
Thank you, I am happy to be here with so many striving to improve their companies and their technologies.

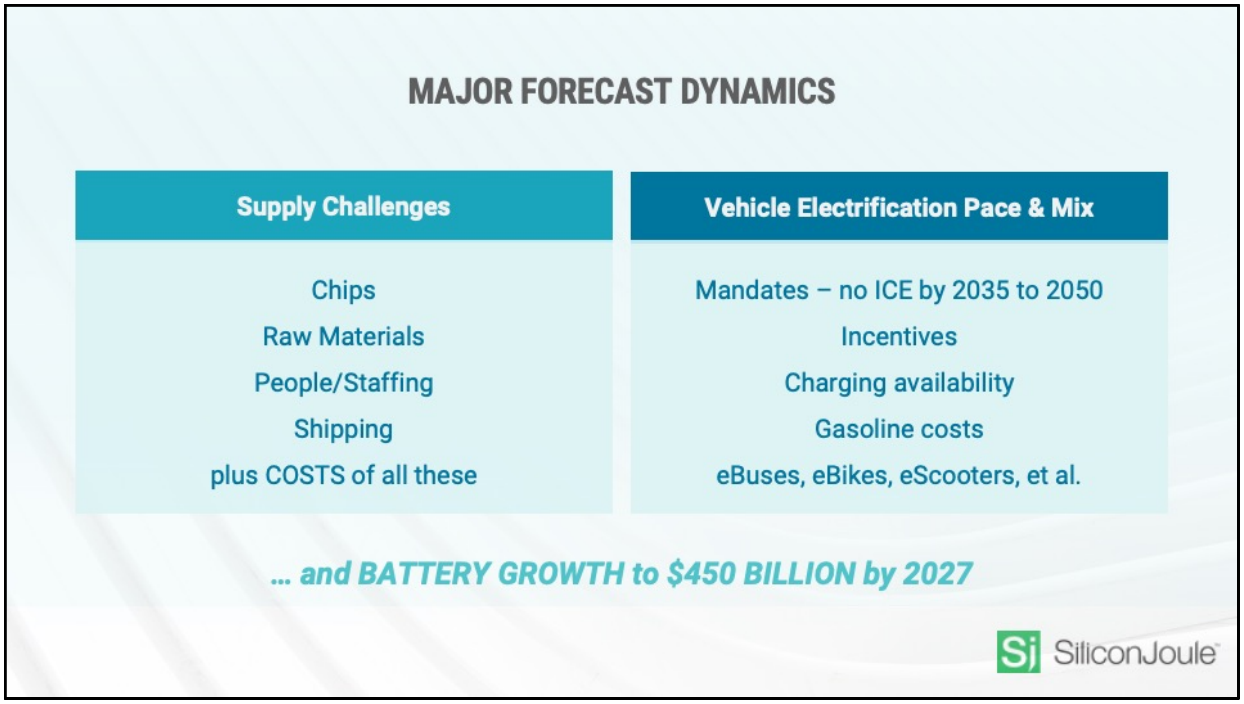
We will cover the numbers built up from a disciplined model, yet I will also provide insights behind the numbers to help you shape your opinions on the outlook for battery demand across transportation applications. We clearly remain in a Golden Age for batteries, and that is both good news, and the basis for such intense global competition for growth and position.

In addition, at the end I will share my opinion on three bad and good policies for people and our planet.


I believe we all can accept our planet is warming and weather patterns are changing with more extremes. The examples are all around us, from hot and sunny London this Summer to droughts and fires elsewhere.

How best and how fast to reduce CO2 emissions is another subject, yet I think all can agree that batteries have a huge role to play across many applications in transportation, across our energy infrastructure, and many industrial and personal uses.

Though challenges exist, I believe lithium and lead based batteries will both get a lot better, and I am personally investing my time and money in both.

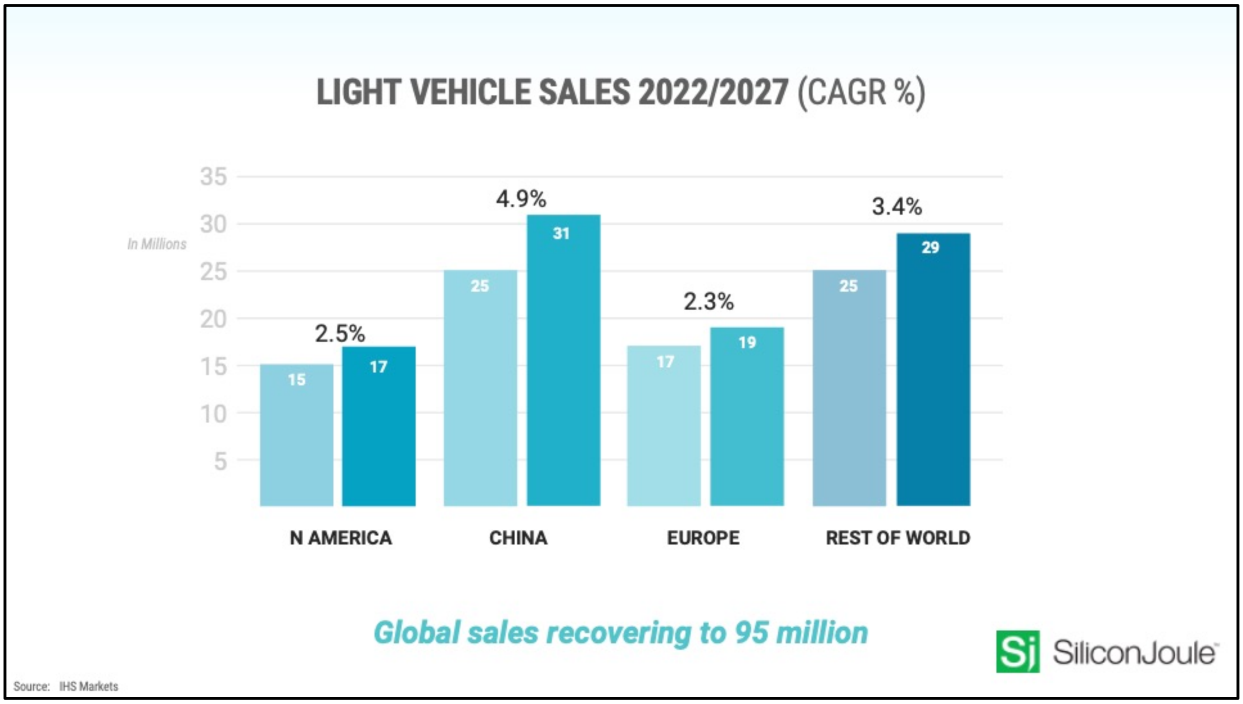



I have presented a forecast about each two years for the last decade, so that means I start with some humility, especially with so many changing dynamics, including the influence of local and geo-politics.

Shown are just some of the issues impacting today's forecast starting with the supply challenges. Some issues like shipping costs and chips may improve sooner, yet critical resources like people and raw materials may challenge plans for a longer time.

Regarding the pace and mix of electrification, let's start with government policies which include new inputs almost weekly. Germany is now on track to phase out EV incentives, yet mandate EVs, while China extends their incentives. And the US just announced new EV incentives, and last month California joined some countries calling to stop ICE vehicle sales by 2035.

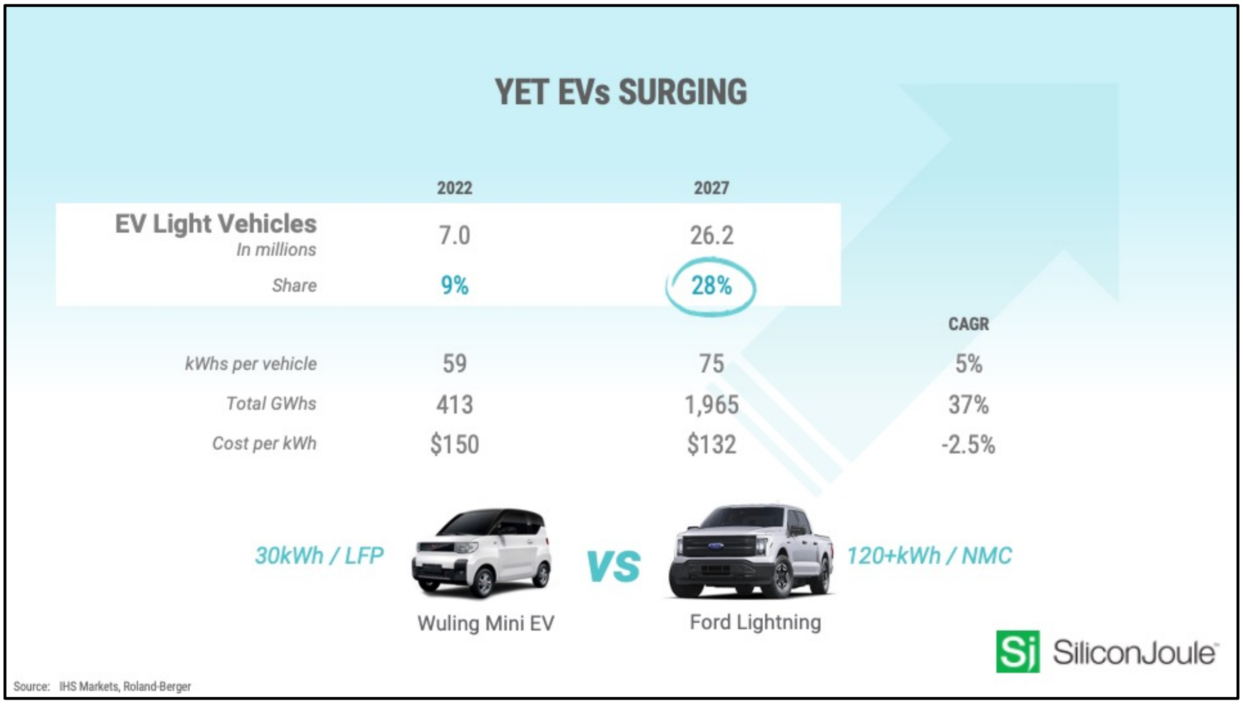
Before the details and background, the transportation battery market is forecast to TRIPLE from this year (2022) to about $450 Billion by 2027.




Let's start with the new vehicle sales forecast with the help of IHS and others.

Total new light vehicle sales are still recovering from the pandemic and related supply issues and are now forecast to grow about 3.4% per year to 95 million by 2027.

China's forecast growth of about 5% is roughly double the growth rate of the European and North American markets.




Yet, EV sales are surging, and they have the biggest impact on the battery forecast, so let's start with the assumptions for EVs, which also illustrate how the forecast model is built.

EVs (excluding PHEVs) are forecast to grow from about 7 million this year to 26 million or about 28% of all new vehicle sales by 2027.

Translating that into batteries, energy and value requires a look into vehicle designs and costs.

As the pictures depict, small EVs in China can have packs at 30 kWhs, while many premium vehicles and pickup trucks can have packs exceeding 100 kWhs.

