FUTURE AGENDA
Open Foresight

THE WORLD IN 2030
Better Batteries

Better Batteries

New solid-state batteries offer safer, higher performance than existing options and become viable options for use across multiple sectors. Competitive pricing and proactive policymaking accelerate global uptake.

Price of battery energy (2030)	**$60/kWh**
Number of recent US battery patents	**200,000**

Battery development has become a priority area for a broadening range of companies in recent years. Significant investment is underway as a number of new technologies compete for fast-growing markets. Five years ago, we identified that energy storage was the missing piece of the renewables jigsaw: "If solved, it can enable truly distributed solar energy as well as accelerate the electrification of the transport industry."[1] Today, as economies focus on faster decarbonisation and increasing electrification, particularly in transportation, the speed of new battery development has become a central issue for many researchers, policy makers, investors and companies.

Why is this? If we can get significantly more energy from a lighter, more compact, but affordable battery then the implications are enormous. Not only will this accelerate the adoption of electric vehicles by extending their range and providing a cheap way to store renewable, particularly low cost solar, energy, but it will also release a host of new developments in other areas from wearable electronics to electric planes, drones and scooters.

Given the demand for high performing batteries is building, it is hardly surprising that there is as much focus today on creating the batteries of tomorrow as there was when the first rechargeable battery was invented 160 years ago: according to a USPTO search in the past decade or so over 200,000 battery related patents have been issued.[2] The rush to deliver the next generation technology is bringing together a host of new partnerships and foremost in many discussions is the potential impact of solid-state batteries. Within the next decade these could become the catalysts for substantial and lasting change across many sectors.

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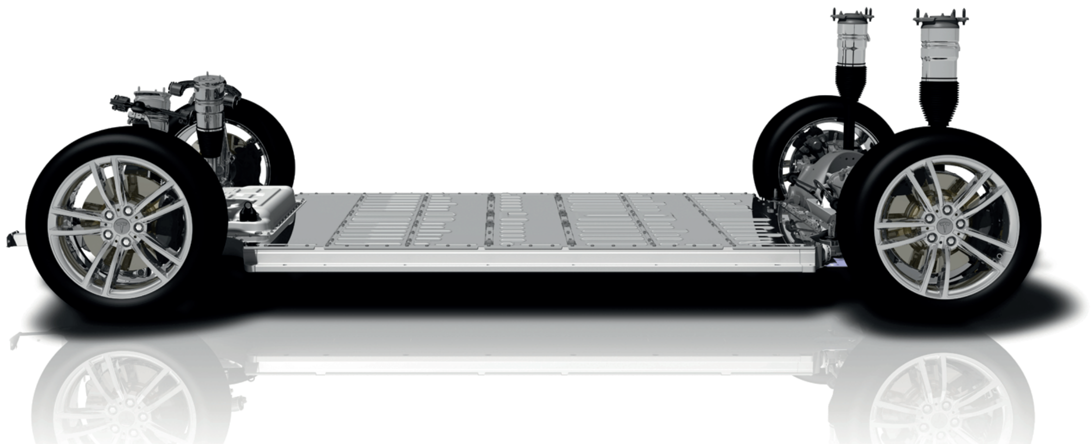

Current Technology

It may be useful to consider what happens inside a battery to help clarify where change is likely to happen. A battery is a pack of one or more cells, each of which shares some common core elements: a positive electrode (the cathode), a negative electrode (the anode), a separator and an electrolyte which can be liquid, solid or gel. Electricity is generated when a chemical reaction takes place that moves electrons from the anode to the cathode. Using different chemicals and materials for these affects the properties of the battery: how much energy it can store; the energy output; how much power it can provide; and the number of times it can be discharged and recharged.[3] In most devices there is a trade-off between battery size, design, safety, efficiency and performance.

Although well recognised and undergoing continuous development, technologies such as today's lithium ion (Li-ion) batteries are not yet sufficient to meet some performance needs and so are not able to replace alternative systems such as the diesel engines for trucks or the kerosene engines which power planes. If they are to have wider impact, advancements needs to be made in several areas. Top of the list are two issues: energy density (how much energy a battery can hold per kg) and power density (the rate at which energy can be discharged): Energy density helps maximise range for an electric car or extend the battery life for a laptop whereas as power density is all about how quickly energy can be released so is an important element for aviation.[4]

Across the field, there are all sorts of initiatives exploring how to make a better battery – both in terms of technologies as well as the companies driving and delivering the innovations to market. With large stationary batteries to store electricity for domestic use, companies such as Sonnen (recently acquired by Shell) use lithium iron phosphate batteries and sees them as an intelligent storage system that automatically adjusts the energy usage in the home.[5] Such is the effort to innovate that over the next decade, some chemical companies expect to create batteries that are half the size of those we use today but with twice the capacity – so a four-fold increase in energy density.[6] This will open up multiple nascent markets.

