. And while Tesla charging certainly doesn't have to supply all of that, it does require that for our part, we have a few new focuses in order to scale.

First, if you want a fully electrified global fleet, all of those vehicles have to have a great and reliable charging experience. So, as many of you know, recently, we have started opening up our networks on a global basis. Over 50% of our superchargers in Europe are currently open to other electric vehicles. We've also opened up in Asia-Pacific with our first sites in Australia and just yesterday, we opened our first 10 supercharger sites here in North America in the U.S. to other electric vehicles.

We've also invested a lot to be able to make this a really easy experience for our new customers. All you have to do is sign into our Tesla app to unlock a post and start charging. We've also -- on physical site changes, we've also added hardware to our sites, they're called magic docks and basically, that is installed in areas where we have different charging standards and they allow for other electric vehicles to come to our site without having to bring their own adapters or hardware. We've also just started installing our fourth generation, supercharger posts, those are being installed in Europe first. And while it's not a big mention -- not a big thing to mention, they do have longer charging cables so that we can more easily reach the charge ports of different vehicles.

The second thing we need to make sure we do when we talk about scaling all of this charging infrastructure is we need to make sure that it's powered from renewable sources. We're very proud that over the last two years, we've procured enough renewable energy to offset the amount of charging we've provided to customers. But as we look forward and we talk about this fully electrified fleet on a global basis, we really want to make sure that the demand for charging more closely follows when renewable sources are available.

Now this chart is on an aggregate basis for the U.S. and it varies based on what your renewable generation sources are locally. But basically, what this shows is we want to kind of move that charging curve and for solar and wind in this example, it means more daytime charging. And we think the best way to go towards daytime charging is to install AC charging that is convenient and low-cost, everywhere vehicles are typically parked throughout the day.

So that's really the plan. While supercharging and home charging definitely stay a big part of the puzzle, our teams are currently scaling to install AC charging, everywhere vehicles charged during the day so we can power them from renewable sources.

So, summing it up, while we've spent 10 years installing infrastructure that is low cost, it's efficient and it provides a great customer experience, we're really just getting started, when we talk about supporting Masterplan Part 3. We've got a scale capacity on an industry-wide basis to 9 petawatt hours on an annual basis. We've got to open up to non-Tesla's and make the charging experience for everybody really great. And we've got to power all of this via renewable sources.

And one more thing, yes, we've got to scale our infrastructure. And yes, we want to power it via renewable sources at Tesla. So, we also want to make sure that we're continuing to focus on providing really incredible charging experiences.

With that, want to welcome up our leaders of supply chain, Roshan and Karn to talk a little bit a little bit about that topic.

KarnBudhiraj

Thanks, Rebecca. Hi. My name is Karn, and my team leads supply chain for electronics, powertrain and battery at Tesla. And we've also got responsibilities for indirect purchasing, construction procurement and warehousing and distribution.

Roshan Thomas {BIO 19053050 <GO>}

Hi. My name is Roshan. I've been with Tesla for over 14 years. My team manages vehicle commodities, solar, logistics, planning and capital equipment.

KarnBudhiraj

10 years, forgot that. So today we wanted to provide you a quick overview of Tesla supply chain and what really separates us from the typical automotive supply chain. As you've seen in presentations prior from Pete, Andrew and some others, Tesla designs a lot of the sub components that go into our vehicles. So, we're not buying things that are off the shelf from suppliers. So, supply chain is not purely a commercial relationship as it is in most other companies. We actually have an arm within supply chain called supply, industrialization, engineering, and the burden of taking a drawing, a design from concept and turning it into thousands of products produced at the right cost and at the right yield falls with this group.

Of course, they worked very closely with design engineering. But really, the level of detail that our engineers get involved in terms of building the capability of the suppliers is pretty detailed. So, once we get a new part, naturally, with electric vehicles, a lot of the supply chain doesn't exist. Our engineers would basically take the drawing, turn it into the manufacturing concept, do the equipment selection and physically go to the supplier and stay there for weeks or months however long it takes to basically do the line bring up.

Once the line is brought up and we're hitting the right rates, the right quality at the right yield, then we work on things like automation and yield improvement and those types of activities. So there's a big group of mechanical, electrical, industrial, you name it, engineers within supply chain and it's their responsibility to take care of this.

Now, this is a huge strategic advantage because we manage every detail of our supply chain because we are so integrated with our partners that we know about issues before they happen, it's almost live. We've got dashboards, we've got connections and across the 10,000 or so factories across the world that are making our components, we have a pretty good view of the health of those suppliers and this has been a key asset and how we've been able to kind of manage things through a lot of different issues over the past couple of years.

So supply chain is a game of perfection, perfection is a passing grade. It's like a-- if one part doesn't show up, that line goes down and our CEO finds out about it in less than 20 minutes. And Tesla is very different than Apple, they outsource manufacturing, we do at in-house. So supply chain is kind of right in the middle. And perfection is increasingly elusive and very expensive if you kind of look at all the issues we've had to encounter over the past year. And today, we're just going to talk about how we got through the past and then what are we to do going forward and how we're going to get there?

So, let me draw your attention to this slide. On the left, you will see a portfolio, our existing portfolio of products, right? At the top, you've got the S and X platform; in the middle, you've got three 3 and Y. I think, everyone's more than familiar with those and then the Tesla Energy platform which is a very high rate of growth for us. And you see --

Roshan Thomas {BIO 19053050 <GO>}

Don't forget the solar and superchargers.

KarnBudhiraj

And solar and supercharger. Thank you, Roshan. And you'll see a reduction in so -- and then we've basically got the Tier 1 and Tier 2 parts. This might be boring, but a Tier 1 supplier is any supplier that builds and supplies parts directly for consumption in our five factories and our Tier 2 supplier basically does the same thing for a Tier 1 supplier. So they are the supplier to our supplier. And depending on the supply chain of any one of these products, this can actually go down to the Tier 6 levels.

For example, if you're talking about the battery cell, we really get involved with the minds of like what we're procuring, the lithium, the cobalt and all that sort of stuff because we're procuring such high volumes of it. So, you'll see a reduction in the number of parts on the S and X platform to the 3 and Y platform. And this is because of the great work our design engineers have done of making the car simpler and easier to manufacture.

In parallel, we actually had a similar strategy and supply chain. We had cast a wide net to a lot of suppliers through the S and X platform. There was a lot of suppliers that we invited to partner with us. And we used that platform as sort of a filter to see which suppliers have the technical, financial and cultural capabilities to match us, right? Like, who do we invite to the party when we really scale things up. And we've really dramatically reduced the number of suppliers that we were dealing with for the 3 and Y platform, and this is an approach we'll continue to do for future platforms as they come along that are even more high volume. So this has really been our approach. It's made things a lot easier and it -- we could figure out the suppliers that were capable of moving at our pace and then the ones that didn't have the desire to or the capability to. You need both desire and capability.

Secondly, the complexity on the Tier 2 level is very high, right? These are the suppliers to our suppliers and there are a lot of components. So think about silica and think about resistors, capacitors, diodes, all the little assemblies.

Roshan Thomas {BIO 19053050 <GO>}

All the raw materials.

KarnBudhiraj

Raw materials, that's even further down.

Roshan Thomas {BIO 19053050 <GO>}

Yes.

KarnBudhiraj

But all these little subassemblies that have to come into Tesla, the complexity is immense. So, even though at the Tier-1 level, we're talking about 8,000 parts total, it seems like a lot but it's not a lot. The management of the Tier-2 is really where we excel. And I'd like to illustrate that with an example.

Meet the car computer, very innocent sounding name and it's anything but, this is an absolute monster to manage. So, I think you've all seen the picture on the left of the autopilot board. That's the top of the autopilot board. The autopilot board also has a bottom and the bottom is populated heavily with components. On the other side of the heat sink, you've got the MCU, the multimedia cluster board, this board is equally complex, it's also double-sided eight layered and these boards -- these computers run so hard at peak operation that they have to be liquid cooled through a heat sink. So, this assembly requires taking those two boards and then bonding them to the heat sink, that's hermetically sealed as an assembly, of course, flashing the software and all that sort of stuff and then that's one part number that comes to Tesla.

So this is an example of one Tier 1 part number, that's a very complex assembly to manage of the Tier 2 level. And there's more than 7,000 components here. There's a -- as we stand here, components being assembled onto a car computer every 1.4

milliseconds, the line that builds this computer is the length of a football field. So, it's quite complicated. And initially, when we first started building this board due to the complexity of it, we had to rely heavily on labor, but once we dial then the quality, the rates and the yield, we started focusing on making this more efficient. The only way to control cost is by removing labor. The first step is removing labor. The second step is fully automating and the third step is turning off the lights and letting the factory run ideally. And that's going to be the goal for us here. So 95%, but our work is not done, we're going to be going a lot further than this.

So, this illustrates the point that a part is not a part, a part has a lot of complexity underneath it. Supply chain is a game of multiple tiers and what's made us successful is our involvement and all the details with our supplier engineers that our Tesla employees, that are Tesla supply engineers, so they are like on our payroll that go and ramp-up these capabilities at our suppliers and then just managing each and every attribute of it. 7,000 a day through the chip shortage, through the pandemic, through all the other stuff that we had to deal with was very difficult to manage, but because we had all the details, we were able to pull this off.

Of course, supply chain is not just about parts, it's also about logistics and a lot of other things. So, I'll hand it off to Roshan for sharing some stats.

Roshan Thomas {BIO 19053050 <GO>}

Yeah. So talking about in board complexity. Just over the course of just last year, we moved about 16 million pallets from our suppliers to our factories. Just to visualize that, if you put those pallets side-by-side, it could cover half the circumference of the earth. And talking about again the Tier 2 complexity, over 1 billion electronic components get moved every week to support the production that Karn and team manages.

KarnBudhiraj

This is right now, 1 billion components a week.

Roshan Thomas {BIO 19053050 <GO>}

Right.

KarnBudhiraj

52 billion a year. This is going to go up by the way.

