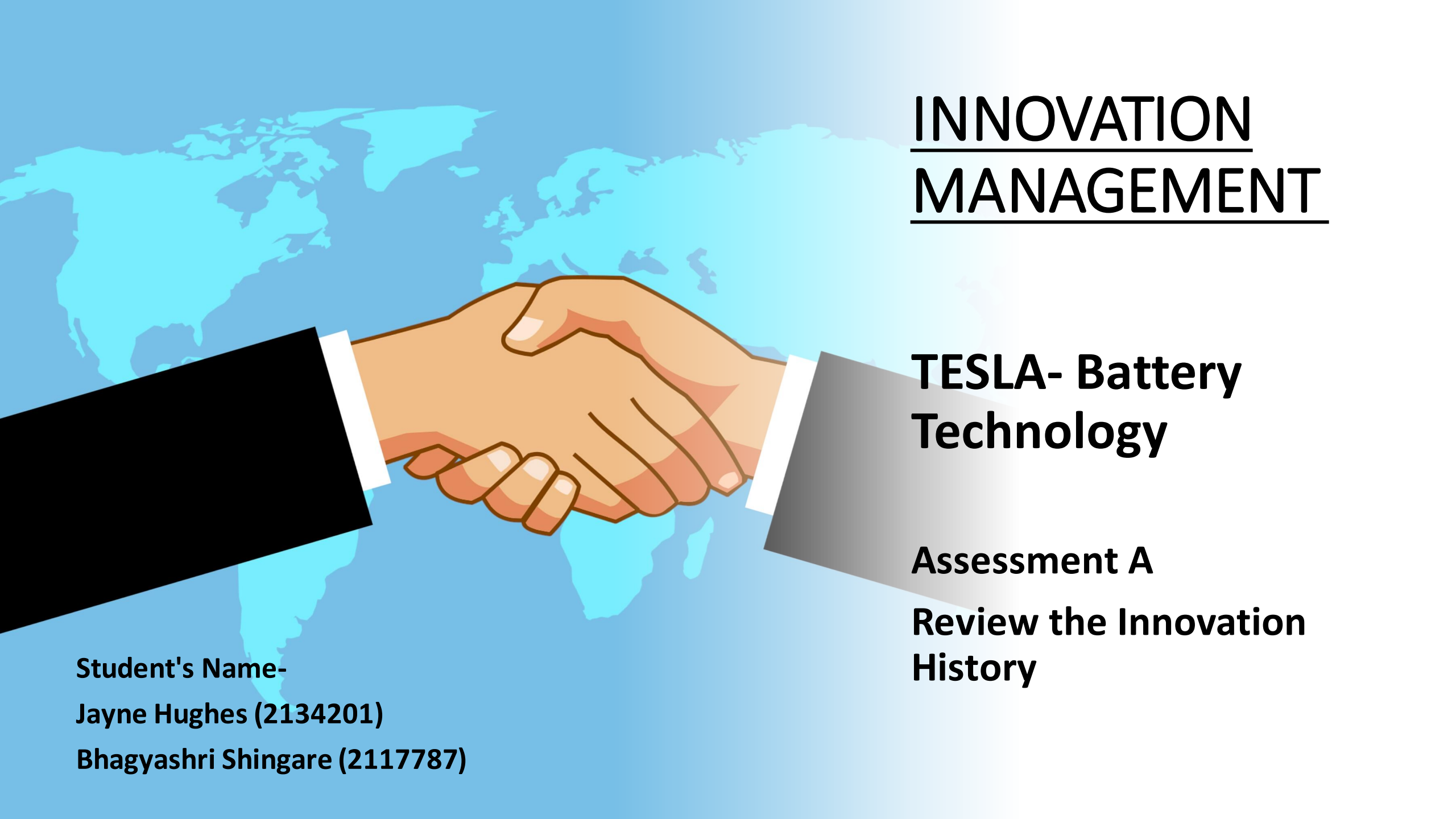


An illustration of two hands shaking in a firm grip, symbolizing a partnership or agreement. The hands are rendered in a stylized, cartoonish manner with orange and brown tones. They are positioned over a light blue background that features a faint, stylized world map. The map shows the continents in a darker shade of blue. The handshake is the central focus, with the hands emerging from the left and right sides of the frame.