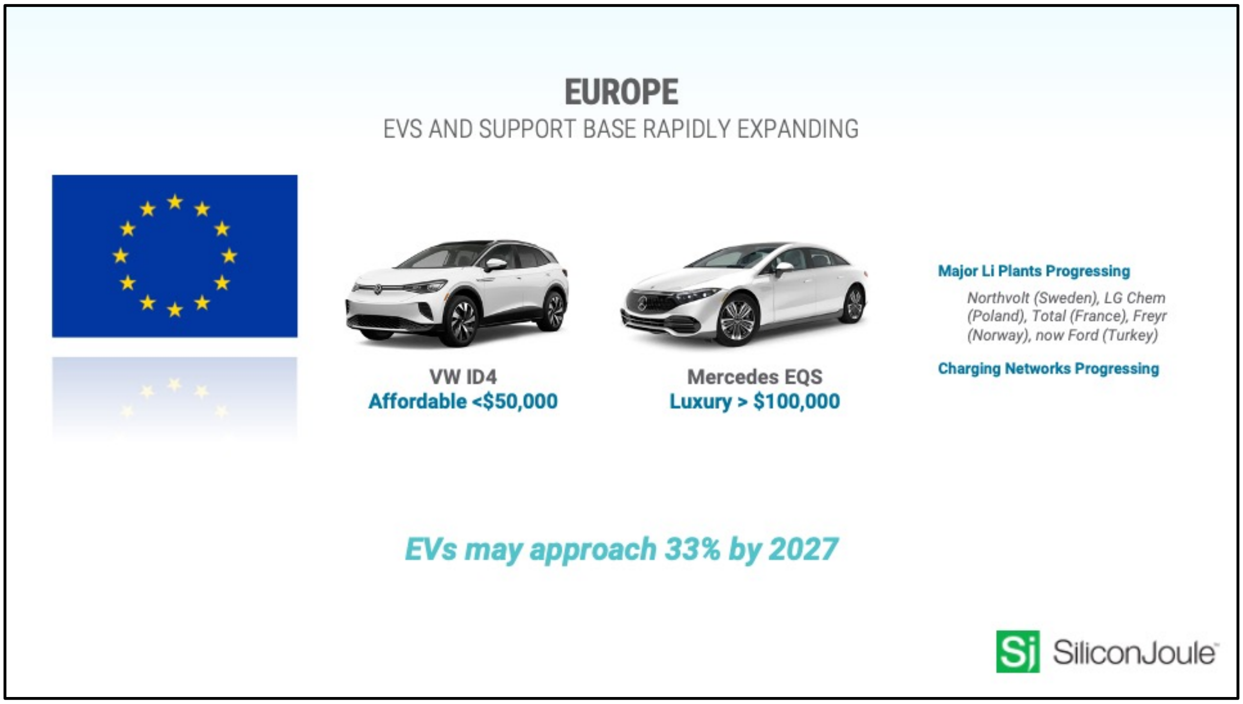
With the aid of IHS and others, we forecast the average battery size in EVs to increase from 59 kWhs in 2022 to 75 kWhs by 2027, principally as the EV growth in Europe and North America continues with their larger battery sizes.

Also, included in the model is the average battery PACK cost of $150/kWh in 2022, declining modestly by 2027 to $132/kWh following the recent surge in battery costs.


Let's provide some insight in key markets, starting with China as the largest market for EVs. China uniquely features a large share of very small, inexpensive EVs best illustrated by a top seller previously mentioned known as the Wuling Mini (from GM/SAIC), which had been selling for under $5,000.

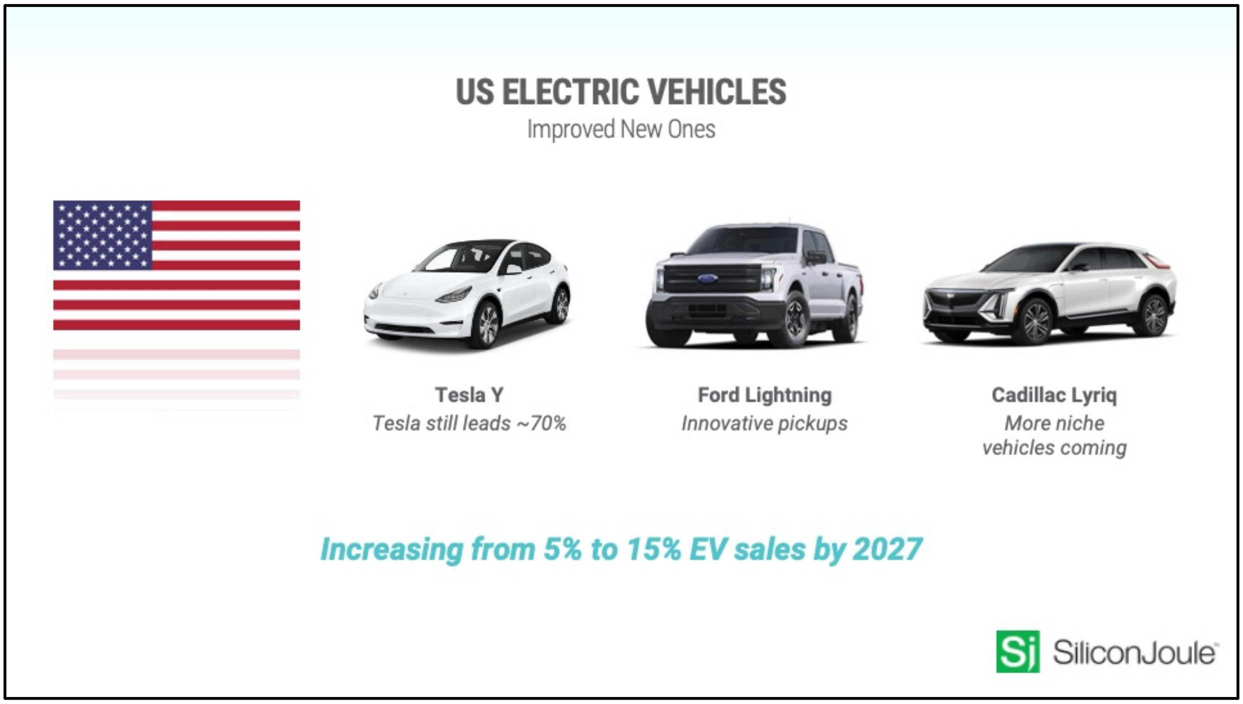
Tesla's Model 3, at a price of about 10X the Mini has also grown from the large Shanghai plant.

And BYD with its full range of large and small EV and PHEV vehicles is growing dramatically. It has become the largest global maker of New Energy Vehicles, as the Chinese characterize electrified vehicle sales. EV sales may approach half the total new vehicles sold in China by 2027.




Europe's EV sales are accelerating also with both the affordable ID.4 from VW, and the super premium models like Mercedes EQS. To better assure local battery supplies significant battery capacity is being put in place by both local companies, including Northvolt, Total, and Freyr, and South Korean and Chinese companies across Germany and Central Europe.

Beyond the challenges of sourcing the raw materials outside of Europe, and most refining of the materials in China, Europe's battery producers in Germany and Central Europe now face the added challenge of increasing electricity and natural gas costs. And with coal purchases notably increasing across Europe for electricity production in the face of Russia's new policies, it may prove hard to argue that EVs will actually reduce CO2 emissions for quite some time considering battery and EV production and the electricity source for charging. Yet EVs may approach 33% of new sales already by 2027.

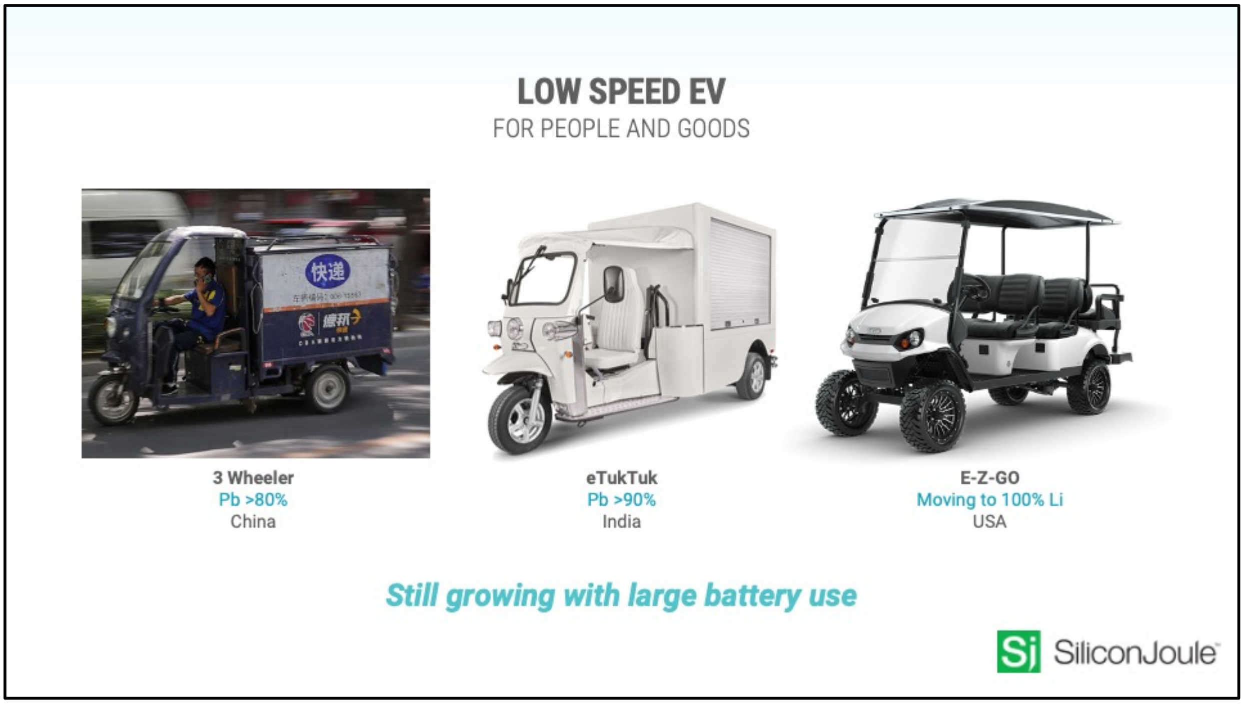



The US EV story looks different than three years ago, yet you still are not going to find too many low price EVs for sale. Tesla still leads the US market with about 70% share, yet Ford and GM will launch many EVs across the forecast period. Ford's early success with its popular electrified versions of the F-150 pick-up truck and Mach-e Mustang may suggest EV demand will accelerate as supplies improve. However, many of the new EV models, now also coming from GM like the Cadillac Lryiq and eHummer are targeted at higher end consumers with expensive vehicles.

It is possible the US EV demand could reach 15% of new vehicles by 2027. The new federal tax incentives may accelerate demand also, yet the tighter conditions for incentives have to be considered, And this past month US EV prices have jumped again by as much as $8,000 per vehicle from GM and Ford, considering the rise in raw material and other costs.