Roshan Thomas {BIO 19053050 <GO>}

And on top of that, we also have the responsibility to make sure the right component is supplied to the right service location to support the growing fleet of our vehicles and we have about 685 service centers that these components need to show up just in time. And then we've also been as a result of pandemic and even before that, we're working on dual sourcing and triple sourcing some of our critical components. As a result of it, we have suppliers around 45 countries in the world.

KarnBudhiraj

Yeah. Our approach really has been to bring the manufacturing of subcomponents closer to the point of consumption. It makes the supply chain more green because you're not burning diesel moving stuff around and it also gives us a security of supply of having multiple sources in case one factory gets taken offline.

Roshan Thomas {BIO 19053050 <GO>}

And that's how we got through pandemic also.

KarnBudhiraj

Yeah.

Roshan Thomas {BIO 19053050 <GO>}

So last three years were incredibly hard. Karn and I used to look lot younger pre-COVID. But on a serious note, pandemic really changed the game of supply chain management. We were just not being a regular supply chain person. We were rolling up our sleeves and negotiating with state governments, city managers, mayors to help kick-start our suppliers to restart their operations. There are some really inspiring stories where our supply chain team really fought hard to make sure that the factories don't go down. And it's also a testament to the resilience of our supply partners.

Having said that, it was not all about resilience and never-give-up attitude. We had also laid the foundation of having dual sources and also in many instances, we had many things that we had simplified, the parts that we had simplified, the supply chain design that we had simplified due to which we were able to get through the pandemic in much better shape than rest of the automotive.

KarnBudhiraj

It forced us to adapt. We encountered issues one at a time. It was really a team effort. We heavily relied on the government relations team. You've literally had to -- the COVID pandemic, as you're aware, happened at different countries at different times. But unfortunately, you need all the parts to make the car. So at any given point, there was one factory that was lying down.

Roshan Thomas {BIO 19053050 <GO>}

Right.

KarnBudhiraj

There was one jurisdiction that was being -- that didn't want to -- they wanted to shut down the factory because they -- you had an outbreak. So learning the rules, understanding, coming up with arguments points, leveraging the team and getting those, it was a difficult but good experience.

Roshan Thomas {BIO 19053050 <GO>}

Exactly.

KarnBudhiraj

We learned a lot.

Roshan Thomas {BIO 19053050 <GO>}

Yeah. And as we were just figuring out to work with COVID, then the port congestion hit in on the West Coast. Logistics lead time went up by twice the amount and we were operating with less than 35% accuracy in the system. That means at any given point, the ETAs of the vessels were 75% off. So we figure out how work with that and then the chip shortage hits.

KarnBudhiraj

Yeah, the chip shortage. That was a nightmare. But we got through it. I mean, I think it's a testament to the tenacity of the team and the resilience of our supplier partners. It's mostly behind us. And I think the results speak for themselves. Tesla was able to grow production volumes at a time where the rest of the industry had a hard time staying flat. I think they shrunk actually cumulatively.

And we're often asked the question, how did we manage through it? And the answer is very much kind of baked through the presentation today. First, we designed our own electronics. So in order to control cost, we really had to go and build relationships with all the Tier 2 suppliers to negotiate them directly. So, these relationships were formed over ten years ago and we've really gotten to know them well.

So when a shortage hit, we knew who to escalate to, who to call, who to ask for help and really kind of swarming the issue at the point of constraint. So the best team, strong relationships with vendors. And then we also have a pretty sophisticated capacity planning function. Tier 2 capacity needs to come on earlier than Tier 1 capacity. Tier 3 capacity has to be even earlier. And our team does a very good job of having that strategic alignment with all our partners to make sure that the capacity is ready before we need it.

We're a mission-based company. Our goal is to put as many EVs out there. We did not let the pandemic phase us. We were full the throttle. And it was pedal to the metal in terms of our demand signal, that also helped. The silicon industry has very long lead times, they invest billions of dollars in sophisticated fabs that take years to build. So, that stability and demand is something they appreciate it and it's something that is very, very much a Tesla thing.

So, this was looking back, right? This is how we got here. This is how we got from 0 to 40,000 cars a week. Let's talk about how we get to 20 million. So, the question gets asked, is Tesla going to basically break the chip industry if we grow to 20 million vehicles. The answer is no. But let me walk you through a logic on that. So as it stands right now, a Tesla enabled with the full self-driving computer has four times the silicon content of a regular vehicle. So at about the 2 million run rate, we're consuming about 700,000, 12-inch wafer equivalents. That's the industry churn that's thrown around for capacity in silicon. That's how much we're using. So little bit below a million. And the global wafer capacity based on the estimates we've seen is about 135 million. So we're about 0.5 % of the industry, not a lot.

Now, if you get to 20 million, when we get to 20 million, and if we don't make any simplifications in terms of part count, which is also a separate work stream, I think Colin talked about it, Pete talked about it, we're not going to have all these different components, we're really going to simplify the architecture because simpler is better. But even if you don't do that and we take the most pessimistic case, we're going to need 8 million wafers, okay? And the industry is going to scale to 200 million by that point. So still, we're less than 5% of market share. And if we run the same offense we ran all along and continue to work with our partners and invest in fabs and invest in capacity, we'll have the capacity ready by the time we need it. So I really don't see this as an impediment from a supply chain perspective to get to 20 million.

Roshan Thomas {BIO 19053050 <GO>}

Now, I would like to talk about a page that we took out of the electronic playbook and applied it to the mechanical side. Our vehicles use currently the heat pump base technology for the thermal system, but before heat pump, our vehicles used to have a dispersed thermal system connected by hoses. Engineering was inspired from circuit boards and then created a system, which was extremely integrated where 60% of the system was the size of a basketball where it contained about 100 components, 50 sealing interfaces and several different manufacturing processes, all were packaged into this tight size.

Now, why are we talking about this? Well, we launched a system right during the outbreak of the pandemic in Model Y. The team was forced to manage 100-plus components from different suppliers around the world remotely. So, there are four videos playing at the same time. One is the video of the manual line that was created when we started the production and this manual line produced a lot of quality issues, let alone throughput. So we quickly pivoted to a semi-automated line.

But in spite of that, although the three -- throughput was great, the quality issues sustained. So our team decided that fully automated is the only way to go. So before we automate the line, we created a 3D simulation. Now, not many companies or teams have this capability. We're at this point now when a part gets packed, we have the ability to create a 3D simulation of all the complex subassemblies that would be involved in making the part and tell the suppliers exactly what equipment to purchase, what to test and create an end-to-end line in simulation. And that's what we did here.

So, with the help of a simulation, we had a very detailed subassembly cell, which was juxtaposed with the suppliers' factory layout. And then we, after a back-and-forth of iteration and optimizing the processes, we implemented this fully automated line in less than eight months. And the results were remarkable, 99% reduction in labor force.

So a line that would need thousand associates to build the super manifold in full volume now just takes 10 associates. And the quality also went up by an order of magnitude, we have a defect rate of less than 0.005% and a super manifold rolls out every 7 seconds because we have created many automated lines. And these factories are the size of two football fields by the way.

KarnBudhiraj

Roshan, (Inaudible) on that one. 99% two football fields.

Roshan Thomas {BIO 19053050 <GO>}

So why are we talking about this? In a world where labor costs are increasing, labor participation is decreasing, there is a huge turnover and the cost of implementing automation is going down by 3x in the next 10 years. This is how we are thinking about complex assemblies and we were going to push this type of thinking into our supply base more and more who will be building our complex assemblies. This is the only way we think we can confidently scale to the 20 million vehicles target.

To summarize, we have laid the foundation in getting ready to execute Masterplan 3. Our strategy is supply chain design simplification. We are going to make sure that we have more control into the Tiers of the supply chain. We are going to grow responsibly and sustainably with our long-term partners and we will automate.

KarnBudhiraj

Yeah. So going from 0 to 40,000 cars a week was tough? I mean it took a lot of trial and error. It took a lot of learning, there's a lot of pain, there's a lot of mental scar tissue as Elon calls it through that process. But now that we're at that level and the foundation is set, going from 40 to 400 is not going to -- it doesn't really phase us. We have a capable team. We've got capable external partners that have gone through hell with this. The leadership team has galvanized behind the mission and we're going to get it done. So I'd like to thank you for your time and hand it off to Drew and Tom for the next presentation. Thank you.

Tom Zhu {BIO 18977664 <GO>}

Hi, everyone. My name is Tom Zhu. I'm now responsible for Global Production and Sales and Delivery Service. I joined the company back in 2014, and I've been running the company's business in greater China and APAC. Today, I'm representing all the Giga factories and talk about how we can make more cars and faster.

So right now, we have four vehicle factories on three continents to serve our markets. The total number of manufacturing employee is over 65,000. This is also including our amazing team in Reno. They are making powertrains, battery packs or drive units for our vehicle factories. The total installed capacity in all these vehicle factories is about 2 million cars a year. That said, we're always looking for opportunity to grow more capacity from the existing footprint. So, you expect this number will grow over time.

To build more factories is the start to build more cars and we certainly the expert of it. This is the before and after image showing you the progress we've made back in 2019 when we build a gig factory in Shanghai. So in nine and a half months time, we built a greenfield project to against established the vehicle factory. And three months later, we started to deliver our first customer vehicle.

People always ask me, how Tesla can build a factory that fast. Really, we learned from our free manufacturer a lot. We talked to the survivor from the production and tried to avoid all the mistakes we made, and we decided to design a straight line with minimum number of up and downs and turns for easier manufacturing ability and easier construction. We also challenged all the assumptions that people ever know to build a vehicle factory, we deleted and we simplified all the redundancies and the buffers that's helped us to save a lot of time.

Also, we have a very strong in-house construction team in Tesla. If there is ever a job cannot be done by others better and we bring this in-house. So we have this in-house construction team, have a full control over all the activities on site from design, engineering to construction, site management. So this team not -- didn't just build Giga Shanghai, they also build Giga Berlin, Giga Texas and Giga Nevada and they're really the hero behind the scenes.