The opportunities presented to deliver more effective batteries for electronic vehicles has become a particular focus. Although the Tesla – Panasonic collaboration on NCA (lithium nickel cobalt aluminium oxide) batteries is often in the news, it is very much geared around Tesla as a single customer. Other electric car manufacturers, and indeed Tesla for its energy storage products, are increasingly opting for NMC (lithium nickel cobalt manganese oxide) batteries for the next few years but may well shift as the other technologies hit the performance targets.

No matter what specific technology is being advocated, time again over the past 15 years we have heard that to be price competitive, an electric vehicle has to have battery packs that are less than $100/kWh. This is where companies such as GM are placing their business case bets.[7] Together with faster charging abilities and enough stored energy to overcome users' "range anxiety" this is widely seen as the tipping point at which the market dynamics will change in favour of widespread adoption. Several organisations, such as the IEA and Bloomberg NEF, expect that, with improvements already in motion, this hurdle will be overcome by Tesla / Panasonic shortly and that, by 2030, costs may well be down to around $60/kWh.[8,9] This would mean the purchase price of an electric vehicle could soon be the same as that of a comparable petrol / diesel car without subsidy. With better performance and aligned government policy, the ease of switching will become increasingly attractive to consumers.

Makers will have to be on their metal to provide a step change in the next generation of batteries. There will be competition other over price, reliability, energy consumption and durability – including the number of times they can be recharged. However, although the battery technology is clearly pivotal, a combination of complex supply chains and legacy decisions by some companies means it unlikely that there will be a single solution any time soon.

Non-Technical Challenges

While the technical debates rumble on, supply-chain access and the circular economy are mounting challenges. Issues include the ethics around the use of rare metals and the declining supplies of increasingly expensive cobalt. Cobalt itself is a by-product of copper mining and is under specific focus because over half of its global reserves are in the politically fractious and ethically dubious hands of organisations in the DRC that, for instance, use child labour as part of the norm. Despite this, many key manufacturers continue to source from there.[10] Minimising the amount of cobalt used, and making sure more of it is recycled, are priorities for many new innovations. Actions have already been taken, for example Hydro and Northvolt have recently launched a joint venture focused on large scale end-of-life battery recycling in Norway.[11]

As the demand for more batteries increases, there could be significant supply challenges for other raw materials as well. So much so that the World Bank foresees a 20% gap between supply and demand by 2025 and that "global demand for strategic minerals such as lithium, graphite and nickel will skyrocket by 965%, 383% and 108% respectively by 2050".[12] As a result, there is a pressing need to accelerate the search for alternative materials with a secure, sustainable supply in both research labs and the mining sector. Companies such as Johnson Matthey have been exploring how high-nickel chemistries could allow lower levels of cobalt.[13] Others are looking at how best to use new materials like graphene within the electrodes.[14]

Globally there is widespread appetite to embrace the circular economy and policymakers from all corners are increasingly focussing their attention in this area. It is complex as regulations differ across the geographies. In China, for instance, retailers have the responsibility for overseeing how batteries are re-used after the initial customer has finished with them – whether that be repurposing or recycling.[15] Equally in Europe the WEEE regulations have gradually been tightening targets. In the US, where recycling rates for batteries loiter at around 5%, changing habits as well as technologies are now very much front of mind. Some, for example, have been looking at means of repurposing old batteries for use in solar farms.[16]

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Future Options

While there is renewed interest on the potential of a wide range of technologies such as hydrogen fuel cells and thermal energy storage, in discussions to date it seems that most of the combined research, investment and industrial focus is on delivering better batteries at scale: Flow batteries and air batteries are two options attracting attention, but by far the most significant for future impact are solid state lithium-Ion products.

Flow batteries are a design where two acidic liquids are mechanically pumped within a battery pack. Although requiring more maintenance than lithium batteries and having a low energy density, they provide an exceptional lifetime of up to 100,000 cycles and so are ideal for stationary systems such as storage for renewable energy. They have benefitted considerably from the increase in solar energy - market analysts expect demand to more than double by 2025.[17] Several companies, including Foxconn, Flextronics and Jabil, have allocated significant investment to this technology.

Air batteries have been a focus for much recent research, especially since breakthroughs with lithium-air technologies were announced by the University of Cambridge. These claimed up to 90% efficiency – five times that of conventional batteries.[18] Others have yet to replicate their success, especially in achieving thousands rather than tens of charging cycles and achieving improved battery life.[19] There is additional momentum in other areas, for instance, in the use of graphene cathodes and lithium hydroxide. As a signal of industrial intent, Tesla has filed several patents for metal-air batteries including lithium-air designs.[20]

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Solid State Batteries

While these options may have some future impact in niche markets, today Li-ion batteries continue to provide the highest energy density while charging rates, operating temperatures as well as lifetime length can all be fine-tuned with the choice of cell and chemistry.