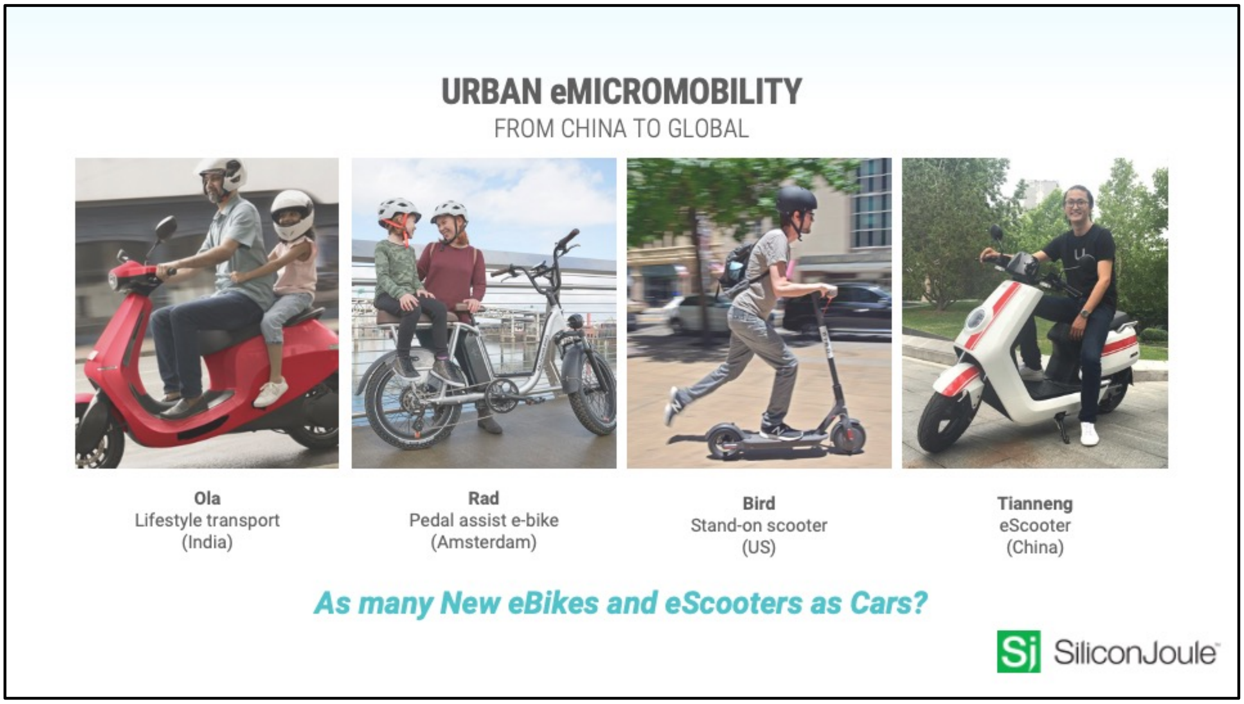

Another bright spot for EV adoption is with last mile delivery in urban environments, where the daily range is typically under 100 miles (160 klms), and vehicles are only moving possibly one-third of the time due to stop lights, high traffic and the time to drop off packages.

Both established companies and startups, such as Ford and Rivian are competing aggressively for market in this sector, and big users like Amazon and others are providing the pull with advance orders to help them address their total carbon footprint.




Low Speed EVs are an important market for lead and lithium batteries across the world to deliver people and/or goods. Chinese 3-wheelers and India's growing use of eTuktuks use mostly lead-based batteries for their very low cost vehicles. In the US LSEVs are used for golf, or people transport in industry or speed limited towns and communities.

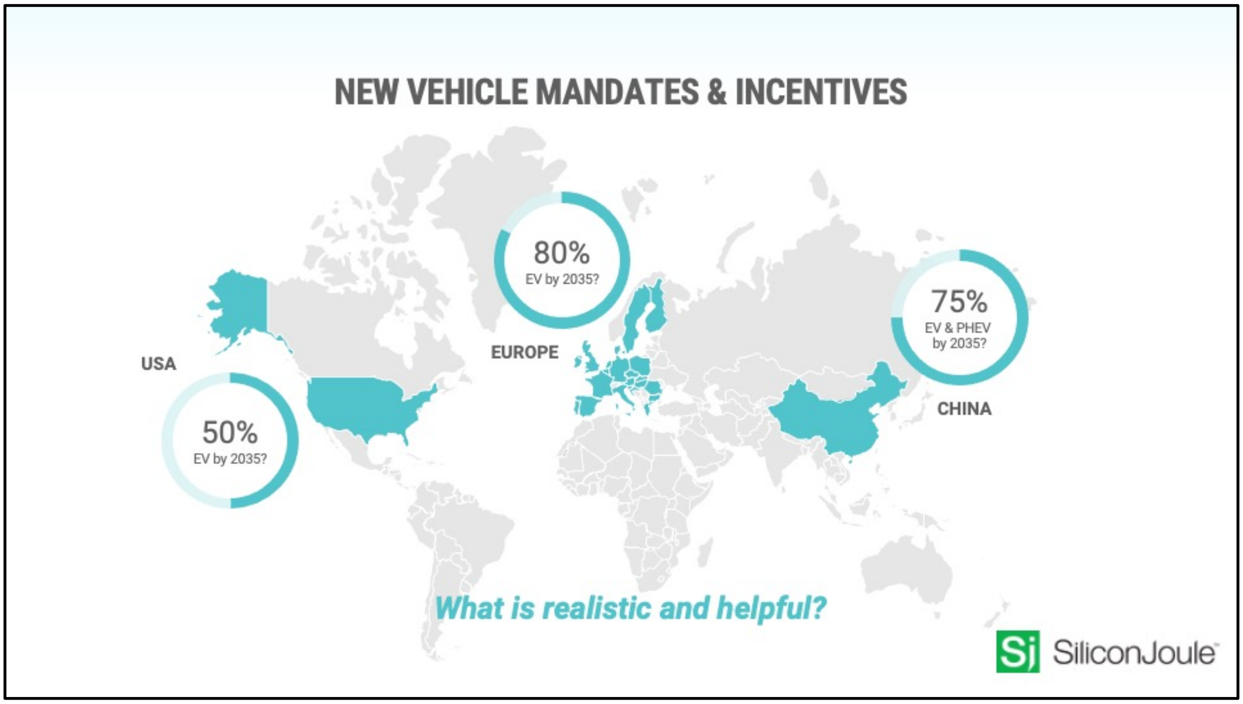
In contrast to LSEVs in China and India, the US has seen a transition to higher cost lithium batteries in golf and other applications led by EZGO, based mainly on claimed energy and maintenance savings.




The broadening type of vehicles in the so-called E-micromobility group, whether individually owned or shared across many cities, today extends well beyond the huge following in China of eBikes.

Regarding the largest sector of this group, I would follow the presentation later today of Huw Roberts of CHR Metals, as Huw and his team have an on the ground perspective of these markets.

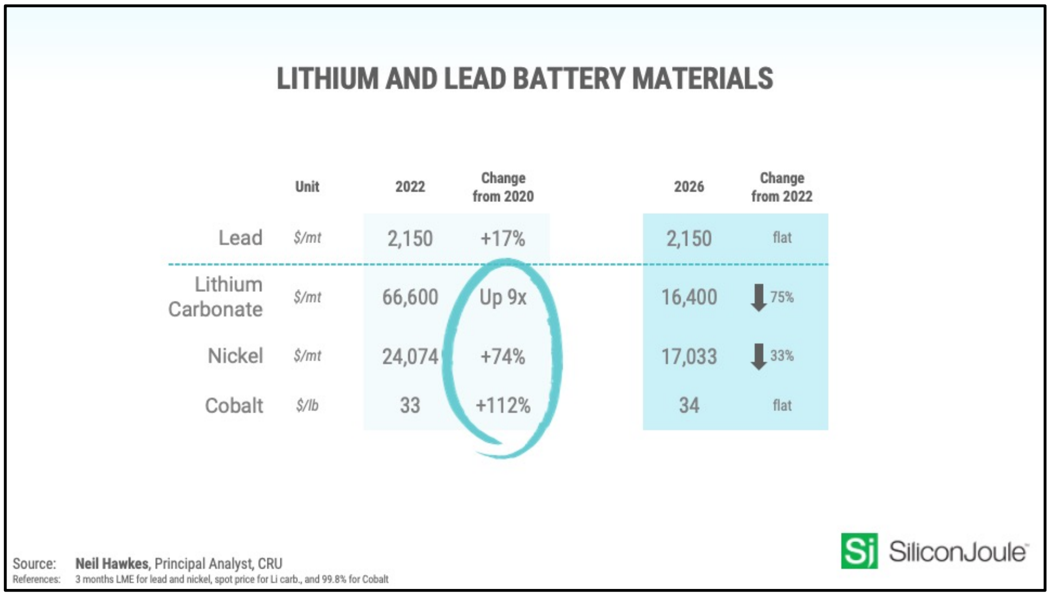
Beyond China, the notable growth in eBikes and eScooters across the world is being driven by many factors, from reluctance to buy, park and insure a car in many cities, a decline in public transport use, especially through COVID, and many cities' efforts with safer new lanes to reduce cars and traffic.  Though the battery packs are small with pedal assist eBikes and eScooters, the larger impact may be on the number of new larger vehicle sales avoided.




My forecast covers the next five years, yet many of the government targets and mandates kick in closer to 2035.

Whether these mandates are realistic or even helpful for our planet at this pace for electric vehicles before the grids are legitimately more green and resilient can be debated. Also, real total costs without government incentives, including recycling, materials, resale values and other issues have to be validated for many buyers, yet vehicle makers have to adjust to the possible reality of the mandates.

And Europe and China are likely to lead the world in EV adoption, and possibly could be as high as 75% or more of new vehicle sales by 2035.