INNOVATION MANAGEMENT

TESLA- Battery Technology

Assessment A

Review the Innovation History

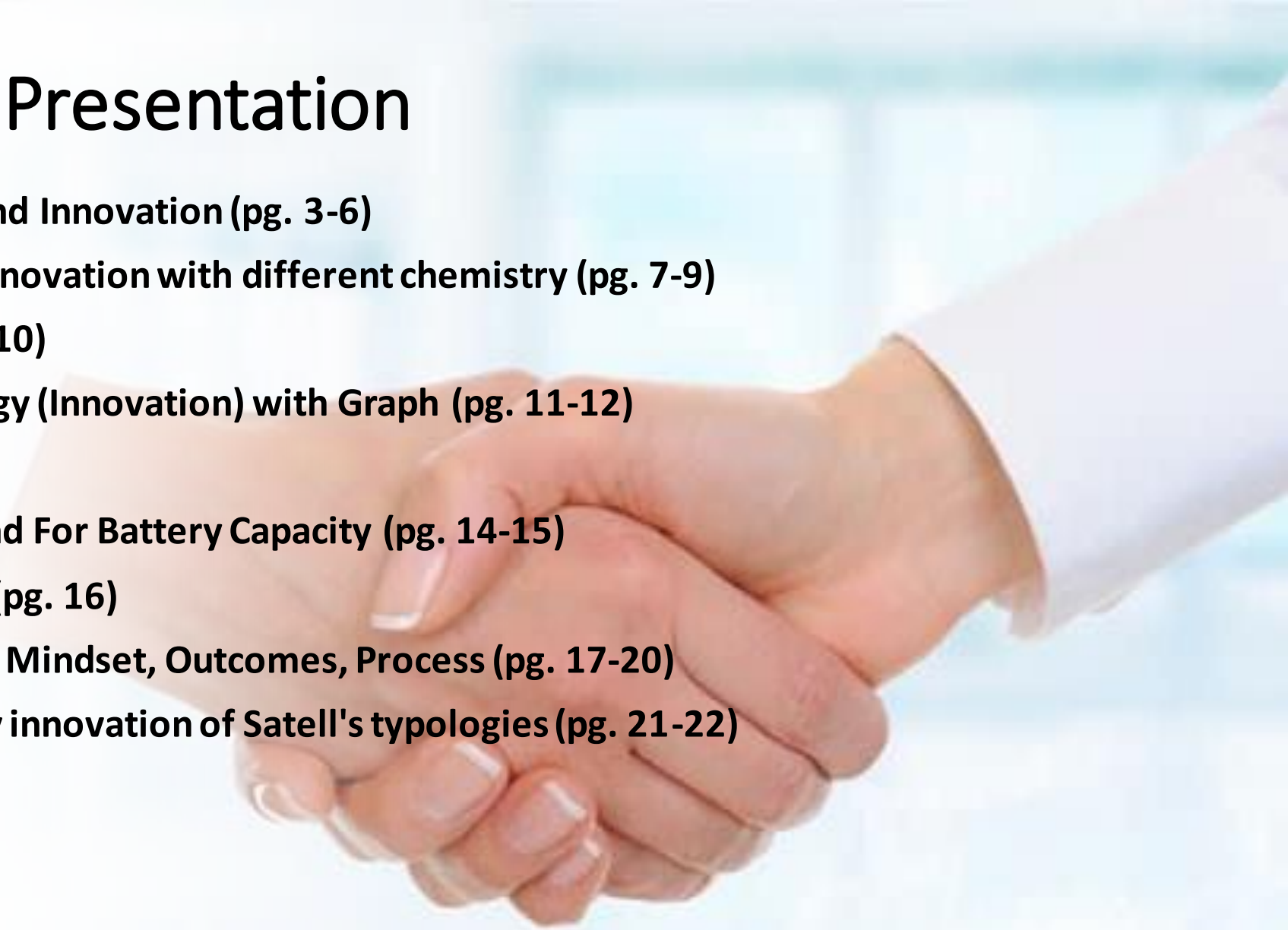
Student's Name-

Jayne Hughes (2134201)