Like, Larson shared earlier, going forward with the new platform, the more modular design and intensified Gigafactory will be able to make more cars and even reduce the footprint. That also means we can build more factories at the same time. With the drawing after of all manufacturing teams around the globe, I'm happy to share early this morning, we hit the 4 million mark for total Tesla ever built. And the 4 million vehicle actually built in this factory. When you took a tour on our shop floor, you probably looked past it, right? So it took us 12 years to build the first million vehicle and about 18 months to the second -- building the second million. The third million took us 11 months and just shortly less than seven months, we built he four million cars. So we're getting better at a faster -

Unidentified Speaker

- exponential growth.

Tom Zhu {BIO 18977664 <GO>}

Really kudos to the team. So what it takes to run the giga factory? Well, if you have 600 robots, 10,000 trained employees or 5,000 human and 5,000 Optimus and 100s of process, you can do it. Sounds simple, but it's extremely hard.

So there's two key metrics that we predominantly focused on. It is an overall equipment effectiveness and the cycle time. In Tesla, we're setting the passing grade for our vehicle factories with 90% OEE and 45-second cycle time. What that means, the OEE really evaluate the equipment uptime, the machine performance and quality. Simply put, this is the actual production time on a good quality product versus the plan, the productive time, the higher the better.

The 45 second cycle time that means you expect every 45 seconds that there's a car rolling off the final assembly line in the factory. And the faster we rent, the faster we can get the economy of scale. If you look at the chart on the right-- on the left, Shanghai be able to significantly drop our labor hours per car during the ramp, the little dip that has happened in the last Q2, 2022, because of the COVID shutdown. And on the right is the Fremont model Y shop, even this is a 6 year old facility. The team there will still be able to optimize the material flow, eliminate all the single point of failure and drive higher output, hence reduce the labor hours. And actually, this factory keeps setting a new record. Yesterday, they just had a new factory daily record.

Unidentified Speaker

Congrats Fremont team.

Tom Zhu {BIO 18977664 <GO>}

Absolutely. So, how can we reduce the cycle time? Keep improving efficiency. We followed the philosophy Elon shared about a building rocket, which is questioning, basically found the right problem to solve and we start with delete, simplify, then we try to accelerate to pressurize the line and find if the solution actually work, and at last, we think about the automation.

There's one example in Gigafactory Shanghaiing the paint shop, we find that there is an overlap baking range between the PVC sealer in the top coat, it was done by two different ovens and we decided to combine the two processes eventually that helped us, didn't just help us to reduce the cycle time, but also save 9% of the energy consumption and the 9% of the CO2 emission.

Also, we communized the S and X design in Fremont. Right now, we have a common body and common headlamp. We eliminated about 40 parts and reduced about a 10% of the cycle time. So all these improvements really help us to get through a faster ramp trajectory and we didn't just learn from these high volume existing factories, we also learned from the new factories. Most recently, our Gig Berlin factory team implemented a 5G private network on the shop floor, helped us to overcome about a 90% of the over cycle issues for a particular process in GA shop. We're going to soon implement this globally.

So right now, we have an integrated global organization from production all the way to sales and delivery service. This will help us to strength feedback loop between manufacturing and the service. We obviously want to bring a delight for customer ownership experience to our car owners and with this direct feedback loop, we'll be able to turn customer escalations and the feedback into quick actions and improvement on shop floor immediately. With that effort in the past six months, we'll be able to reduce the time in service and early ownership service, also service appointment with time significantly.

So four factories not enough. If we want to hit the 20 million car a year target, we're going to keep building new factories, new lines and that will come up with new product as well. And with all Giga factories and now in the one organization would be able to replicate unified ideas across factories. Also, we will help the new factories that rent faster and also produce a better quality at the lower cost.

Now, I'm going to hand over to Drew to talk about cell manufacturing.

Andrew D. Baglino {BIO 21161872 <GO>}

Thanks, Tom. Yeah, we're not just talking about new vehicle factories but also new cell factories. And we're going to talk about how we follow the same model when we do so. But first I thought I'd just provide a little bit of an update on cell production.

So remember Battery Day, we showed this video with the spoon and how we went from dry powder to film. Let's just say, there's no spoon now. So many of you in this room saw this on your tour today, but here is our dry electrode machine here in Texas one of the lines, we have installed here, fully automated, no spoon from powder and foil into coated electrode out. From a peak productivity perspective, per tool perspective, is over 20x productivity of the tools that we showed folks on the tour and (Inaudible) back in battery day. So we've made a lot of progress on the key, one of the key parts of the cell manufacturing process.

And we've also continued to focus on refining the way we make cells and the factories that the cells go inside. We, as you can see on this chart, from typical 2,170 cylindrical cells to 4,680 made a huge leap, which is basically a 5x reduction in the factory footprint and volume and footprint. And then from going from what we did in Fremont in our pilot line to Texas, we improved further and we're improving again when we go into Nevada. And what this actually represents is a series of actions taken by a very integrated, holistic design team across the product design, the manufacturing design, the process design, equipment design and the facility design. They all need to work together to make this happen. And you can see on the bottom just as an example of simplicity up, investment down and scaling up, parts, we've reduced the number of parts in the cell. Number of processes, significant reduction in the number of processes. And collaborating with those five design groups, we've been able to result -- build -- end up in a -- with a factory that's 10x smaller volumetrically, which means it's faster to get built. It's much lower CapEx per gigawatt hour of output and we can go and scale to our objectives of 240 total terawatt-hours, 1 terawatt a year, of stationary storage of 20 million vehicles a year, with the scalability that is required to achieve our goals.

And we're not just looking at the cell factory itself, but also upstream materials where necessary. What you see here is a -- the rendering of the 50 gigawatt hour a year. Corpus Christi lithium refinery that we've already broken ground on here in Texas, the facility will start commissioning by the end of 2023 this year. This is a good example of something where we're basically talking about breaking ground and starting commissioning within 10 months and with actual production within 12 months, that's the target, similar to what we did in Shanghai, again the result of collaboration and internal execution of construction and partnership with local communities.

Third, this site is 30 minutes from the Corpus Christi ports, located directly on rail. The process route we're taking is a direct soda ash leach of the input material, which means there is no acid roasting. We don't have any of the sort of waste products associated with an acid roasting step. We're designed to consume lithium spodumene, which is a very commonly traded lithium rock. But it is flexible to other feeds from primary and secondary sources.

And similarly, we're working on our cathode facility here in Texas. Maybe you've seen it as you're driving around, which is a 60 gigawatt-hour year cathode facility behind the main building here, 10 months build time there as well. The install -- the equipments being installed for the first line as we speak and will be commissioning starting next quarter. So we are doing this where we need to. Our plan is not to do it always. There are lots of confident companies out there, but we are also trying to sort of accelerate the pace of the industry by trying some new things that are a little bit more scalable and de-risking certain innovations that improve productivity per -- in terms of CapEx per gigawatt-hour and things like that.

And with that, I think that sums up our efforts on the factory side. Mike, you want to come up and we'll talk about energy. All right, take it away.

Michael Snyder {BIO 4141423 <GO>}

All right. Hello, everyone. My name is Mike Schneider. I lead our Megapack organization. I've been with Tesla for almost nine years. I'm excited to talk to you today about the Megapack product and the business and some of the exciting things we have ahead of us.

From the beginning with this business, we have always focused on building successful projects for our customers and not just the batteries in the box. We've built a hardware and a software platform that is able to adapt to environments all over the world, and that is able to scale from small island projects to large gigawatt-hour scale batteries.

We've invested our time and our talent to best understand every aspect, every step in the process and every risk of a project to ultimately provide a solution that is thoughtful, intuitive, provides great value to our customers and is as plug-and-play as possible.

And yeah, just looking at these projects, it's incredible to see them all come together in one montage.

Andrew D. Baglino {BIO 21161872 <GO>}

Seeing the future.

Michael Snyder {BIO 4141423 <GO>}

Yeah. It's compressed. It's 10 years of building these projects and it's incredible to see the impact and to see what we have in front of us.

Andrew D. Baglino {BIO 21161872 <GO>}

Absolutely.

Michael Snyder {BIO 4141423 <GO>}

We're on our sixth generation of our industrial product, which is the Megapack XL that we're building out of the Lathrop, California. We've deployed over 16 gigawatt-hours of industrial and residential products across 50 countries and really Megapack is a market leader. Its best-in-class in efficiency, reliability, energy density and easiest to install, lowest cost to install.

Andrew D. Baglino {BIO 21161872 <GO>}

And we call it XL because it is actually the like largest, heaviest object that you can transfer around the roads of the world without having to shut them down and get crazy permits and things like this. So it is extra large. There is not going to be an XXL, let's just say it that way.

Michael Snyder {BIO 4141423 <GO>}

There's been incredible demand for the project -- for the product. 2023 is going to be a great year. We have gigawatt-hour scale projects being built, the Lathrop factory continues to scale and ramp up and there sinew products on the near-term roadmap. So a lot to look forward to.

How did we get here? Number one, a maniacal focus on all aspects of delivering stationary storage. What do we mean by that? What are some examples? As you see here, the Megapack enclosure for one example, we designed the wire ways directly into the base of the enclosure. So typically, you need to install a bunch of conduits and cables under the ground. Now, you can lift them up and install them directly into the base, increasing the speed of deployment and lowering the cost.

Next, we see the batteries in the power electronics and the power electronics is really the beauty and the elegance of the Megapack. So, this is what converts the DC power to AC power on the grid. The brain is built directly into the product. It is able to connect to any grid in the world right out of the box. It allows it to -- all the Megapacks on a given site to work as one unit. And really, it's what makes it what it is. So I think it's the most incredible feature of the Megapack.

As you build out the full site, what we end up with is the most energy than solution on the market upwards of 300 megawatt hours per acre. And just as a frame of reference, this solution is 2x more power dense than a typical gas peaker plant. So this is the future, this is where we're going.