LITHIUM AND LEAD BATTERY MATERIALS

| | Unit | 2022 | Change from 2020 | 2026 | Change from 2022 |
|---|---|---|---|---|---|
| Lead | $/mt | 2,150 | +17% | 2,150 | flat |
| Lithium Carbonate | $/mt | 66,600 | Up 9x | 16,400 | ↓75% |
| Nickel | $/mt | 24,074 | +74% | 17,033 | ↓33% |
| Cobalt | $/lb | 33 | +112% | 34 | flat |

Source: **Neil Hawkes**, Principal Analyst, CRU
References: 3 months LME for lead and nickel, spot price for Li carb., and 99.8% for Cobalt



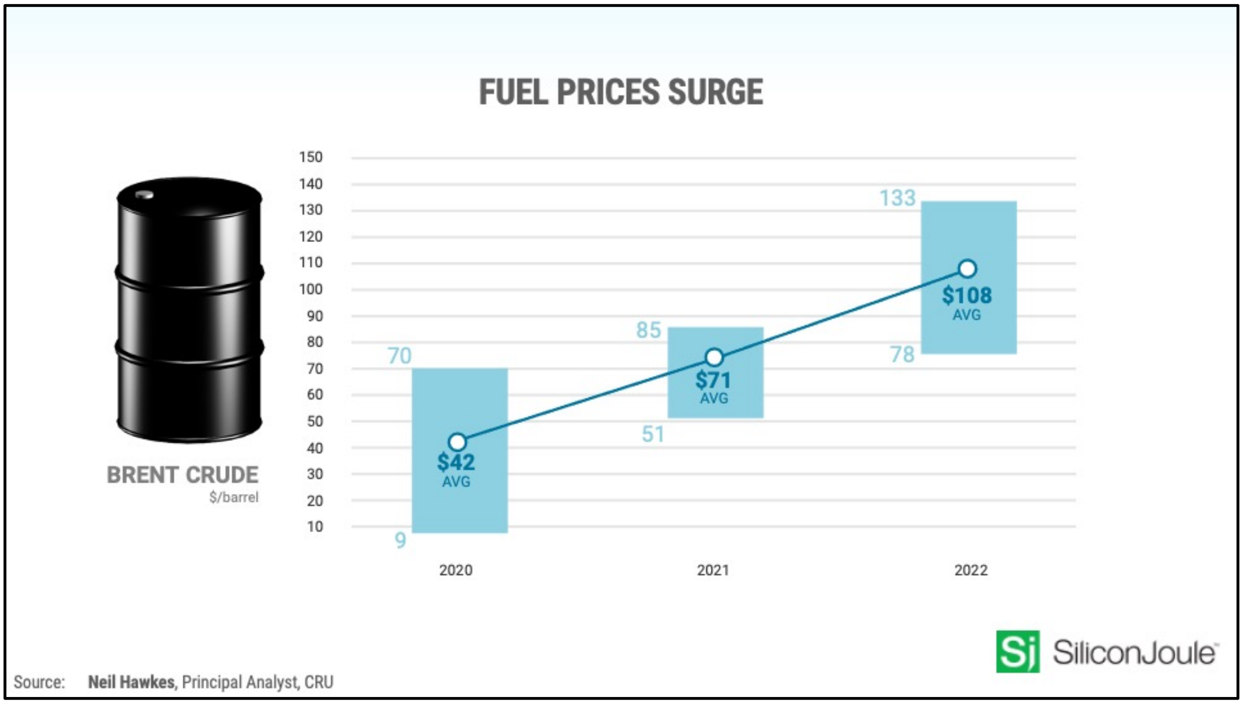
As we all know here, the battery business is a materials based business, and with both lead and lithium based batteries already at significant operational scale, it is the material source cost, and or some material science or packaging improvement that is needed to improve costs. And it has been a very tough 18 months for people sourcing lithium battery raw materials and batteries.

Shown here with the help of Neil Hawkes of CRU Commodities are select recent and forecast material costs for lead and lithium batteries. After two decades of declining lithium battery prices, current costs have increased about 25% from 2020, and this has driven the rise in EV car prices posted worldwide this year, and particularly this Summer.

Spot lithium carbonate prices are up nine-fold, and nickel and cobalt have nearly doubled, as the EV demand increases, along with supply disruptions, squeezed markets.

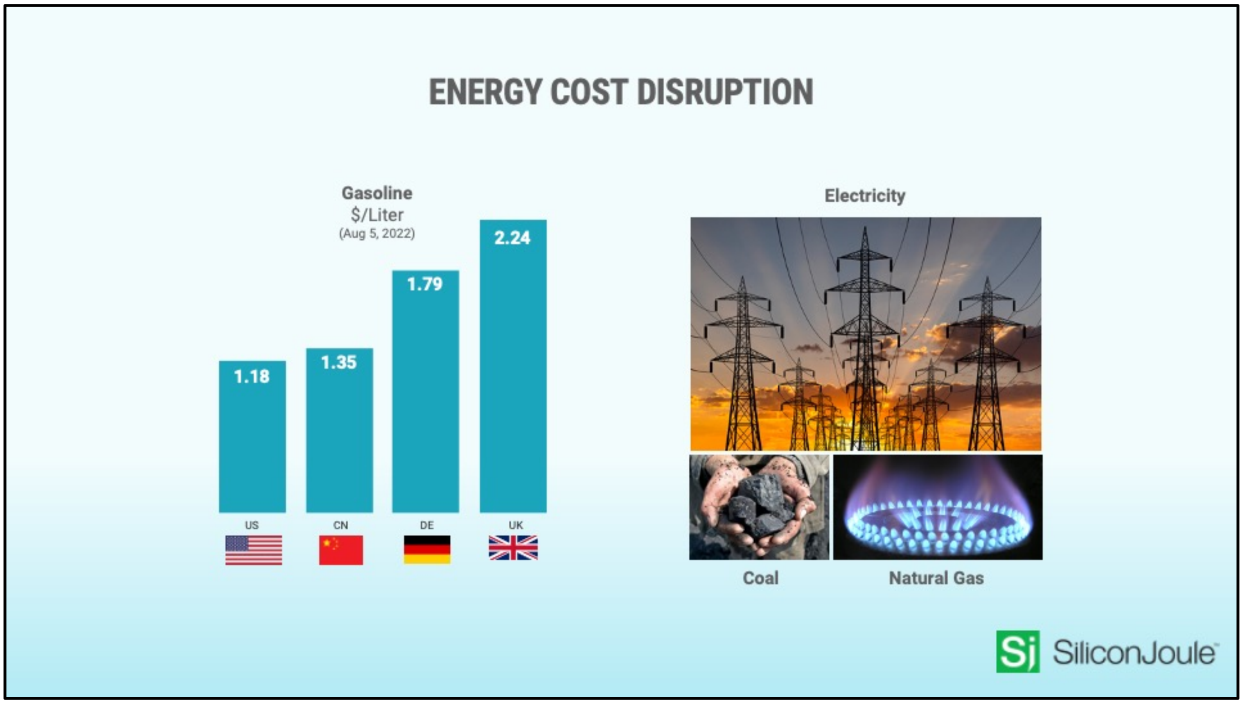
The forecast from CRU out to 2026 reflects an easing in the lithium costs, from a more balanced supply and demand. Yet, as the Russian conflict, and government policy changes across South America, Africa and elsewhere have shown, any predictions are subject to a lot of risks, including the timing and cost of bringing on new mines.

LME referenced lead prices at 2,150 per metric ton, or under $1 per pound, are forecast to remain roughly at this same level, benefitting from the ever increasing supply from recycling, combined with modest increases in lead demand.




Any commodity discussion this year must include the global surge in gasoline costs, and also for the primary fuel sources for electricity, especially for Europe.

First shown is the average, along with the high and low within the year for a barrel of Brent crude oil. From unique lows in 2020 with the collapse in demand early in the pandemic, the ramp in prices has been a unique driver for the inflation we are reading about daily worldwide. Also, vehicle usage has increased coming out of the pandemic reflecting some resistance to take public transport for those who can afford the private transport option.

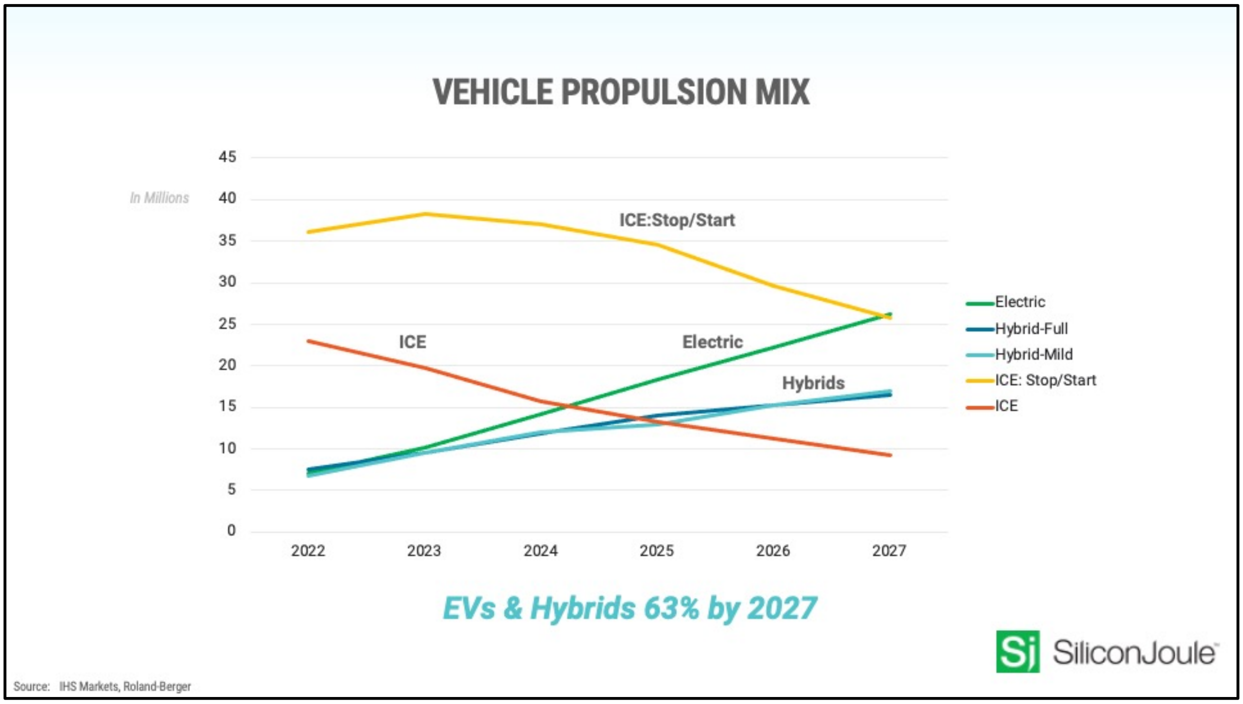



Though gasoline costs have increased across all major economies, the surge had UK customers last month paying the equivalent of $2.24/liter, notably above China, Germany and the US.

Also, rising electricity costs, especially in Europe, are a big challenge for many customers and industries with some governments taking interim action to shield users from the full impact. It takes a lot of electricity to operate lead and lithium battery plants for charging, ventilation and more, and as we saw last week, BritishVolt deferred their startup considering these high costs.