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- **Tesla Battery technology and Innovation (pg. 3-6)**
- **Tesla Battery technology Innovation with different chemistry (pg. 7-9)**
- **Material Dependency (pg. 10)**
- **R & D for Battery technology (Innovation) with Graph (pg. 11-12)**
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- **Tesla Batteries Innovation (pg. 16)**
- **Understanding innovation- Mindset, Outcomes, Process (pg. 17-20)**
- **TESLA's Battery technology innovation of Satell's typologies (pg. 21-22)**
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Battery technology and Innovation-

- Tesla has three main batteries:-
- TESLA 18650/1865
- TESLA 2170
- TESLA 4680

Battery technology and Innovation-

- Tesla's first battery option is Nickel Cobalt Aluminium (NCA). The company started using NCA battery chemistry years ago in the form of 18650 cells (recently called 1865) cylindrical batteries, designed for general purpose.
- They were difficult to use, due to a high number of small cells (low capacity) in the battery pack (several thousand), but available at a consistent quality and in high volume. The 1865-type cells were used in the Roadster and Model S/Model X (including the refreshed ones).





Battery technology and Innovation-

- Later, Tesla figured out that it would be better to have a larger battery cell (higher capacity per cell, and a lower number of cells), optimized for electric cars. This is how the 2170-type cylindrical cell entered the market in high volume for the Tesla Model 3/Model Y as well as for energy storage product.
- Though the size is different: 2170 cells, which are larger and more energy-dense than the 18650 cells

Battery technology and Innovation-

- Tesla's third battery option is the newest and so far the largest cylindrical cell format, the 4680 cell it raved about a few years ago at its Battery Day event, and now entered the market. The cell is physically 5-times bigger than the 2170-type, which allows for further optimizing the system and introduction of some new technologies.
- The 4680 batteries have **5 times more energy with 6 times the power and enable a 16% range increase**. At the battery-pack level, the form-factor improvements alone result in a 14% reduction in cost per kWh
- The Model Y crossovers coming out of Tesla's new Gigafactory in Austin will be fitted with 4680 Tabless battery cells. The vehicles will also be the first from Tesla to feature its structural battery pack.





Battery technology Innovation with different chemistry

- Those are the three cylindrical cell types used by Tesla in its electric cars, but there is a fourth one -LFP batteries.
- Fast-forward to more recently, and Tesla started using battery chemistry in China, which eventually made its way to the US. Lithium Iron Phosphate (LFP) battery cells will be used in all Tesla's single-motor rear-wheel-drive vehicles. In the US, this means only the base Model 3 uses LFP chemistry, though a new Model Y LFP variant may be on the way. We should also note that, as far as battery cell size is concerned, these are all 2170 cells. LFP batteries are the foundation of the less expensive, entry-level Tesla models.

Battery technology Innovation with different chemistry

Diversified Cathode Approach

- Tesla is also moving to (slightly) different chemistries on the cathode side. And yes, that's plural chemistries, which is at least as noteworthy as the nitty-gritty chemical details. Tesla now wants to provide three different types of lithium-ion batteries, ranging from more economical to I'm-giving-her-all-she's-got-captain.