Andrew D. Baglino {BIO 21161872 <GO>}

This is the product that retires the fossil fuels.

Michael Snyder {BIO 4141423 <GO>}

Yeah.

Andrew D. Baglino {BIO 21161872 <GO>}

One power plant at a time.

Michael Snyder {BIO 4141423 <GO>}

We'll talk about power electronics a little bit more. Tesla is a leader in power electronics. We've deployed over 1.4 terawatts across energy storage and vehicle and we deliver more power electronics than the solar and the wind industry combined on a per annum basis.

Andrew D. Baglino {BIO 21161872 <GO>}

And power electronics, it's hard to under -- to overstate how impactful they are. They are really the glue in the sustainable energy economy between generation, storage and the end-use. Those power electronics devices are switching thousands of times per second -- hundreds of thousands of times per second to efficiently react to whatever is needed either in the car and the grid and because they are so like sort of software driven at their core, they can provide functionality that hasn't been available to the grid in the past and it's one of the reasons why renewables and storage together are such a great solution.

Michael Snyder {BIO 4141423 <GO>}

Yeah. And one reason that we focus on power electronics and control so much is because of the impact that it has on the projects directly. So, just as an example here on the left, we have a firmware feature that we call virtual machine mode, and what virtual machine mode is it contributes to grid stability like a car shock absorber that dampens oscillations or vibrations and keeps the ride smooth. So you can imagine if you don't dampen those vibrations, the vehicle could lose control or someone could get hurt. On the grid, you could have a blackout.

We have one grid operator that is utilizing virtual machine mode and said they will not operate their grid at 100% renewables unless they have this feature -- unless they have virtual machine mode working.

Andrew D. Baglino {BIO 21161872 <GO>}

Yeah.

Michael Snyder {BIO 4141423 <GO>}

But they tried and it didn't work very well.

Andrew D. Baglino {BIO 21161872 <GO>}

And virtually why is it virtual machine(Inaudible) like synthetic inertia, where you turn the battery power plant into like through software behaving like it's a giant spinning machine literally and that like inertia stabilizes the grid. And you don't -- but you don't need a giant spinning machine. You don't need like a huge fossil fuel power plant or giant hydro turbine. You're just going to have the battery do it. And you can program it to whatever you need at that part of the grid or even have it be dynamically changing as the grid conditions change, right?

Michael Snyder {BIO 4141423 <GO>}

That's why we focus so much on and we believe it's the future of how batteries are going to add value, it's going to be more about adding power stability just as it is about energy.

Autobidder is another software feature I wanted to mention. Autobidder is an autonomous energy trading platform that in its most basic senses, buying energy low and selling it high and the owner can net the difference of that. But operating battery storage is actually very complex, upwards -- needing upwards of hundreds or even thousands of decisions every 5 minutes. So it's much more complex than a PV, a solar plant or a wind plant or a thermal battery, a thermal generation plant.

And it's mostly because of the versatility and the ability of the battery to provide so much value in different ways that these decisions need to be made in real time in order to optimize and get the most value out of the batteries that can.

So there wasn't a solution that existed in the market. So we built one ourselves in the market that we've been to markets, we've deployed them in, in Australia, in Texas, in the UK. It is proven to be a market leader. We're continuing to invest in Autobidder as we expand to new markets.

Second point of how we got here? A relentless focus on speed of execution and there's two points to be made here. First one is in building factories. What you're seeing here is a time lapse of the mega factory that that was built in Lathrop. We took it from a JC Penney Distribution Center to a world-class manufacturing facility in less than 12 months, which is incredible. And really the way that we did this is similar to what my colleagues have described, it's leveraging the vertical integration of Tesla. It's getting the vehicle manufacturing team in the same room as construction and engineering and making decisions quickly with all the decision -- with all the stakeholders and decision-makers. We're using the lessons learned from Lathrop as we speak, as we plan for our next factories.

Second, it's about installing projects faster. I've mentioned this already, but plug-and-play is kind of at the core of what we're going for. Over the past four years, we've increased the installation speed by 4x and we've reduced the total labor involved across both construction and manufacturing by 3x. We think that this is key to unlocking our ability to scale and our customers ability to scale with us. We need to make be laser focused on reducing that time for when the Megapack leaves the factory to when it is operational on the grid.

Andrew D. Baglino {BIO 21161872 <GO>}

And it's not just about centralized storage. It's also about distributed storage, the future roadmap of (Inaudible)here at Tesla. And maybe some of you know about this sort of retail plan we have here in Texas and I just wanted to talk a little bit about how that all fits together. So Tesla electric really unlocks the full value of distributed energy and storage products. So it enables, our customers to become their own utility. The data on the page is from our South Australia virtual power plant, another Tesla electric setup that we have.

Over 2022, it's 5,000 customers that we have the data for. You can get a sense for what's happening. So just if they were being provided default utility service and you looked at the cost of serving them in electricity, on average, $140 a month. If they all had solar and Powerwall, but the solar and powerwall wasn't interacting with the grid, wasn't participating in the energy market, the cost of serving that customer would go from -- would half, go from $140 a month to $70 a month.

If Tesla Electric is operating those assets in an intelligent way to benefit the grid, Tesla Electric being basically a software that we developed out of Autobidder for the purposes of these distributed energy resources, we can actually pay the customers to bring their energy services to the grid. That's what happened in Australia last year. And it's always a little bit of a special case there. They represent the future, South

Australia in particular, solar and wind supplied 70% of South Australia's energy in 2022 that compares to 30% in Texas and 35% in California. But it -- but this is an indication of where this is all headed of both centralized and distributed storage resources, providing the key to unlocking fully renewable grids. And Tesla Electric is the retail plan that we're using to bring that to bear for our customers that have our products.

And this is how we're rolling it out. First, as it exists, it's available for in Texas for people who have Powerwalls in their homes, but we need to extend beyond that. Over a billion people live in markets with competitive retail electricity and there's over 2 trillion in annual energy spend In these markets. This is a huge opportunity. And the --our intention is to bring this to market-by-market in the same way that we've approached Tesla Insurance where we can bring value to our customers to reduce their total cost of ownership of our products.

So actually, what we're going to do next and this is pretty exciting here in Texas by the summer, we're going to offer a retail electricity plan to people who have our cars where they can have unlimited overnight home charging for $30 a month.

This is part of reducing the total cost of ownership of our vehicles, and the reason why we could do this is because Texas has a ton of wind, and in Texas, the wind blows at night. So, actually, serving these customers with electricity at night for their cars is the best thing to do for everyone. This is a way to incentivize people to charge at home, at night directly, from renewable power. It's part of the grand Masterplan we talked about at the beginning.

So we're very excited about this and we do see this similar to Tesla insurance as I said, is further reducing the total cost of ownership of electric vehicles.

So putting this all together, we're really at the beginning of this massive ramp in energy storage deployment.

Unidentified Speaker

Yeah. Reflecting back on the Masterplan, we talk about tens of terawatt hour -- needing tens of terawatt hours of stationary storage. So, we have our sites set on annual production rates of 1 terawatt hour, which is 25x our capacity at Lathrop.

In the near term, we see really strong demand for the Megapack product, over 100 gigawatt-hours per year, in 2023 and growing by over 100 gigawatt-hours per year over the next few years. So the demand is there and naturally as we continue to focus on cost and speed and value, the things that we've mentioned, it's clear we need to build more capacity and we need to ramp it quickly.

So while the challenge is big, it's also a huge opportunity for Tesla, it's a huge opportunity for the Megapack business. And I'm excited to see the impact that it's going to make on our good transition.

As am I.

Yes. Alright.

Alright. Thank you.

Thank you all. Yes.

All right and Glory, Brandon, come on up.

Brandon Ehrhart {BIO 20557611 <GO>}

Hi. I'm Brandon with the Legal team. Thank you. Not just for coming, but being investors. Now we have an active and engaged Board and Management Team. We've met with you. And today is the culmination of that. We've heard you, which is why we're excited to share this Investor Day with you.

Now you will hear more from our Board at the appropriate time, but for now, I'm excited to introduce Laurie Shelby, who is going to discuss sustainability and our employees. Laurie?

Laurie Shelby

Thank you, Brandon. Hi, everyone. My name is Laurie Shelby, and I lead the Environmental Health Safety, Security and Sustainability Team. I've been with Tesla for 5.5 years.

So I'm going to talk about Tesla's impact, and of course, that starts with our awesome team members. So you've heard a lot today about our amazing products, our process, our software. You've seen lots of numbers and lots of graphs. You've also heard a common theme and that common theme is that Tesla's team is what drives our success and makes a difference. Whether you're in our factories, and our sales, service and delivery centers, our warehouses or in the field, you can see and you can feel the collaboration that's happening. And you also can see the pride that everyone has in working for Tesla.

So, before I go on, I want to give a big shout out and thank you for our Tesla team globally. So let's -- that was great. That was great. Thank you.

So we are creating a lot of meaningful work through our jobs. We're a huge employer and we're growing every day. We're at 129,000, And more than half of our team works in vehicle manufacturing, and almost 60% of our team is based in the U.S.

People want to join our mission, and we need to grow, and we need to hire the best people. Engineers want to work for Tesla. Look at number one and number two, SpaceX and Tesla. In 2021, we got 3 million applicants. 3 million, that's incredible.

And our culture, our culture at Tesla is anyone at any time can raise an idea or make an improvement, suggestions across safety, people, cost, production, quality, because we have a very simple process called take charge. And take charge is really employee engagement. And as take charges go up, as you can see in this graph, injuries go down. And you know why? People who do the work -- the people who do the work, know how to improve the work.

Sustainability. Sustainability is everything. It's our mission. You've heard about it all day, part of our master plan. But at Tesla, we don't just tick boxes to meet a requirement. We really focus on the impact that our products and our software will deliver. In 2021, our customers avoided 8.4 million metric tons of greenhouse gas. That's equivalent to taking 1.7 million ice vehicles off the road for a full year. Yes.