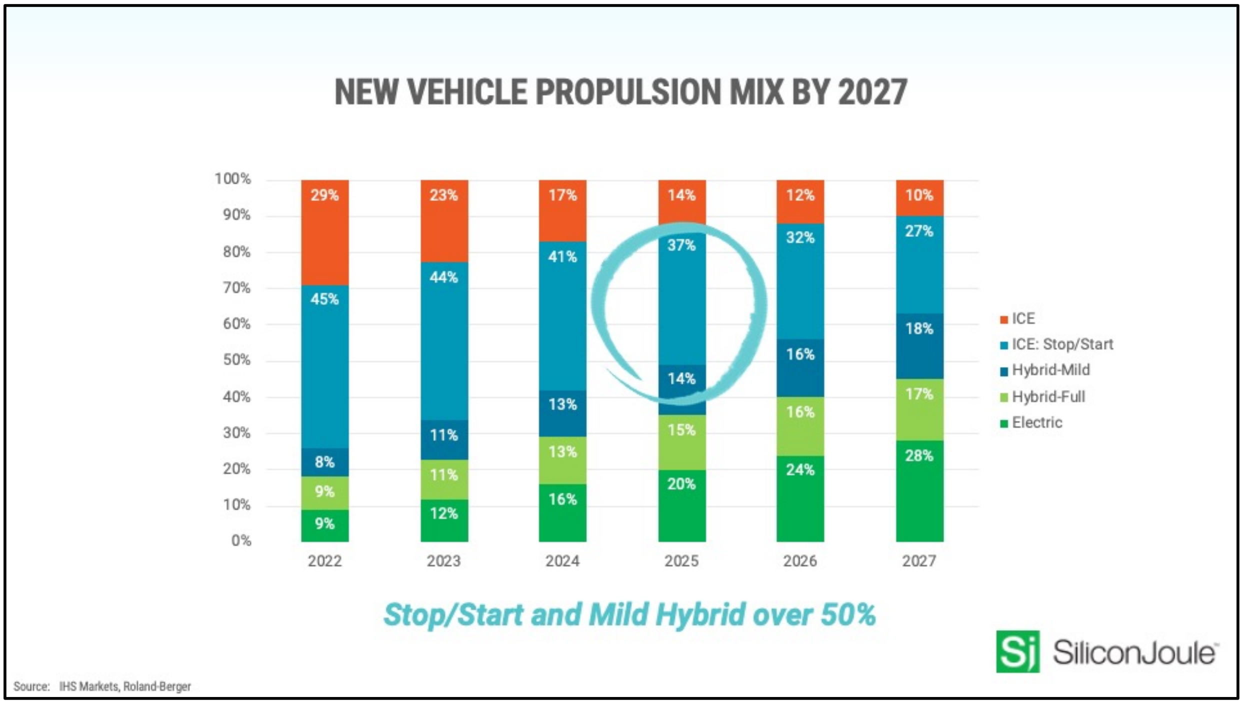
At least in the mid-term, the costs of battery making, and also charging EVs will be higher in many places.


Given the higher gas prices, we have seen a predictable shift to buy more fuel efficient vehicles in the US…assuming you can find them. The consumer preference, along with some improvement in the supply of smaller vehicles in 2022 has supported the increase. Sales reports from Ford, Honda and Toyota reflect this trend, especially for gas sipping hybrids like the CRV, Rav4 and Prius which have integrated harder working batteries to deliver good performance with smaller engines.

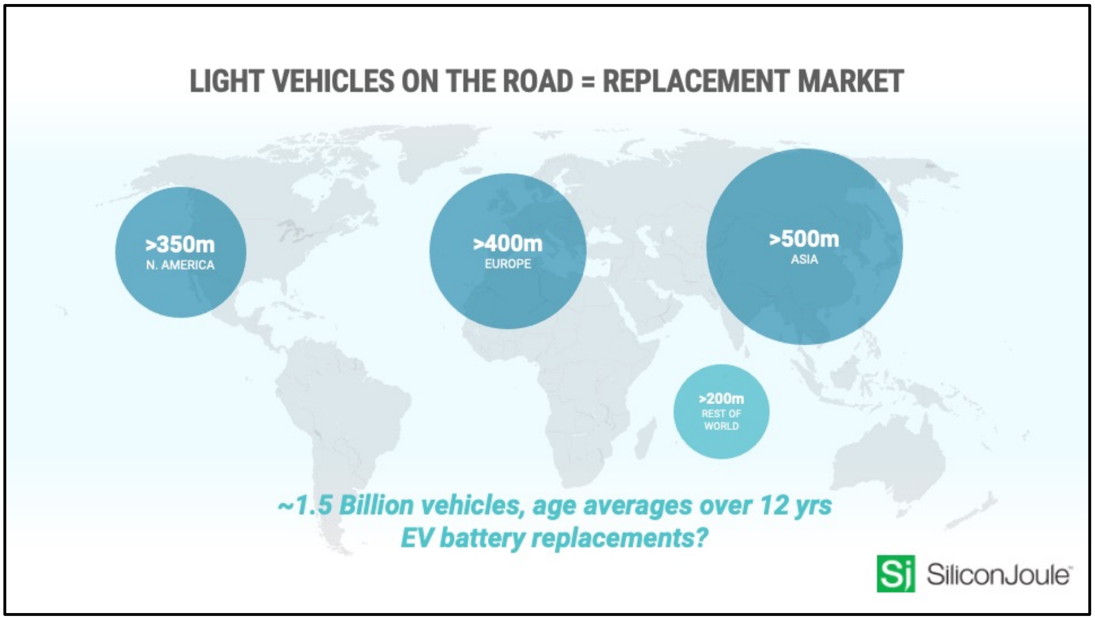



With the help of IHS Markits and Roland Berger, shown here is vehicle propulsion mix trend in the forecast. Any forecast can be disrupted by the dynamics discussed, yet the combination of EVs and high voltage hybrids are forecast to represent 63% of new light vehicle sales by 2027, with a corresponding decline in ICE engine vehicles. These are the segments driving the uniquely high battery growth.

For the EVs, I have also assumed better lead-based batteries will continue as the preferred choice for the critical low voltage EV or auxiliary battery for safety and sustained connectivity. Battery monitoring and redundancy in the auxiliary application is a key target for OEs seeking to optimize the reliability and safety of their EVs, regardless the propulsion system status.




Here is the propulsion mix presented in a different way. This illustrates an important share of the lead battery business, in that stop/start along with some mild 48v systems will still be over 50% of the new vehicle mix forecast in 2025, and of course the battery replacement period after that.



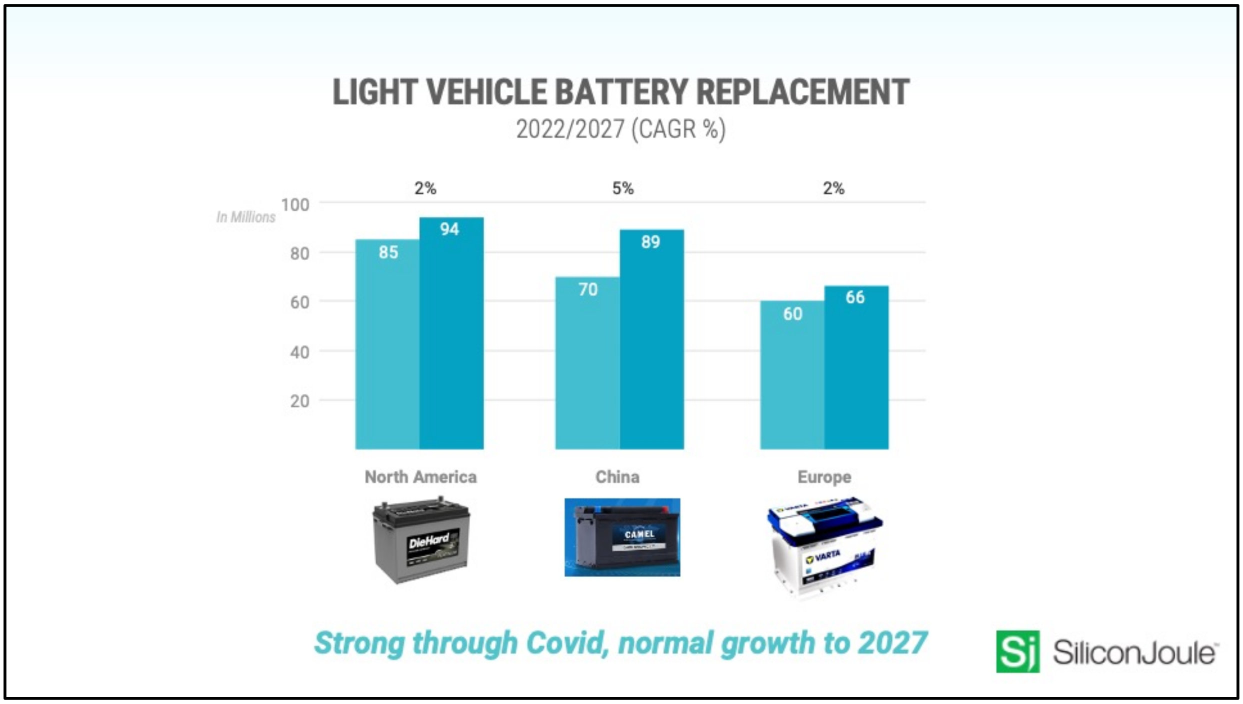

Having covered the new vehicle battery trends, let's cover the large replacement battery market.

Today, there are nearly 1.5 billion light vehicles on the road worldwide, and this excludes the trucks, buses, motorcycles, eBikes, etc. And nearly 99% of them are not EVs today, requiring battery replacements at intervals influenced by many factors, including their ambient weather, which means certainly faster replacement in Saudi Arabia then in much cooler Seattle, Washington.

With the constrained supply of especially affordable new vehicles since the onset of Covid, the average age of light vehicles on the road has been further lengthened, and reported at now an AVERAGE of over 12 years in the US, as one example. Though battery replacements for today's fleet are reasonably predictable, replacement forecasts for pure EVs are challenging.

If you had bought an EV for $40,000 eight years ago, and now was at the end of your warranty and had a weak battery, would you rationalize to spend $25,000 to buy a replacement battery through your dealer? I doubt most people would, and this will be an interesting part of the evolution of our fleet worldwide.

This high battery replacement cost may have two different consequences, the first being a difficult resale value, and the second issue being a prospectively shorter vehicle life. Will we need to build more EVs than we would have to build smart hybrids, because the average life of an EV on the road may be 40% shorter?




Shown here is a forecast for light vehicle battery replacements in units to 2027.

China's replacement battery growth of 5% reflects the significant expansion of vehicles on the road over the last ten years. The US and European market growth may continue in the 2% range, while the mix and value of those shipments grow at a higher level due to the replacement of more batteries to support stop/start systems.

For North America, this year we have seen very strong growth of about 25% through June of heavy duty/commercial batteries, which producers explain is in part catch-up from constrained supply through COVID. And the boom in marine and RV battery sales during Covid has eased in 2022 as seen through both retail sales data and industry shipping reports.

## BATTERY FORECAST #1

PROPULSION SECTOR

| | GWhs | | | $ In Billions | | |
|---|---|---|---|---|---|---|
| | 2022 | 2027 | | 2022 | 2027 | |
| EV & Hybrids[1] | 764 | 2,801 | 3.7x | $118 | $397 | 3.4x |
| Li Share | | 75% | | | 84% | |

***Lithium supplies are dominant, yet lead based still relevant in LSEVs and other mobility solutions, especially in China, India and developing markets***

SiliconJoule

[1] Includes Light Vehicles, and all others with full or partial propulsion assist from eBikes, eTuktuks to Heavy Vehicles and Buses

To aid the understanding of so many market drivers, the forecast is split into two sectors, and the first shown here is for propulsion batteries for all vehicles: light vehicles, buses, trucks, LSEVs, bikes, etc.