IRON BASED
LONG CYCLE LIFE

NICKEL + MANGANESE
LONG RANGE

HIGH NICKEL
MASS SENSITIVE

TESLA **LIVE**

Battery technology Innovation with different chemistry

- Tesla currently uses an NCA chemistry (that's lithium-nickel-cobalt-aluminium), while lithium-nickel-manganese-cobalt (NMC) chemistries are common across the rest of the EV industry. Cobalt is the most expensive of these elements, and most of it is sourced from mines in the Democratic Republic of the Congo, where unsafe working conditions and child labor are serious problems. As a result, the industry has been trying to reduce cobalt usage.
- Tesla says it has developed two new chemistries that appear to be cobalt-free. That starts with a new "high-nickel" cathode chemistry, which relies on "novel coatings and dopants" to replace the stabilizing presence of cobalt. Although the presentation did not go into specifics, Baglino referred to this as a "100-percent nickel" formulation at one point. This has the highest energy density of the bunch but also costs the most and is intended to be used for the Cybertruck and Tesla Semi, where the extra energy density is most needed.
- A little cheaper is a new nickel-manganese cathode in something like a two-thirds/one-third mix, according to Musk. The implication was that this is also cobalt-free, but this wasn't explicitly stated. This chemistry drops the price considerably in trade for a bit of energy density. NMC cathodes in an 8:1:1 ratio already exist, so dumping the remaining cobalt is presumably less of a leap than the "high-nickel" chemistry that *also* dumps the manganese (apparently?), but we don't know how they're making this one work, either.
- (And just for the record, all mining has an environmental impact, and nickel is no exception).
- Tesla's third chemistry is a known quantity: lithium-iron-phosphate (LFP). This is the cheapest and least energy-dense of the group. To support Tesla's operations in China, it lined up a new battery supply agreement with CATL.
- We must also remember that the cathode is not the only element of the battery and there are constant improvements to all elements, including the anode (silicon vs. graphite content) and the electrolyte.

Lithium-Iron-Phosphate Cathode



Nickel-Manganese-Cobalt Cathode



Nickel-Cobalt-Aluminum Cathode



Material dependency

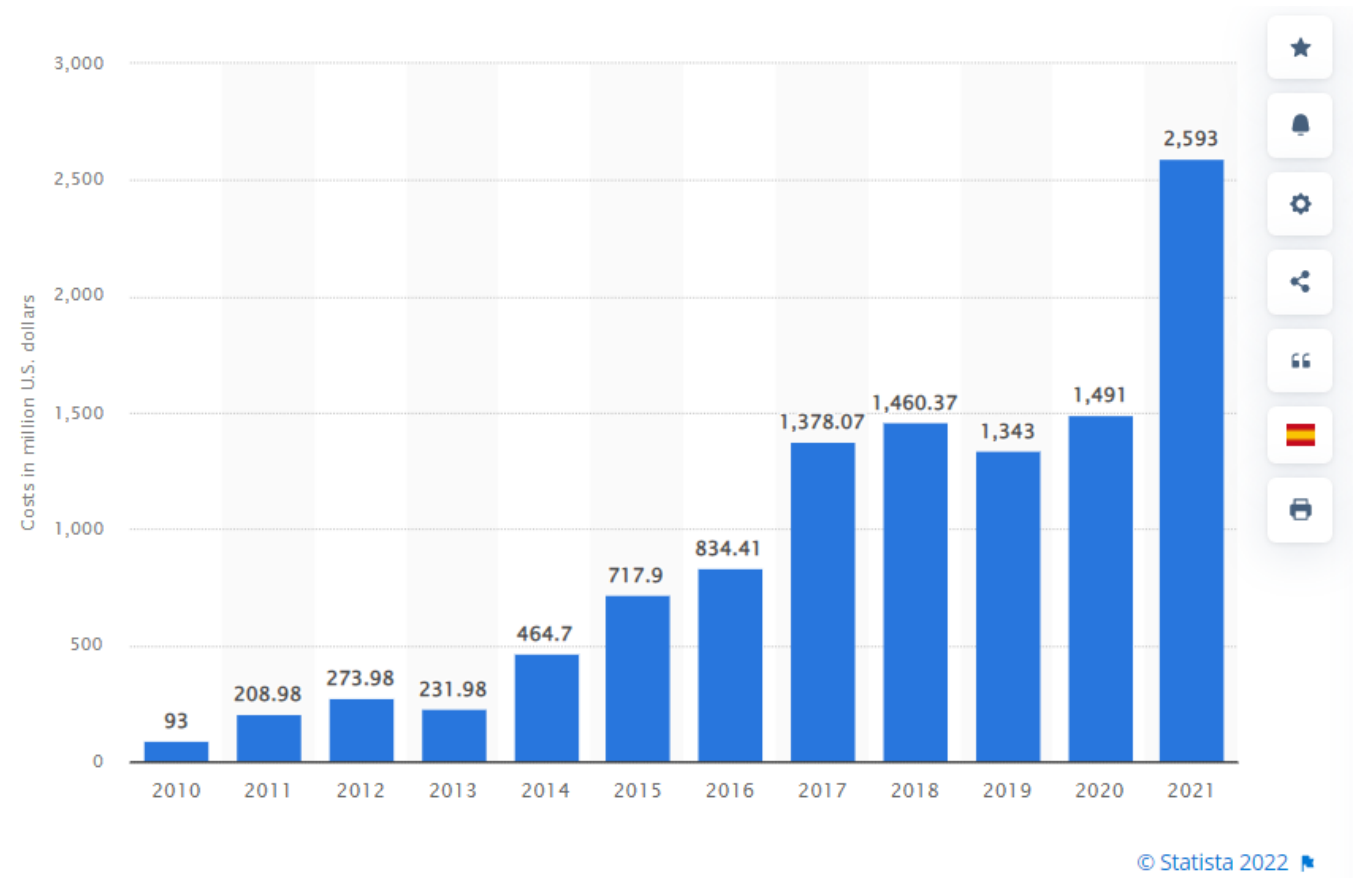
- Cobalt is by far the most expensive element in a lithium-ion battery
- Cobalt — which also is the focus of a new race by miners to extract minerals from the ocean floor — has long been a commodity challenge for major technology companies, not just Tesla but Apple as well
- Tesla recently signed a new long-term deal with commodities giant Glencore to supply cobalt for its battery plants in Shanghai and Berlin.
- The key difference in the lithium-iron phosphate batteries is that they do not need to use cobalt, a rare and expensive element that is a big part of the high cost of electric vehicle batteries, CFRA Research analyst Garrett Nelson said.
- Cobalt prices have tanked during the global economic downturn, declining from as much as \$95,000 per ton in 2018 to \$30,000 this year, but it remains key to bringing down battery costs.
- Canning cobalt is one of the biggest elements of cutting the cost of batteries below the \$100/kWh threshold that is a rough proxy for making electric vehicles as cheap as those powered by internal combustion engines, said James Frith, head of energy storage at Bloomberg New Energy Finance in London. Today's batteries cost about \$147/kWh, down from about \$1,000 in 2010 and \$381 in 2015, he said.
- The element has become a politically sensitive issue, too, with some of the largest supplies of cobalt coming from the Democratic Republic of Congo, where allegations of deadly child labor in mining have ensnared Apple, Tesla, Google and other tech firms in a recent international lawsuit.