We're also focusing on doing really good work and driving sustainability into our operations. We have year-over-year reduction in our water use, in our waste, and we're growing and building a renewable energy program within our operations, just like supercharging as you heard. So it's not just about our products, it's the way we make our products, both phases.

Tesla, our company is solving both sides of the clean energy equation. We've got the clean generation, the clean storage. We also have zero emission transport. As this slide shows, from 2012 to 2021, our products generated more energy that was consumed by all Tesla vehicles and our factories. It's amazing. Yeah, I like the claps. Yeah. I'll take all of the claps.

So our vehicles use less emissions than gas powered vehicles. Even in the worst case scenario, 100% coal grid. The Model 3 has less emissions than the average ice car, and we're only going to get better. You heard about that today. Every product we make is more efficient, every factory we build is more sustainable. So it's only going to get better and better.

So, as we build our zero-emission future, we've been talking with our stakeholders, with our shareholders about how do we improve our reporting framework and we are aligning with a TCDF -- so TCFD. So we're aligning with the TCFD, which I know many of you have been asking us about. I also want you to stay tuned because there's going to be much more coming in our impact report. So, thank you all and up next is Zach Kirkhorn.

Zachary Kirkhorn {BIO 20940148 <GO>}

Thank you, Laurie. All right. So this is our last section of our prepared remarks today. Will kind of take what we've discussed today and summarize it at the corporate level for our financials. Maybe before I jump into the details here, we've never done an Investor Day as a company.

We've never brought our leadership team out and asked them to talk about the things that they're working on. So, I feel very fortunate to be able to work alongside this group of people and support their teams. And I also just want to thank them, they're in a room in the back listening to this, for all of the work that they put in to today and getting the company to where it is today. So thank you to the Tesla team.

When we were preparing for today, folks were asking, well, Zach, what should we talk about? And really the only guidance we gave folks is well, talk about the things that you're working on, and talk about it in the context of the master plan. And what did almost everybody talk about today in great detail, all of the work that they're doing to take cost out. Because in this industry, in this business, you survive or you die, based upon the ability to manage our costs.

And so I'd like to talk about cost as well. If we look at our longest-running scale production product, this is the Model 3. We reached 5,000 cars per week, which was our design capacity in mid 2018. And since then we've taken 30% of cost out of this product. And there's two points I want to make about this. The first is that cost reduction as you have heard throughout the course of the day is deeply ingrained in our culture. And I think one of the most important reasons why we are here today as a company.

The second point that I want to make, is that when we're working on cost reduction, it's easy just to take cost out and make our products worse. But we have to take cost out and improve our products at the same time, this is the hard thing to do, but it's the necessary thing to do to continue to move forward. And if you look at a version of a Model 3 that we've built today and you compare it back to a Model 3 that we built in 2018, there's a long list of improvements that we put into the car while also taking costs out of the product.

Cost reduction doesn't just come from one place. There's no silver bullet here. And we push the boundaries on volume with the Model 3 Program, increasing volume 3x over this period of time. We've improved productivity. So in our Fremont factory, we are twice as productive now as we were, in mid 2018.

We've made a lot of progress on overhead efficiencies and product improvements as we've discussed, and a long list of other things including localization, our factory in Shanghai. And as we ramp up volume and as we find efficiencies, we work with our suppliers to do the same and that leads to material cost reductions that improve the affordability of our products.

And as we look forward to our next-gen vehicle, our target is to reduce 50% of cost, and we've talked about that a bit earlier today. From -- going from the Model S and X platform to the 3 and Y platform, we took out 50% of cost. So the task here is to do it again. And this is very important, because as we improve affordability, the number of customers who have access to our products dramatically increases, and as we link this back to our master plan, it enables an exponential growth in our volume with linear reductions in the cost of our products.

The second point I'll make here is that, and again cost reductions don't come from any single one place. And so you can see the buckets here on the vehicle side, battery and powertrain, manufacturing cost reductions and others, these buckets are relatively equal in size. And so in order to take 50% of cost out of the product, we have to go through everything.

But more importantly than just the cost of the car upfront, when we're transitioning to a sustainable economy, particularly with vehicle ownership, it's really important to think about the lifetime cost of the products.

And this chart here is showing what the total cost of ownership per mile is over the course of five years. And we have to think about financing costs, insurance costs, the cost of power, Drew [ph] talked a little bit about that with the plans that were doing in Texas, wear and tear and maintenance on the cars, et cetera.

And we're already at a place today in the U.S. where a base Model 3 on a cost per mile basis is less than a Toyota Corolla, which is the highest selling car in the world. And as we move towards our next-gen platform, we will continue to reduce this. And as we work on Robotaxi variants of this platform, this cost will come down even down even further. So this is a product that has -- that we expect to have substantially lower cost per mile than the highest volume products in the world.

The next thing on cost reduction I want to talk about is operating expenses. We spent a lot of time on our earnings calls talking about gross margins and product cost. We don't spend a lot of time talking about OpEx, but I think this is one of the really important parts of our story.

So since 2018, we've reduced our non-GAAP OpEx 60% as a percent of revenue, and 75% on a per delivered car basis. This is quite staggering, and I want to go into the details about how we've done this. The first component of OpEx which is R&D, the single most important thing here is that we constrain the number of programs that we work on.

So minimizing the number of programs that we're running in parallel and the key here is to maximize the revenue and cash generated from every program that we work on. And also maximize the technology sharing between the programs. So we talked a little bit about how power electronics and our energy business is shared with power electronics in our vehicle business.

If we look at the SG&A side of this, I think, the story here is pretty dramatic. So we're showing here a comparison of SG&A per car delivered, compared to the traditional auto industry, which is both in OEM and the dealership network. And our estimates are that we're 60% to 70% lower on a per car basis. And if you turn this into dollars, this is many thousands of dollars per car.

This is part of the reason why on the last earnings call, I made the comment that we think about operating margin more so than gross margin as a company, because the integration that we have here on the SG&A side, particularly with vertical integration into our dealership network, this provides efficiencies that give us a competitive advantage from cost structure standpoint, relative to other companies.

The other thing that I'll note here is that this wasn't always the case and it wasn't that long ago where these bars would be inverted. And if we go back a little bit in time, when we talk about when we launched Model 3, in the Fremont factory, we went from 2,000 cars per week which was S&X adding 5,000 a week to that for Model 3, got us to 7,000 cars a week.

You've heard some folks here today talk about production hell, but I don't think we've ever talked about as a company as back office operations hell, which also happened at the same time. And 7,000 cars a week, 350,000 cars a year. We want to go to 20 million cars a year and we're struggling at 7,000. And we're saying to ourselves, we have to completely rethink the way that we're managing our back-office operations if we have any hope of efficiently scaling this company.

And so this began a process that we're still continuing to work on today, but it's something that we refer to as the Tesla operating system. So, in the same way that we're vertically integrated into the software that manages our cars, we've also vertically integrated into the software that runs our company. And all of our major departments in the company are using not all of them yet -- but almost all of them are using our in-house software.

Most recently, we removed third-party recruiting software and we're now running our own recruiting software as a company. And this matters a lot because rather than having a complex web of third-party systems that are generic solution, that takes a lot of effort to customize for our particular needs, we've been able to put in place with an in-house applications engineering team, dedicated lightweight software that does only what we need it to do and nothing more.

And that team works very closely with process improvement teams that sit within the business, who are looking through all of the processes that we're managing as a company, and following the exact same process that Tom mentioned in the manufacturing space to look at our processes, delete process steps that we don't need, simplify process steps that are existing, and automate what's remaining.

And the results of this have been, quite staggering to be frank. I think it's exceeded our expectations as well. On the left side of this chart are some examples of the efficiency improvements that we've seen within our SG&A areas as a result of the strategy. The North American sales team is four times more efficient now than they were in 2018. Order operations team, financial services, I mean these levels of improvement are large and there's not enough pixels on the slide here to list out everything. So it's just a couple of examples.

And then in the same way that when we look to take cost out of our products, we want to feature up the product or improve the product while taking cost out, the same has been true with the use of Tesla operating system and that integration with our process improvement teams within the company.

And so we've increased performance and added capabilities, while also dramatically reducing cost on a per car basis. There's a list of self-service functionality that we've put in place, which customers like and also simplifies our operations behind the scenes. We've used the Tesla operating system to expand into our captive insurance phase, which we are fully vertically integrated into. We run our own in-house software. We have our own agents, our own claim software and claims folks who run our insurance business.

This is also very important because as a technology company, data is very important and we use the systems and the access to the data in the systems to pull out extremely granular and targeted reporting that enables us to see every aspect of our business in real time. So we can make adjustments to our operations as needed.

And there are sometimes, examples where we say, man, I wish we were tracking this piece of data. Well, it's a team's meeting away from the applications engineering team to make a request and then we can start tracking that data and make those changes. And so the feedback loop associated with process improvement, inside the company is pretty astounding.

The last thing I'll just mention here which is something I'm personally quite proud of, we've made a lot of progress in our closed processes within the finance team, getting our 10-Q and 10-K filed, it's amongst the fastest of the 20 largest market cap companies. So great work to the finance team here.

So all of this work on cost reduction is extremely important, because we have a lot of money to spend ahead of us, to achieve our goals within the master plan. So we've mentioned over the course of the day today, 20 million annual vehicle production as our target, 1 terawatt hour of annual energy storage production, and then expanding cell production, service and charging in line with the growth of those other businesses.

And so we've estimated what we think the total cost to get there will be. And there's certainly error bars around these numbers as we continue to progress and innovate, but of this, we've spent about $28 billion of that so far in the history of the company. And maybe this total investment looks large. I actually think it's quite small, relative to our ambitions. And if you look at our 2022 operating cash flows and you just say, well, let's assume some modest growth to that, maybe not all that much if you're being conservative, but the ability to pay for this level of investment from the forecast that we have, is very achievable for us.