The increase is dramatic - over tripling of the capacity to 2.8 terra-watt hours, and $378 Billion in value by 2027. This may help some rationalize the huge capacity and investment announcements we read about nearly every week of some new capacity going into Kansas or Hungary or India. These expansions may raise again the question of timely availability of the raw materials and their costs.

## BATTERY FORECAST #2

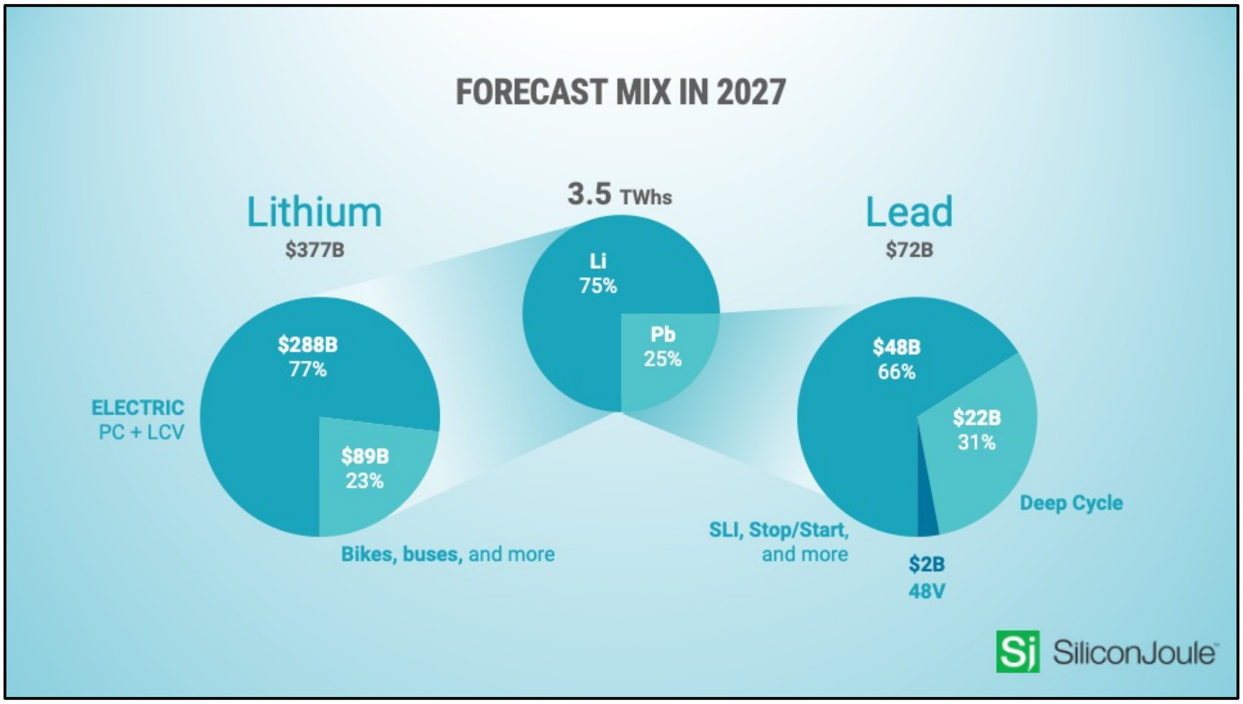
| | GWhs | | | $ In Billions | | |
|---|---|---|---|---|---|---|
| | 2022 | 2027 | % CAGR | 2022 | 2027 | % CAGR |
| SLI + Stop/Start[1] | 615 | 698 | 2.6% | $35 | $52 | 8.5% |
| Pb Share | | 97% | | | 92% | |

***Lead supplies remain dominant; driver of growth is higher mix of higher functionality batteries (AGM and EFB) and some lithium growth***

SiliconJoule

[1] Includes SLI, Stop/Start for Light vehicles, Auxiliary/LV EV Battery, commercial, motorcycles and specialty

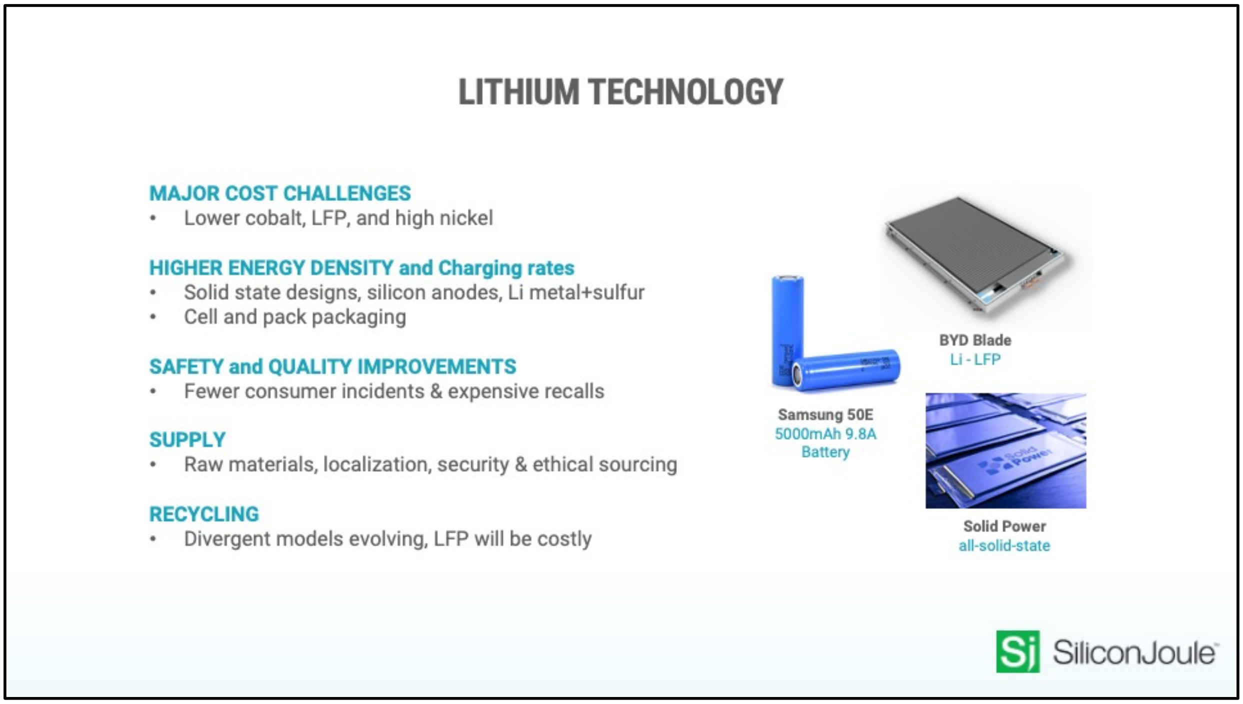
This is the forecast for transportation batteries providing the SLI, Stop/Start, and LV EV auxiliary functions, plus batteries for motorcycles, power-sports, marine, etc. Though the implied energy capacity growth is less than 3% per year, the value growth is over 8% from the mix of higher-grade lead batteries principally for stop/start, and some lithium batteries which will be sold at higher prices.




This summary of the two forecasts gives a combined 3.5 terra-watt hours of shipments, then split into the lithium and lead markets by value.

For lithium, light vehicles are the dominant consumer, yet large battery packs in buses, large trucks are still significant.

For lead-based batteries, the SLI and Stop/Start functions represent the largest demand sector, yet the deep cycle or propulsion for LSEVs, eBikes, and others are forecast to represent about one-third of the total global lead battery market.




This may be the perfect audience to discuss the merits and challenges of distinct battery technologies, yet I will simply summarize my perspective, which also underpins the forecasts.

For lithium, the cost surges are the most important current issue, and significant changes are being  explored by vehicle and battery makers to address this with more LFP, less cobalt and higher nickel in the cathodes, silicon-based anodes, and other designs.

Longer term, the safety and recycling issues will continue to represent major challenges.

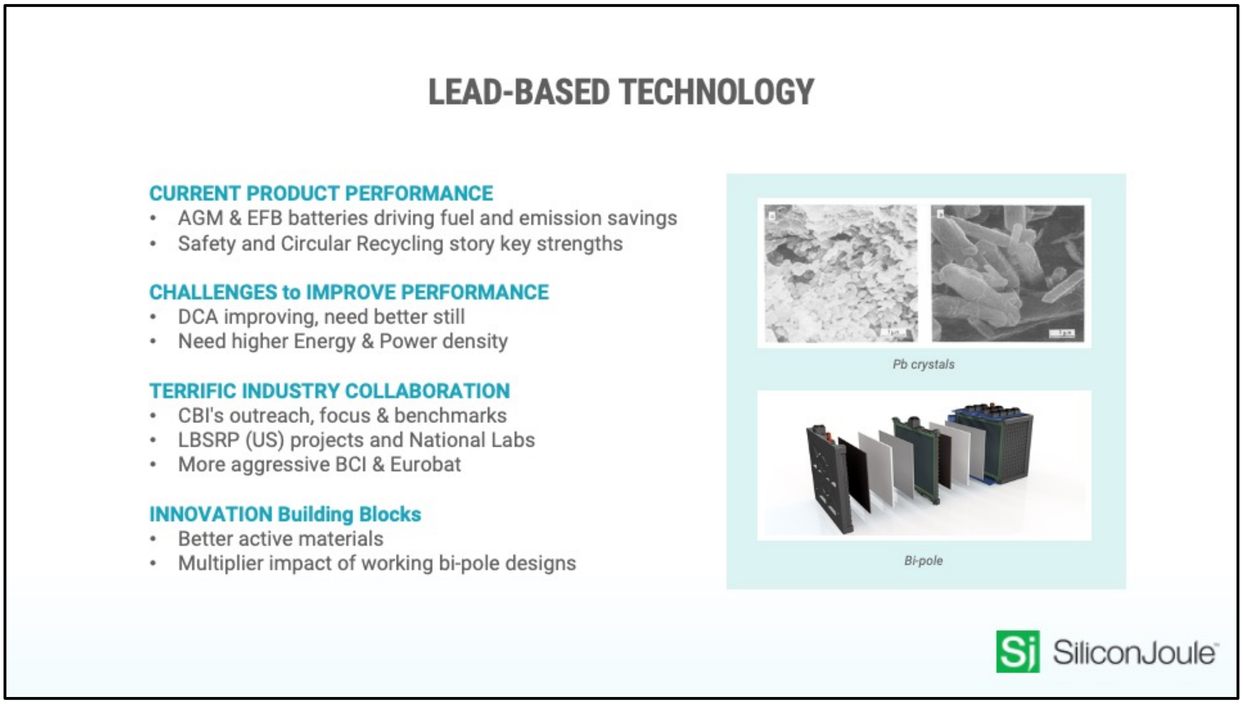
My guess is some continued large recalls are almost inevitable and hugely expensive; and end of life recycling will be a cost, not a savings, especially for LFP.

We do not know from who, or when, or at what cost, we will see the the first large capacity solid state lithium battery installed in series` production.  Yet, a working assumption I have is that it will arrive, likely after 2027, and hopefully the extra energy density it allows in design will offset at least the higher purchase costs per cell.