Current Li-ion technology is expected to reach an energy limit in the next few years but recent discoveries of new families of disruptive active materials should unlock present limits. These innovative compounds can store more lithium in positive and negative electrodes.[21] A number of researchers around the world are also exploring the use of lithium-sulphur to double energy density as well as sodium-ion to also reduce cost and improve charging.[22,23,24,25] Others, such as Stanford spin-out Amprius, have been developing technologies that make use of silicon nanowires to improve anode performance.[26] In the UK, Cambridge based Echion is another new company seeking to improve Li-ion performance by using niobium in the anode.[27] As an indication of mounting activity, some analysts suggest that nearly $2 billion of venture capital flowed into battery start-ups in 2019 with $1.4bn of this focused on lithium-ion research alone.[28] Elsewhere, large corporations are making significant minority investments in lithium technology firms consider for examples Daimler's investment in Sila Nanotechnologies.[29]

Within the notable developments in the Li-ion market, the use of what are called **solid state** (rather than liquid) electrolytes is where much of the current action lies. While there are several different chemistries in development (sulphide-based, oxide-based and polymer-based), the common ambition across all solid-state electrolytes is to improve energy density in a safer way than other options.

- They replace existing liquid electrolytes with a high-conductivity solid membrane which is both lighter and also allows the use of improved anodes and cathodes that, when all combined, can increase energy density by between 50% and 75%.

- They are safer than existing designs. Traditional liquid electrolytes are flammable, but the solid materials are not – even when heated. This makes solid-state batteries (SSBs) particularly attractive for multiple transportation applications just as much as for laptops and mobile phones.

- In addition, they are both faster charging and also have a reduce discharge so achieve a longer shelf-life than traditional Li-ion products.

The UK Faraday Institution, for one, considers SSBs as "the technology of the 2030s but the research challenge of the 2020s".[30] Certainly as extra innovation occurs, different SSBs will be launched over the coming years - the first tranche will improve energy performance and safety then there will be a move to develop other, lighter weight versions. Researchers at the University of Birmingham are just some of an increasing global community focused on optimising performance of SSBs – in their case they are looking at how to improve recycling and exploring how phase-change materials can enable better temperature management.[31] Over in Japan, scientists from Tohoku University have developed a new complex hydride lithium superionic conductor that could deliver higher energy density.[32] Around the world, multiple research teams are engaged in the search for the breakthroughs that will hopefully deliver the potential from new solid-state designs.

The switch to battery power will be profound. In terms of market impact, over the next decade SSBs are expected to ramp up use in high-end electronics and then move into electric vehicles, grid storage and then, probably in the 2040s, electric planes.[33] Global need for Li-ion batteries is predicted to rise eight-fold this decade with electric vehicles accounting for 85% of the core market by 2030.[34] With overall demand expected to then increase by over 200 times between 2030 and 2040, if everything goes as planned, projected market share for SSBs by 2040 maybe around half the consumer electronics market and a third of electric transportation.

With such growth forecasts it is little surprise that, over recent years, companies such as Bosch and Dyson have been busy buying up some leading solid-state start-ups while VCs have invested in more new ones. They are all keen to exploit lithium as the lightest metal around and ideal for high-performance applications. Daimler has announced that it will use SSBs in the new range of Mercedes-Benz eCitaro buses which are being rolled out initially in Germany and then worldwide.[35] In Asia, Toyota has filed more patents in this field than any other company and, partly in partnership with Panasonic, is aiming to introduce all-solid-state batteries by 2022.[36] Samsung has recently announced a new SSB that could give EVs a range of up to 800km.[37] In the US notable start-ups in the area include Ionic Materials and Solid Power - a spin-off from the University of Colorado, plus MIT start-up 24m which has gained a strong following for its 'semi-solid' Li-ion technology as a means of changing the production process and so cut costs in half.[38] In the UK Southampton University spin-off Ilika and Oxford-based, Oxis Energy are two of a number of companies now making marked progress on future innovations.[39,40]