I'm often asked about capital allocation. I think, our strategy here is very straightforward. I touched upon it, a little bit in our last slide, but just to be explicit about it. Obviously, the priority here is to ensure that we're using capital to run the day-to-day operations of the business. This is a working capital intensive business and this has to be managed very carefully. And so, over the course of a quarter, there can be multibillion-dollar swings in our cash balance up and down, just depending upon the timing of when we build and deliver cars. So we obviously have to have plenty set aside for that.

Downside protection is another really important area where we have money set aside for that. And over the last couple of years, throughout the pandemic, I think this just highlights why being ready for downside protection is important.

Preserving daily operations is the engine that then generates cash that allows us to reinvest into the growth of the business and I'm very proud that over the last couple of years, despite the ups and downs in the macro environment and interruptions to supply chains, we have never once pulled back on our investments in growth, so that remains a huge priority for us.

We do then after investing in growth, we look at opportunistic ways to spend our cash. These are more financially oriented where if the return exceeds a hurdle, then we can place cash in that. This is part of our story of cost reduction in the Fremont factory.

And then on the excess side, this is where the Board meets on a regular basis, and thinking about what our cash flow projections are looking forward and whether it makes sense to do buybacks or dividends.

So, to wrap up the finance portion of the presentation today, couple of key messages I just want to leave you all with here is that we use innovation at an intense level, to drive costs down and improve the efficiency of the business. And the reason this is so important is it allows us to improve product affordability. This is particularly the case when we move to our next generation platform.

Improving affordability allows us to comfortably make investments that grow volume, that volume generates cash, that then allows us to make more investments. And as we integrate that going forward, it's our belief as a leadership team here at Tesla that we're going to achieve unprecedented scale in the manufacturing space. And this is what's ultimately required to accelerate the world's transition to sustainable energy.

So with that, this completes the prepared portion of today. We're going to take a short break, and then we'll resume with the live Q&A. Thank you all very much.

Elon R. Musk {BIO 1954518 <GO>}

All right. So. Well, let's see. So this is -- probably most significant announcement of the day is that we're excited to announce that we're going to be building a Gigafactory in Mexico. So. Yes. And we'll have obviously a grand opening and groundbreaking and whatnot, but we're excited to announce that the next Tesla Gigafactory will be in Mexico, near Monterrey. So we're excited about it.

Now, I do want to emphasize, we will continue to expand production at all of our existing factories, so including California, Nevada, here in Texas obviously and well in Shanghai. So we intend to increase production at all factories, so the Giga Mexico would be supplemental to the output of all the other factories.

So this is not to be clear, moving output from anywhere to anywhere, it is simply about expanding total global output. Yeah, so it's going to be good.

So, yeah, -- you okay, Laurie. So, I think that's -- yeah, we're quite excited to announce that. In fact, I believe the Governor is here, it's hard to see. Welcome. Secretary of State, I believe. So anyway, we look forward to it, and having a big event for the great groundbreaking and opening. So, let's see, with that we can move to, I guess, Q&A.

We've obviously got significant bench strength here. Probably like a bench, maybe we have too many people on stage, but we'll try to answer questions within reason. Yeah, this is meant to be kind of more of a long-term sort of discussion as opposed to what will be the production for the rest of the quarter type of thing. So let's try to orient our questions towards long-term value creation and with that fire away.

Unidentified Speaker

Rod?

Questions And Answers

Operator

(Question And Answer)

Q - Rod Lache {BIO 1528384 <GO>}

Hi, it's Rod Lache with Wolfe Research. Very exciting plans about the next-generation vehicle and powertrains and batteries. I was hoping you can maybe talk to us a little bit about the timeline for deploying this, and it sounds like it's more than just a vehicle, it's is a kind of a paradigm change on how vehicles are assembled? How batteries are put together and everything?

And does that also just get reconfigured into everything that you do. So, the model Ys that are being built here will be built very differently in the future. Maybe just give us some feel for what happens from here and what's the timeline for implementation?

A - Elon R. Musk {BIO 1954518 <GO>}

Well, I'll talk a little bit about that, but broadly speaking, the most profound architectural changes will be in future vehicles. Retooling a factory means bringing the factory down for an extended period of time, and that we prefer not to do that I think. But there are variants in how Model Y is produced. So we've got a variant where there's rear casting, where there's a front and rear casting, and we have the structural battery pack. And then there are a number of small improvements that occur, but I think for really, really big changes, those would be future vehicles. Yeah, I know you guys want to add? (Inaudible)

A - Unidentified Speaker

Me? Yeah. So, I mean as far as, I agree with you 100%, Elon, it's really easy to put innovations in new vehicles, but long-term, we'll obviously bring them back. We've always talked about that, but we don't want to take our factories down. As far as the timeline goes, we're going to go as fast as we can, left to right. As always, Elon alluded to the fact that Mexico will build our next gen vehicle, but we will also be doing that in other plants. And so it's really about getting them all up and running. We expect that to be a huge volume product, and we're going to move that quickly over the next couple of years.

Let's go to Adam.

Q - Adam Jonas {BIO 3339456 <GO>}

Thanks. First, another winner, Mexico. (Foreign Language). That's great. Congratulations. Elon, the question on applying first principles thinking and innovation to an area that up to now has seemingly been outside of your control, and that is on mining and extraction of some of the key materials.

I believe a couple of years ago, you had a patent on sodium chloride to extract lithium from some clays, spodumene clay and things of that nature. Any -- how does that fit into the plan of maybe bringing real innovation into a mining sector that could use a little, maybe waking up and getting those costs down, because that could be a real gating factor it seems.

A - Elon R. Musk {BIO 1954518 <GO>}

Well, we're going to address whatever we think the limiting factor is at any point in time. So we would like to do the least amount possible. So, we don't want to get into the mining or refining sector. We will do that if we have to. I do think the focus really should be on refining capacity. We need to make just a very giant [ph] amount of anode, cathode, lithium, lithium hydroxide, lithium carbonate. It's really the refining capacity that is the biggest choke point. Yeah. So that's why we're building a lithium refinery in Corpus Christi.

A - Unidentified Speaker

In terms of the mining companies that are out there, and looking at that part of the value chain. So we do have large suppliers of lithium right now and we -- they are aware of how we're approaching the Corpus Refinery and the technologies were trying there. And the reason we're making them aware of it is, because we think they're fundamentally more scalable and as we proved them out, we plan to share that with them. Because as Elon says, it's not really like we want to do these things, we're doing them because it's not happening fast enough.

So if we can prove that it can be done faster, intention is to transfer that knowledge to our large -- our current suppliers. And the same is actually true. There's actually a clay process that we were playing with and we continue to work on. The same is true on that. So we've worked with our suppliers as well on trials and we're sharing knowledge there and the intention is just to help the whole world do this better. And ultimately, this year is getting the lithium out or whatever it is out of the ore.

A - Elon R. Musk {BIO 1954518 <GO>}

And we're obviously building a cathode processing facility, just adjacent to this building. So little further down the road you'll see another large construction that's for cathode refining. But we'd prefer others did that. We're doing it because we have to know, because we want to.

A - Unidentified Speaker

Yes. And in that case, there just isn't really any large-scale cathode production in the United States and it needed to be done. And again, if we're going to do it, we're going to try to do it from a first principles perspective. So we have tried a bunch of new things there, we're confident that they will work, and as they prove out again, we want to bring them back to our suppliers that they can build new facilities more quickly with less investment.

Right, let's go to Ben.

Q - Analyst

Hi. Ben Kehler [ph] for Baird. So similar, on the renewable side, is there more that you can do in Tesla to nudge the rest of the renewable industry to speed up, since it's such big pillar of the master plan 3?

A - Elon R. Musk {BIO 1954518 <GO>}

Well, I don't know what more we can do, but I can say that just like entrepreneurs out there that want to have like a guaranteed chance of success, it would be refining lithium or anode and cathode or any materials whatsoever for lithium ion cells as no-brainer. Yes, we're doing everything we can.

A - Unidentified Speaker

Yeah. On the renewable energy thing, the thing that that we can do at Tesla is the more we reduce the cost of storage, the more we reduce the cost of stationary storage, and the more we bring like flexible load to the grid in the form of like cars charging at the right times, the more valuable renewables are. Because in Texas, right now, I wasn't joking, like there's a lot of wind.

And at night, wind is -- there's like almost too much wind, because they don't want to turn the nukes off or whatever. So, bringing really low cost storage onto the grid, makes renewables more valuable, which ultimately will accelerate their deployment. So that's how we focus on it, I guess.

Yeah, Philippe.

Q - Analyst

Thank you. It's (Inaudible) Jefferies. I've got two questions. The first one, when I think about in this industry, everybody wants to be Tesla. Every car marker is trying to emulate what you're doing or done. The one thing they don't do is focus on having as much growth as possible with as few models [ph] as possible. So I'm just trying to understand as you aim for 20 million units in 2030. How many models do you think you need to get there? And how does it fit into your drive to hyperscale? How do you manage this? And also, the fact that probably consumers at some point don't want to see a Tesla or the same Tesla at every street corner. So I'm just trying to get your sense of that.

And my other question is on bidirectional. I mean, you talked a lot about making the world more renewables and better usage of cars. I think bidirectional charging is one way of better using cars, but you seem to have been reluctant about doing that in the past. So I'm just wondering what your latest views are on the topic.

A - Unidentified Speaker

Sure. Bidirectional, it wasn't like a conscious decision to not do it. It just wasn't a priority at the time, I think is maybe the way to think about it. As we looked -- as we continue to improve the power electronics in our vehicle, we've found ways to bring bidirectionality while actually reducing cost of power electronics in the vehicle. And as at all things Tesla, the goal is usually to get more for less, and so we are in the middle of kind of like a power electronics retool, I would say that will bring that functionality to all of our vehicles over the next two years, let's say, but it's -- yeah I guess that's how I'll say there. Yeah.

A - Elon R. Musk {BIO 1954518 <GO>}

I don't think many people are going to use bidirectional charging unless you have a Powerwall, because if you unplug your car your house goes dark, and this is extremely inconvenient.