Another lithium question is the prospects for 12v lithium batteries in vehicles, and its impact on lead battery use today.

Though Tesla (model 3) and Hyundai have select lithium 12v solutions, a bigger issue than the costs may be the risks across distribution and at end of life. This is different than the large integrated propulsion battery packs which are likely to come back to the dealer. One way to control the risks of widely dispersed sale and return of 12v lithium batteries is to “require” their return to the dealers.

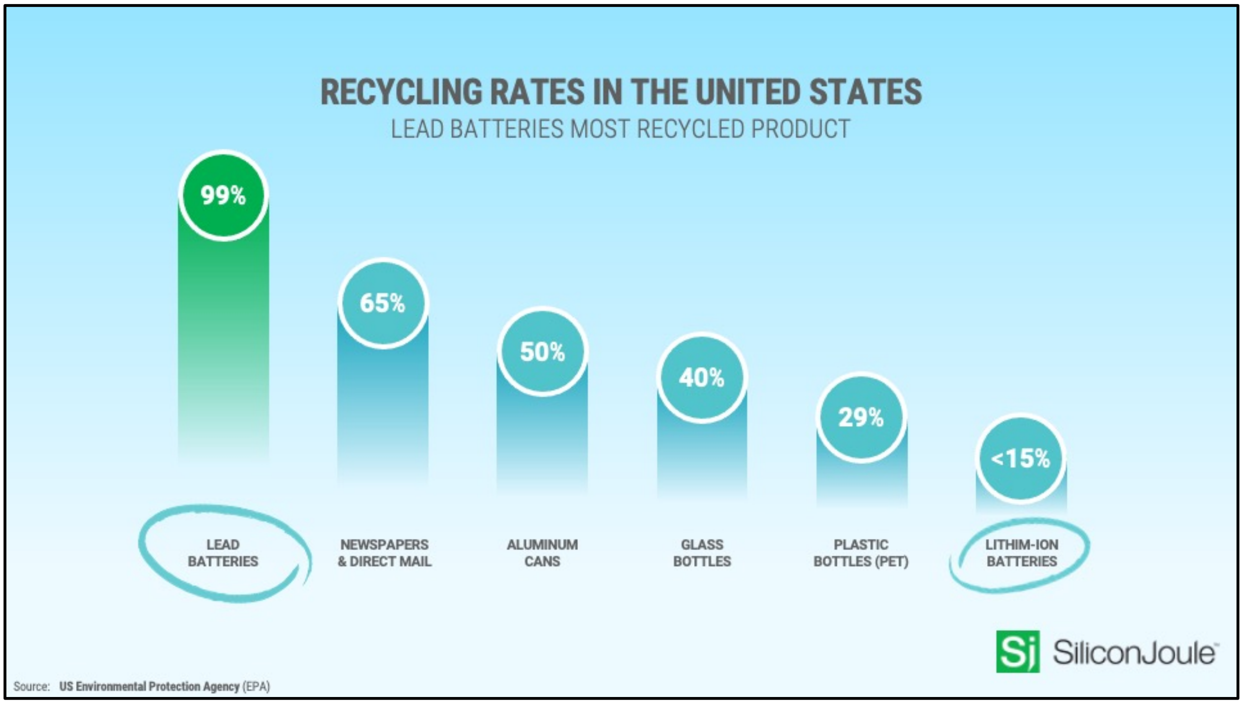
Yet, the EU and others have consistently worked to protect the independent actors in the vehicle parts business is the first issue, and you do not want fires or explosions on trucks, in garages, or at recycling plants designed for other products. Insurance companies and lawyers are likely watching this space, just like the wider lithium battery issues.



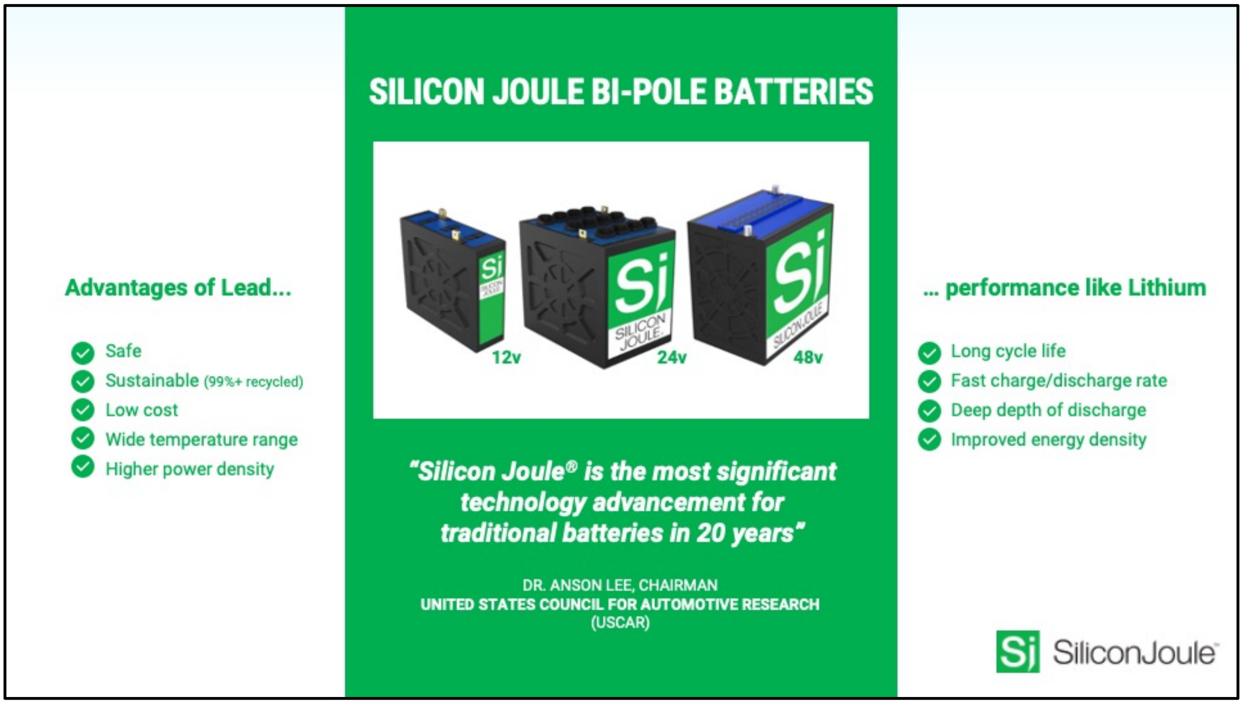

This group understands the opportunities for the improvement of lead-based technology.

We are tapping barely one-third the theoretical energy potential, yet the positive collaboration of the CBI and LBSRP groups, and many component providers are focused to truly improve the performance on clear benchmarks, both for transportation and the emerging ESS applications.

The two images shown highlight for me the best pathways I understand for lead-based battery improvements. First is the optimization of the particle shape and distribution of the active materials. The second image is of bi-pole battery architecture, which can multiply many performance attributes of existing mono-polar lead designs. And I want to thank the many here who are working diligently on these opportunities.

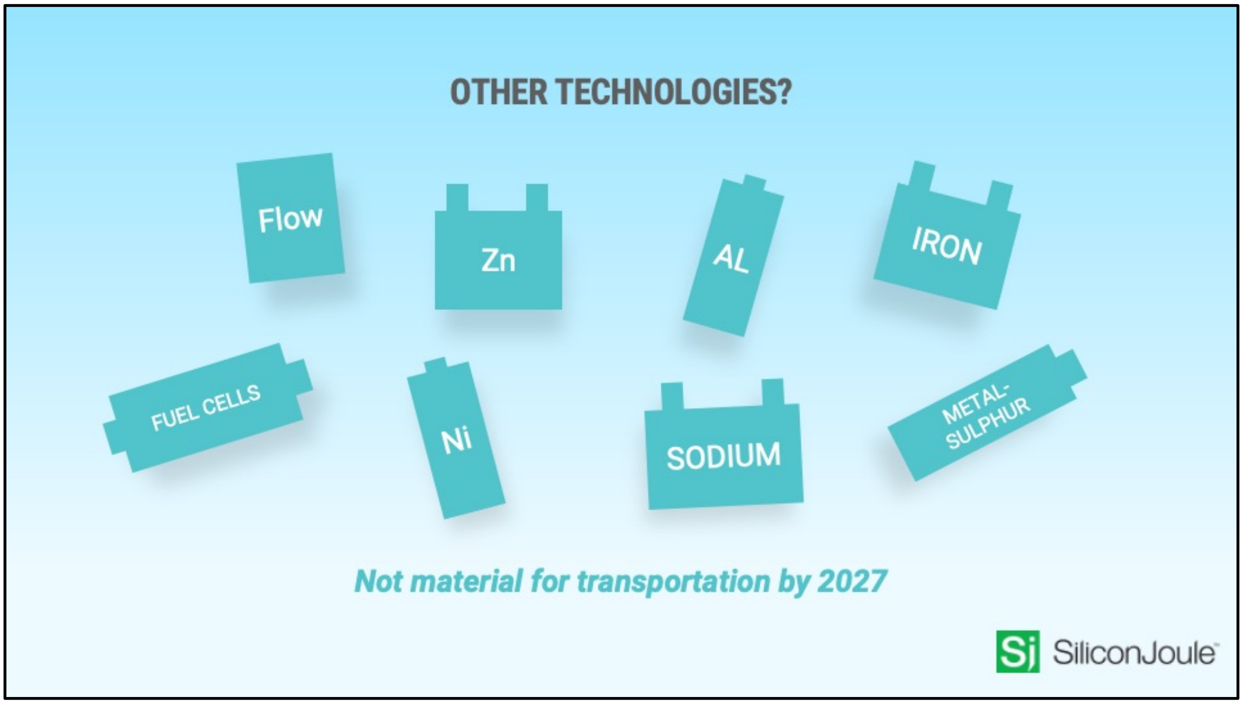



This slide illustrating confirmation from the US Environmental Protection Agency of the unique position of the recycling of lead batteries cannot be shown enough. It is has the HIGHEST recycling rate of any consumer product in the US, and far in excess of lithium batteries as well.




I will keep this commercial very short. Shown are existing 12, 24 and 48 volt Silicon Joule designs now being produced in small quantities by our company and also with a large battery company on a pilot line.

We believe our bi-pole design platform, with our growing list of partners, will deliver unique transformative opportunities for companies supplying batteries for transportation, industrial and ESS applications.




What about fuel cells and sodium-based or other battery solutions out there.

Though some of these may exit the R&D and pilot stage for different applications, and become sustainable solutions, I do not believe for transportation that any will be material by 2027.

My added input in assessing the prospects for any of these is that low cost materials are critical for long term success in the largest applications for batteries, such as for transportation and energy storage supporting our evolving grids.