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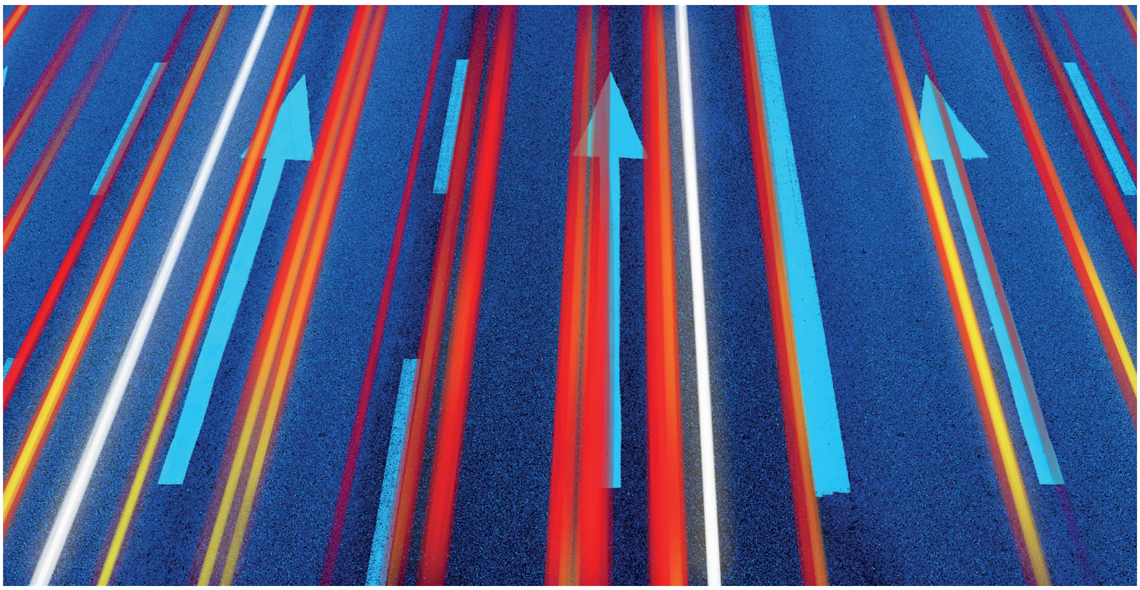
Leading in 2030

Although there may well be singular moves for using better batteries by companies such as Tesla and Dyson that are highly vertically integrated from design to retail in their respective sectors and so can control their supply chains, other organisations that deliver improved performance in the next decade will be far more collaborative in nature. The complexity of the industrial partnerships between chemical companies, battery manufacturers and their myriad different customers means that to deliver significant change the whole ecosystem has to evolve in tandem. In some industries, such as automotive, collaboration among many stakeholders of the whole value chain is needed. This requires coordination. While NASA continues to be a catalyst for technology development in the US, in Europe, initiatives are underway to align multiple parties around the likely changes by 2030.[41] For example organisations such as the Fraunhofer Institute have been created and are sharing updated technology roadmaps for the past few years.[42,43]

As such defining which single company may be the winner across multiple markets is very difficult – with lots of cross-licencing of technologies and co-ownership of intellectual property, mapping who will have the most long-term influence is a challenge for many investors. With new announcements, such as the forthcoming Tesla Battery Day, now occurring on a regular basis, we can, however, expect the progression to better batteries to quicken further over the next few years. Moreover, as the 2030 net zero emission targets now being introduced in leading cities such as Oslo, Mexico City and Paris are more widely adopted, policy will act as an accelerator.

The outstanding questions for many will nevertheless remain how far and how quickly can mainstream industrials move by 2030 to address this pivotal energy storage challenge. As we discuss this further during 2020, it will be interesting to see where more experts see new solutions emerging. If only half of the current targets can be achieved, then the impact on how we consider and use renewable energy globally will shift dramatically.



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The World in 2030

This is one of 50 global foresights from Future Agenda's World in 2030 Open Foresight programme, an initiative which gains and shares views on some of the major issues facing society over the next decade. It is based on multiple expert discussions across all continents and covers a wide range of topics. We do not presume to cover every change that will take place over the next decade however we hope to have identified the key areas of significance. Each foresight provides a comprehensive 10-year view drawn from in-depth expert discussions. All foresights are on https://www.futureagenda.org/the-world-in-2030/

Previous Global Programmes

The World in 2020 was published in 2010 and based on conversations from 50 workshops with experts from 1500 organisations undertaken in 25 countries as part of the first Future Agenda Open Foresight programme. This ground-breaking project has proven to be highly accurate in anticipating future change and the results have been used by multiple companies, universities, NGOs and governments globally. Rising obesity, access not ownership, self-driving cars, drone wars, low cost solar energy, more powerful cities and growing concerns over trust were just some of the 50 foresights generated. For more details: https://www.futureagenda.org/the-world-in-2020/

Five years on, the World in 2025 programme explored 25 topics in 120 workshops hosted by 50 different organisations across 45 locations globally. Engaging the views of over 5000 informed people, the resulting foresights have again proven to be very reliable. Declining air quality, the growing impact of Africa, the changing nature of privacy, the increasing value of data and the consequence of plastics in our oceans are some of the foresights that have already grown in prominence. For more details: https://www.futureagenda.org/the-world-in-2025/

About Future Agenda

Future Agenda is an open source think tank and advisory firm. It runs the world's leading Open Foresight programme, helping organisations to identify emerging opportunities, and make more informed decisions. Future Agenda also supports leading organisations on strategy, growth and innovation.

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