A - Unidentified Speaker

Yes. Most of the value, it comes in charging the car at the right time. It's not really about sending energy the other way.

A - Elon R. Musk {BIO 1954518 <GO>}

Yes. If you have a Powerwall that can take the house load, then you can use your car as a supplementary energy source to the power wall, and then you're not going to drive everyone crazy by unplugging your car and having the house go off. So I think, there's some value there are as a supplemental energy source down the road, where if you have a Powerwall, you've not diminished the convenience of the people in the house.

Q - Analyst

And the question of number of models.

A - Elon R. Musk {BIO 1954518 <GO>}

Sorry what? How many models --

Q - Analyst

Vehicles models.

A - Elon R. Musk {BIO 1954518 <GO>}

Not that many. Really 10, I don't know. Not that many. I mean what's happened with conventional cars is people have run out of things to do. So when you run out of things to do, they just end up reshuffling the deck, and you have pretty much the same. How many variants of car are there on the road? There's like hundreds. But there -- are they good variants? No, mostly not. They're just variants for the sake of variants. And -- but look at how -- have things converged with the phone, and there used to be hundreds of flip phones, now what do we have? It'll be like that.

Q - George Gianarikas {BIO 19376739 <GO>}

George Gianarikas from Canaccord Genuity. Just had a question about your plans to grow market share in China. And also whether or not the political tensions between United States and China impact your long-term ambitions there? Thank you.

A - Elon R. Musk {BIO 1954518 <GO>}

Hey, Tom. Don't sweat too hard.

A - Unidentified Speaker

Yeah. Well, we're still growing our market share in China, quite as strongly actually. Especially earlier this year, we had a price adjustment. After that, we actually generated a huge demand, more than we can produce really.

And as Elon said, as long as you offer a product with value at affordable price, you don't have to worry about demand. That's basically the philosophy that we follow. We try everything to cut cost from supply chain, from improve the efficiency in the factory and the pass down to add value to our customers. I think, you guys as long as we continue to do that, I'm not too concerned about the market share in China.

And the second part, geopolitical, no one knows. We did our best. We actually create a lot of jobs to the local community, and we generated also with -- at our suppliers' factories, we'll create a lot of jobs as well, and we contributed a lot of to the local economy. I think, as long as we're needed in this country, I don't see much of the risk of that.

Colin?

Q - Colin Rusch {BIO 15823117 <GO>}

Colin Rush from Oppenheimer. One of the things I was struck by in the presentation was the operational efficiency metrics that you guys were talking about. Could you talk a little bit about the velocity of learning cycles and how you guys track that and think about that as an organization, as you work into a variety of other areas from an innovation perspective?

A - Elon R. Musk {BIO 1954518 <GO>}

Anyone want to try that?

A - Unidentified Speaker

I'll say one very high level thing, which is you can't improve something you don't measure and we're like ruthless measurers at Tesla. And once you start measuring things that contribute to operational efficiency, you actually have a path to doing something about it. So, I guess the key is a good measuring stick.

A - Elon R. Musk {BIO 1954518 <GO>}

Okay. It's something I should say with respect to demand, which I've said it a few times over the years, but it sometimes needs to be said again, which is the -- overwhelmingly the desire for people to own a Tesla is extremely high. The limiting factor is their ability to pay for a Tesla, not do they want a Tesla. It's easy for people in this room to lose sight of that. If your income is far in excess of what a car costs, then you look at value for money, but you do not consider affordability. But for the vast majority of people, it is affordability driven. This is why we cannot simply double the price of the car or you could say and think about things in the limit where if you hadn't infinitely desirable car, but it costs $10 million, it wouldn't matter, because most people do not have that. So demand is very much a function of affordability, not desire. Very important.

One of the things we weren't sure about was the price elasticity of demand for Tesla. So like, as we lower the price, how much does demand increase? And we found that even small changes in the price have a big effect on demand, very big. So that was a good thing to learn.

Yeah. And then, as -- this autonomy question is very, very big, because you could potentially have -- I don't know five times the utility of the asset that you currently have. So if a passenger car is 10 or 12 hours a week of usage, plus a lot of parking expenses, an autonomous car could be 50 to 60 hours a week or something like that. And you could get rid of a lot of parking expenses. So, if this is true then as autonomy is effectively turned on for the fleet. It may be -- probably will be the biggest asset value increase in history overnight.

A - Unidentified Speaker

Emmanuel?

Q - Emmanuel Rosner {BIO 16323493 <GO>}

Thank you so much, Emmanuel Rosner from Deutsche Bank. So, as you start launching this next generation vehicle and ramping up volume, what will be your nearest term priority in terms of segment or vehicles focus? The slide that you showed with two vehicles on the right seemed based on form factor. One of them maybe looks like a van and other one looks like maybe like a smaller vehicle, like potentially a Model 2 I guess. What is the nearest focus for you in terms of ramping up the next-gen vehicle? And how do you make sure that by lowering the price point so much, because the cost is going down 50%. You're not cannibalizing demand for your existing vehicles.

A - Elon R. Musk {BIO 1954518 <GO>}

Alright. Demand for our vehicles, in terms of desire to own them, may as well be infinite. It's indistinguishable from infinite at this point. Affordability is what matters. So as you make the car more affordable, we will have demand go crazy basically. The issue is how do we build the cars? The hard part is building the cars. I can't emphasize that enough. The hard part is building the cars and the entire supply chain that goes with the cars. This is a logistics challenge of extraordinary difficulty.

All the things that have to go into the car have to scale with the car, while everything is doing an exponential ramp. And if you miss even one of those things, doesn't matter why, earthquake, flood, fire, revolution. I thought I've heard them all. Any part of the supply chain gets interrupted, and you have a seizure. The hard part is building the cars by far and the supply chain that goes with it. And do you guys want to talk about supply chains though?

A - Unidentified Speaker

Yeah.

Yeah, well, we might.

In the presentation, I had mentioned perfection is a passing grade. We really need everything to happen perfectly and the strategy for mitigating the different risks, some of which were anticipated and some weren't. It's really bespoke to the situation, and then really the unique subject matter expertise and a deep knowledge of the particular supply chain you're managing, to come up with strategies.

So we've seen everything from as Elon mentioned, first the tariffs that flew back and forth. Then the ocean logistics issue, chip shortage, COVID, floods. There was a fire in a fab in Japan that knocked down. There was a massive COVID spike in Malaysia, where a lot of the chips at the backend -- of a lot of chips was down there and more. This was one that Elon was involved with as well. And yeah, that's, -- it's nerve-wrecking. But somehow it works.

Yeah. And all those difficult, I think we have been laying the foundation to be as intimate to our -- all the tiers of the supply chain, building that control and directing the different tiers of supply chain. That's the way we are trying to mitigate the risks that come with it. Again, dual sourcing, triple sourcing, having redundancy is the way we've been trying to mitigate for it.

Yes. And that's fine. When we think about vehicles, when you think about three wires and architecture, SX as an architecture, our next generation platform is more than one segment. And really, we're thinking about all the segments that are available that we haven't captured, and where the market would be, and designing it with our supply chain partners, so that we can go quickly through those segments for where we need. But to Elon's point, if you make a car desirable and affordable, oftentimes it doesn't necessarily matter what segment it's in, because it's one you want.

And we've seen that with Model 3, when a lot of people thought the sedans was not going to be a great hit, but we sell tons of them. So the next generation platform is not one vehicle, it is multiple and it's on the segment, that we will really try and focus on that affordability and desirability point more over than where we started.

A - Elon R. Musk {BIO 1954518 <GO>}

Yes, I mean there's a -- I think, there's an old saying like battles were won with tactics or is it won with logistics. The logistics challenges here are enormous. And when you start like being a very significant percentage of an industry, you can't overcapacitize, it's not realistic.

And some of these things, like you said, like dual source or triple source, you can do that maybe for small things, but you can't do it for big things. Because if you're triple sourced, and one of -- it's like having a plane with three engines, where if any of the three engines fails, you crash. You have to either overcapacitize, which drives your CapEx up and it has idle suppliers somewhere in big warehouses or you design to some overage that's reasonable, and then you have expedited costs, because inevitably if there's something goes wrong somewhere, and you got to fly things around.

So it's really just the rate of progress is the rate at which we are able to scale 10,000 logistics problems. Most significant of those is the cell production. And so, we actually deliberately try to overdo cell production or cell supply to have that exceed what is needed in vehicles, because if it goes below what's needed in vehicles then the factories stall.

So, but then what do you do with all these extra cells? It's like, well, okay, so the much easier thing to scale up and down, is Powerwall and Megapack output stationary storage. So we can then overcapacitize in cells and packs, and scale production of stationary storage, which is much easier to scale than vehicle production. So that's strategically I think a good thing.

Yes, the CapEx for Megapack is tiny, compared to CapEx for vehicles. And also, Megapack demand is quasi-infinite. It basically, as long as we are competitive with utilities, we're going to tell as many. Quasi infinite demand for that really for multitera -- many terawatt hours and we got a long way to go to get to many terawatt hours per year.

A - Unidentified Speaker

Dan. Let's go to Dan.

Q - Dan Levy {BIO 17519730 <GO>}

Thank you, Dan Levy, Barclays. I think we know competitive dynamics differ significantly by region, cost dynamics differ by region. We saw that with your China Gigafactory, far superior cost to what you had in (Inaudible) in your factory, but they're clearly different dynamics. So to what extent are the cost strategies that you've laid out today, do they differ by region or is there more of a global one-size-fits-all approach on reducing cost?

A - Unidentified Speaker

Yeah, I think we're pretty consistent on the strategy here, but we try to have as much localize it as possible. Like in China, 95% -- over 95% of our supply chain are localized, all the way from a first-tier to second tier and to the third tier. And that gave us -- generated a tremendous savings on COGS. And we also have a very localized labor force, and we have access to skilled labor force in the region, in Yangtze Delta region in Shanghai, I'm particularly referring to.