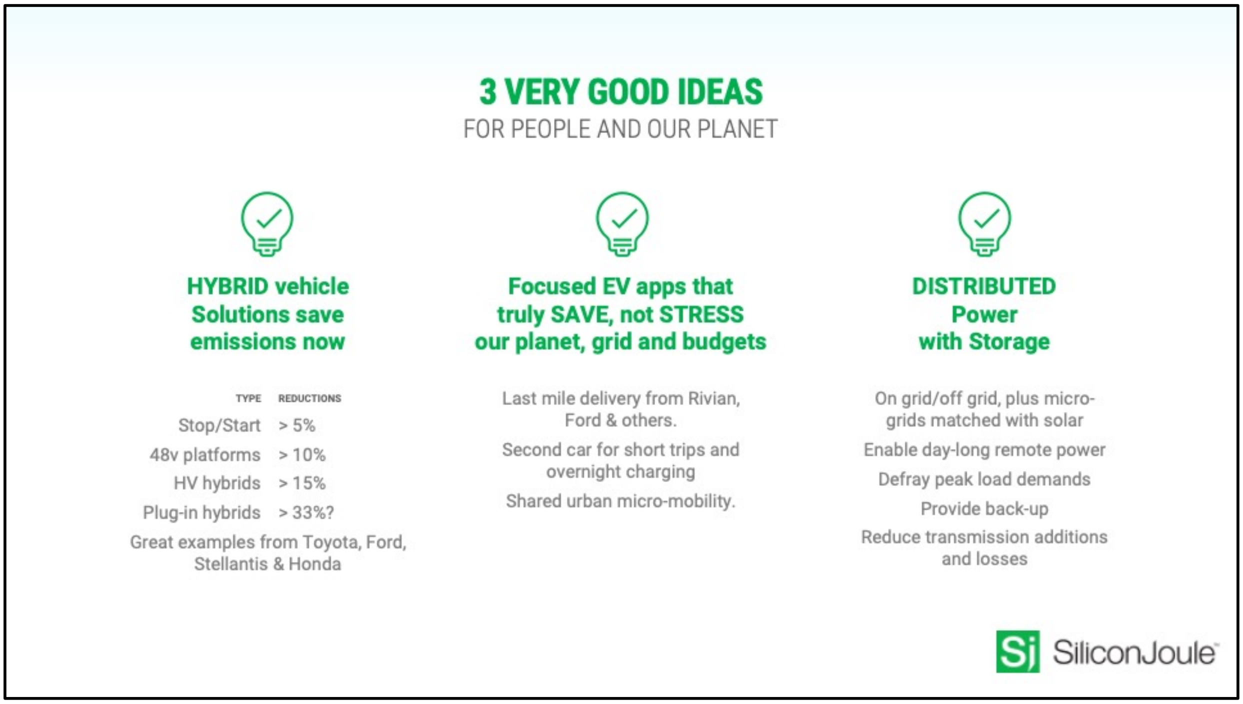

For many of us wanting to do the right thing for generations to come, it can be confusing when many are over-promoting green or idealistic solutions to quite complex issues, or not telling the whole story. In that vein, here is my opinion of three very bad and very good examples and ideas for people and our planet.

First, is the absolutism of many, they are sure only one solution “saves us” from climate change soon, while overlooking so many efficiency gains right now in front of us, like hybrids in transportation.

Secondly, one large group was advocating Western country support for EVs in Africa. Let me refer to Robert Bryce, author of “A Question of Power”, where common sense prevails, I believe. His concept, in my words, is the priority for the delivery and use of electricity in Africa needs first to support education of the youth and emancipation of women from quite difficult daily lives, not electricity for EV vehicles.

Lastly, the EU’s end of life regulation as it applies to lead batteries, may be the best example of a policy with good intentions, and the absolute worst of real implications for our planet and neighbors across the world.

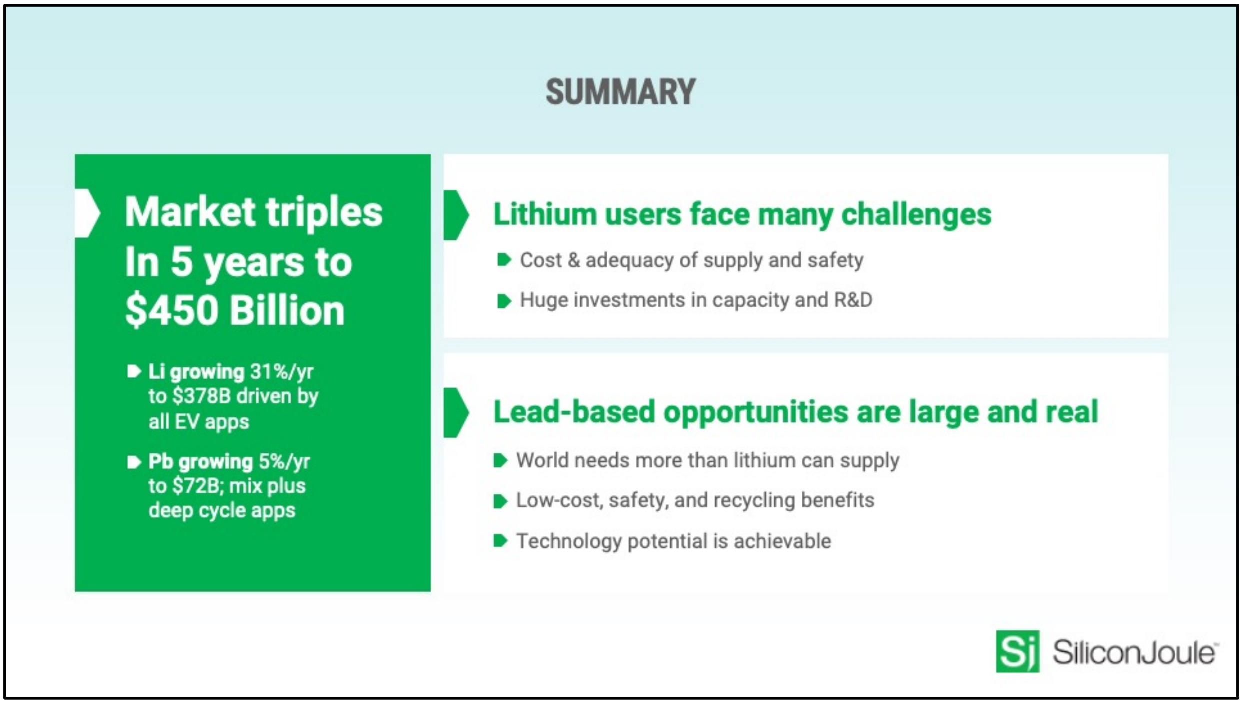
The ban of lead batteries, which can be recycled infinitely, is a perfect example of a circular and efficient economy, safely reducing the use of Earth’s resources. This is contrasted to the status and other implications of lithium batteries from mining to the end of their useful life and recovery, as the alternative to lead batteries.




OK let me be positive, the three very good ideas start with first the whole range of vehicles with better batteries operated in a smarter way with advanced engine and control technologies (eg hybrids)….unequivocally saving money for consumers and governments, and reducing significantly emissions NOW.

Secondly, rather than “EV everything”, accelerate the adoption of those applications that truly save emissions and cost, without stressing the grid and family, business and government budgets. The best examples for me are the last mile delivery vehicles in urban environments, and the generally, smaller second family car, which has short trips and are easily charged at low cost overnight when generation capacity is plentiful.

Another potentially significant contributor to our objective of reducing CO2 emissions is the broad development of distributed power generation paired with energy storage. These paired solutions can add to the credible promise of renewable generation, and both protect and help the grid when needed.




We already detailed the tripling of total transportation battery demand by to $450 billion by 2027.

This is driven by the very high sustained lithium battery growth to $378 Billion, and continued lead battery market growth of 5%/year to $72 Billion globally.

Continued improvement in lithium battery safety and prospectively cost can be achieved.

Yet the material cost challenges are real issues being addressed to improve the affordability of EVs such that they can appeal broadly without sustained government financing.

Lead batteries are better and working harder than they were 10 years ago, yet they have not yet improved enough for a bigger role in the Clean Energy Transition. However, the promising work of many can notably improve the growth trajectory for lead based batteries. So let’s get after it.

Thank you.


I want to thank the many individuals from the companies listed here who have helped me with data and insights shared in this presentation today.

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SiliconJoule

## DEFINITIONS

| | |
|---|---|
| **ICE** | Internal combustion engine (gasoline or diesel) |
| **BEV** | Battery Electric Vehicle (all electric motors/no ICE) |
| **HV Hybrid** | High Voltage >60 volts to several hundred volts, can be plug in or not |
| **48 Volt Mild Hybrid** | Generally dual voltage system aiding regenerative braking, propulsion, etc. in conjunction with ICE engines |
| **AGM** | absorbed glass mat separator, general reference for semi-sealed, reduced electrolyte, valve-regulated lead-based batteries. |
| **EFB** | Enhanced Flooded Batteries often used as a lower cost substitute for AGM batteries in stop/start applications. |
| **SLI** | Generic starting, lighting and ignition battery for light and commercial vehicles. |
| **LSEV** | Low Speed Electric Vehicles - a range of eBikes to golf carts to eRickshaws, generally 36 and 48v systems with modest speed and range |
| **eBuses** | All electric propulsion buses |
| **NMC** | Nickel Manganese Cobalt lithium batteries, often includes the sister NCA (Nickel Cobalt Aluminum) designs |
| **LFP** | Lithium Iron Phosphate lithium batteries |
| **LTO** | Lithium Titanate Oxide batteries |
| **Bi-polar** | Alternative battery architecture, whereby classic grids and connecting straps (in lead batteries) are replaced with a bi-plate offering alternate current flows and voltage blocks. |
| **CAGR** | Compound annual growth rate |
| **IEA** | International Energy Commission |
| **Class 6-8 trucks** | North American reference for the heaviest classes by weight for highway and off-highway equipment |
| **DCA** | Dynamic Charge Acceptance is a measure of rate of charge acceptance, important in hybrid vehicle and other applications, especially at higher states of charge |
| **MPG** | Miles driven per gallon of fuel consumed. |
| **P0, P1 & P2** | Progressive measures of electrification and power assist in so-called mild hybrids, typically in 48 Volt system platforms. |
| **CTP** | Cell to Pack, typically used to describe technology deployed to optimize beyond the cell chemistry in lithium batteries |
| **NMC811** | Improved Nickel Manganese Cobalt design with smaller fractions of Manganese and expensive Cobalt. |
| **kWh** | kilowatt hours measure of energy |
| **GWh** | Gigawatt hours measure of energy |
| **18650 & 21700** | Alternate cylindrical lithium small cells, often packed into larger modules (or bricks) than managed battery packs. |
| **Pouch cells** | An alternative to cylindrical lithium cells |

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|---|---|
| ICE | Internal combustion engine (gasoline or diesel) |
| BEV | Battery Electric Vehicle (all electric motors/no ICE) |
| HV Hybrid | High Voltage >60 volts to several hundred volts, can be plug in or not |
| 48 Volt Mild Hybrid | Generally dual voltage system aiding regenerative braking, propulsion, etc. in conjunction with ICE engines |
| AGM | Absorbed Glass Mat separator, general reference for semi-sealed, reduced electrolyte. valve-regulated lead-based batteries. |
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