And among over 30,000 of employees in China, we have probably less than 20 expats. So very deep localization we have done there, to be able to have such cost structure. And we try to replicate this approach elsewhere, and in different Giga factories. Of course, supplier base that are different. The labor markets are different, region by region and country by country, but we try our best to localize.

Yeah, and I think that absolutely give us the advantage to compete with the auto EMs around the globe. Another thing is we have this direct [ph] selling mode, like Zach said, it would save tremendous money on OpEx as well. We have full control over all the expenditures across the company. And we don't spend money on marketing or advertising. Everything we saved will become -- the value we can offer to the consumers. So on that part we also follow pretty consistent strategy over the years.

I mean, certainly the manufacturing stuff that Colin, Pete and myself talked about, whether you make it here or you make it in Europe, or you make it in Asia, it applies everywhere. We think about that from the ground up, not specific to any region.

Yes, just one thing I would add to Tom's point about localization and to Lars' [ph] point here, but I would actually say that we're moving in a direction of more standardization in terms of our factories, and our processes, and our cost reduction approaches. So, as we've been thinking about the next generation platform, we've been thinking about the volume that we aspire to build against that, how many individual factories do we need to build? And what is the fastest possible way to expand that footprint around the world.

What we've done with Model Y is each factory is an incremental improvement of the previous factory, which requires engineering hours, engineering spend for each factory design, and then you end up with factories that are slightly different from each other. And as we move towards the next generation platform, I think the term you used Lars is copy-paste. So to get it right from the first time, certainly there will be things that we learn and we make adjustments to, but try to have as much standardization and communalization as possible, which allows us to go as quickly as possible with expansion.

(Inaudible)

Q - Analyst

Thanks. Two questions. One for Zach, and one for Ashok. So, for Zach, how do you think about a long-term growth and operating margins for the business? And when we look at $150 billion to $175 billion in CapEx, the remaining balance of that is that essentially the CapEx guidance through 2030. For Ashok, the multi-trip reconstruction that you highlighted, how is that different for what Mobile Light does, with the REM map that they have? And can you give us any color on the AP for hardware?

A - Zachary Kirkhorn {BIO 20940148 <GO>}

So with respect to operating margins, we intend to continue to improve operating expenses as a percentage of revenue over time and we're continuing to take cost out of our products and try to keep gross margins at a place that's healthy as well. And so from the hardware perspective of the business, you know it's our expectation that we'll continue to stay in a healthy place over time. And then there's a software portion that's out and on top of that.

And so Elon has commented on this many times about the impact that full self-driving software can have on the economics of the business. And in that space, profitability operating margins would be impacted dramatically. But specifically to your point about CapEx guidance, the intent of that slide was not to provide specific guidance, but to just be transparent about internally what our rough estimates are and to provide context that we think getting to 20 million vehicles per year, and one terawatt hour of energy storage is very feasible, relative to our expected cash generation for the business.

That's a number that we'll move as we learn. We may choose to vertically integrate more into things. We may find efficiencies elsewhere, to the whole conversation we're having earlier about do we do mining, do we not do mining. But the entire point is to say that this is something that's entirely possible, based upon our forecast.

Q - Ashok Elluswamy {BIO 22648673 <GO>}

Regarding the multi-trip reconstruction, my point I was trying to make was that we want to auto label most of the data and we can collect data from the fleet, and then reconstruct local areas that can act as supervision for those trips. Since we want to build a scalable, self-driving system, we don't want to really rely on HD maps or anything, even though we could like trivially build something using the same technology, but this is mostly for auto leveling. And this provides like precise 3D labels for all the video sequences involved in the reconstruction.

A - Elon R. Musk {BIO 1954518 <GO>}

It's something that I don't know if we touched on this so much, but in terms of training we have one of the biggest neural, net training systems in the world, and that we expect to increase that to believe an order of magnitude by the end of this year and probably another order of magnitude by the end of next year with some combination of Nvidia and Dojo. So, a much of the scale of that is quite (Inaudible) on people. It's enormous.

A - Unidentified Speaker

Maybe the final two questions, one from Alex and one from Chris.

Q - Alex Potter {BIO 16150582 <GO>}

Okay. Alex Potter with Piper. So, I definitely want to ask Drew or anybody else up there for an update on dry battery electrode, right? So, if you try to over-capacitize towards cells, scale, a lot of this, clearly there's a lot of moving pieces, and it's a complex sort of orchestra with the supply chain, but a lot of it comes down to drive battery electrode, at least to me.

So, how are you trending, that was the most fascinating part of the factory tour for me and looking through that window and seeing that this is clearly not a science project, but anything that you're willing to disclose yields progress where you are today versus where you thought you were going to be. Yeah, thanks.

A - Andrew D. Baglino {BIO 21161872 <GO>}

Yes. I mean as you saw right, like this is a real factory making a lot of dry electrode in an automated fashion. We've made a lot of progress. It's a spectrum like, we're perfectionists and we have clear end goals, and we are -- every week that goes by, making progress towards those end goals, whether it's speed of the tool, yield of that process or the downstream process. We have installed out yet on the rate of progress either ,and that's both on the anode and the cathode side.

And I think the great thing about where we are with the overcapacity that Elon mentioned is it's giving us the opportunity to experiment as we go, rather than just being like stock to something that we happen to kick off a year-and-a-half ago and it is here, something that Elon has said to the team, many times is it okay to scrap equipment or money. It's not okay to scrap time.

So, the way we've been approaching it us probabilistically what do we think is the most likely thing to succeed, and even actually in the factory here you saw more than one anode line, that they are actually operating two slightly different versions of the final process step of the powder entering the tool and it's a competition. Which is going to be more higher yield, which is going to perform better? And we have the luxury to be able to do that, and we're taking full advantage of it to advance the technology as quickly as possible.

A - Elon R. Musk {BIO 1954518 <GO>}

The dry electrode problem is really quite a hard problem. We acquired Maxwell really just for the dry electrode technology, but it just illustrates what a gigantic gap there is between something working at small scale and at large scale. And we've had an extremely talented team of engineers working on, to scaling the dry electrode process and having it be reliable and consistent. And we've been grinding it hard literally and figuratively on this for quite a while. It seems likely that we will be able to scale it to volume this year. Yes.

A - Unidentified Speaker

Yes. I mean we're basically increasing the output week over week, like roughly 1,000 week per quarter is our internal target, and we're tracking to that. I think the -- what you saw is effectively like a ton of material per hour per tool. It's kind of like hard to like rationalize like what that really means. But it's, it is, it's different than like, oh something works in a lab.

It's like, when it's tons of material per hour, there's just different kinds of problems like -- even if you have like 0.1% escape of like finds into the enclosure that your equipment is in, now you have a dust problem and like that could short out some electronics. It's like -- just things like this, where when you're on a lab scale, you don't even notice it. But when you're doing thousands of tons over the course of months, it's like, oh, a new failure mode we found and that's where we're at. But we're knocking those out though. And the team is grinding through it. But progress every week.

Operator

The last question from Chris.

A - Unidentified Speaker

Thanks for taking the question. I have a few follow-ups on the next-gen vehicle. First, when do you think we'll get a look at it, maybe a prototype. Second, are there any details that you think you can share in terms of the size, the content, the performance. And then third, I think you mentioned that you would produce it in other plants in addition to Mexico, should we take that to mean that you can launch it at an existing plant before you're finished constructing the new plant in Mexico?

A - Elon R. Musk {BIO 1954518 <GO>}

I think we'll actually have to probably decline that answer. We will have a proper sort of product event, but we would be jumping the gun if we were to answer your questions. Maybe another question, if there's. Yes. I don't know, anyone.

A - Unidentified Speaker

Well, (Inaudible)

Q - Analyst

I have two questions. This has really been a very impressive afternoon. Thank you so much. Elon, I'm curious as you've doubled and you'll double again, how -- what you've learned about sort of managing a larger enterprise, and what you might have to do to manage a bigger enterprise. And then, secondly, I'm curious on your thoughts on how generative AI and these rapid breakthroughs in AI in the last months could help you make cars sort of less hard to make? Thank you.

A - Elon R. Musk {BIO 1954518 <GO>}

I don't see AI helping us to make cars anytime soon. At that point, I mean, -- at no point any of us working. Big problems, so we'll just chill out. I mean, I'm a little worried about the AI stuff. I think it's something, I don't know, we should be concerned about. I don't think. I think we should need some kind of like regulatory authority or something that's overseeing AI development and just making sure that it's operating within the public interest. And it's quite a dangerous technology. I fear, I may have done some things to accelerate it, which is, I don't know.

So, some of the AI stuff I think it's just obviously useful, like what we're doing with self-driving, which is some people think is an AGI type problem. I don't think it's quite an AGI problem, but it certainly requires a very sophisticated neural net, because the road system is designed for eyes and biological neural nets. So naturally, the analog to that is cameras with digital neural nets. And the other thing we found is just, if you actually look at our neural net architecture in the carts, kind of insane frankly - nets upon nets upon nets upon nets.

Q - Ashok Elluswamy {BIO 22648673 <GO>}

Yeah. The visualization tool crashes, when you open.

A - Elon R. Musk {BIO 1954518 <GO>}

Yeah.

Q - Ashok Elluswamy {BIO 22648673 <GO>}

It's so complicated.

A - Elon R. Musk {BIO 1954518 <GO>}

Yeah.

Q - Ashok Elluswamy {BIO 22648673 <GO>}

It's like so complicated. No one can visualize this right now.

A - Elon R. Musk {BIO 1954518 <GO>}

Yeah, it's hard to -- just like literally it looks insane. So I guess something like that's happening in our brains while we drive around, which is pretty well. So, I don't know, like Tesla's doing good things and AI -- I don't know, this one stresses me out. So I don't know what to think, to say about it. I don't know.

A - Unidentified Speaker

Okay. Given it's 7 o'clock, I think that's all the time we have. Thank you very much for coming and--.

A - Elon R. Musk {BIO 1954518 <GO>}

Thank you.

A - Unidentified Speaker

See you later.