R & D for Battery technology (Innovation)

- The development that should peak the most interest, however, is arguably the single crystal cathode patented by Dalhousie academic and head of the Tesla battery research team, Jeff Dahn.
- A cathode is the positively charged electrode that absorbs the electrons and current into the battery. Simply put, they are essential for lithium-ion battery function and maintenance. The paper published by Dahn explores larger single crystal cathodes as opposed to polycrystalline cathodes. Charging and discharging makes the crystal structures expand and contract causing stress at the borders. With the currently used polycrystalline cathodes, the structure disintegrates over time and the battery fails. This allows for a bit more than 1,000 charge cycles.
- The paper shows that the single crystal cathodes that Tesla wants to use degrade a lot slower, resulting in batteries lasting many more cycles – potentially up to 4,000. Additionally, the cathode is currently being manufactured with nickel, aluminium and cobalt, however the paper strongly suggests that the cathode can be made using only nickel and aluminium. This effectively means going cobalt-free, and therefore cheaper.
- We know Tesla is keen on going cobalt-free to avoid using up the limited reserves our planet has, and to refrain from getting involved in illegal child labour that some cobalt mines have been accused of taking part in.
- The only issue is that this crystal now needs the right additives for it to be incorporated into Teslas. What is promising is that Dahn and his team are already working on a Titanium-based coating that could make a battery that lasts 1.6 million kilometres, or a million miles. The era of cheap, durable EV batteries could be just around the corner.
- Tesla has just filed a new patent for a new, more durable battery cell that should also be cheaper to produce. Jeff Dahn and his team are listed as inventors. The cell uses two additives in the electrolyte, vinylene carbonate (VC) combined with 1,2,6-oxodithiane-2,2,6,6-tetraoxide, in order to boost the performance of the cell. The new cells with NMC chemistry are supposed to offer a service life of more than 1.6 million kilometres (Update 16 September 2019).

Tesla's research and development expenses from FY 2010 to FY 2021 (in million U.S. dollars)

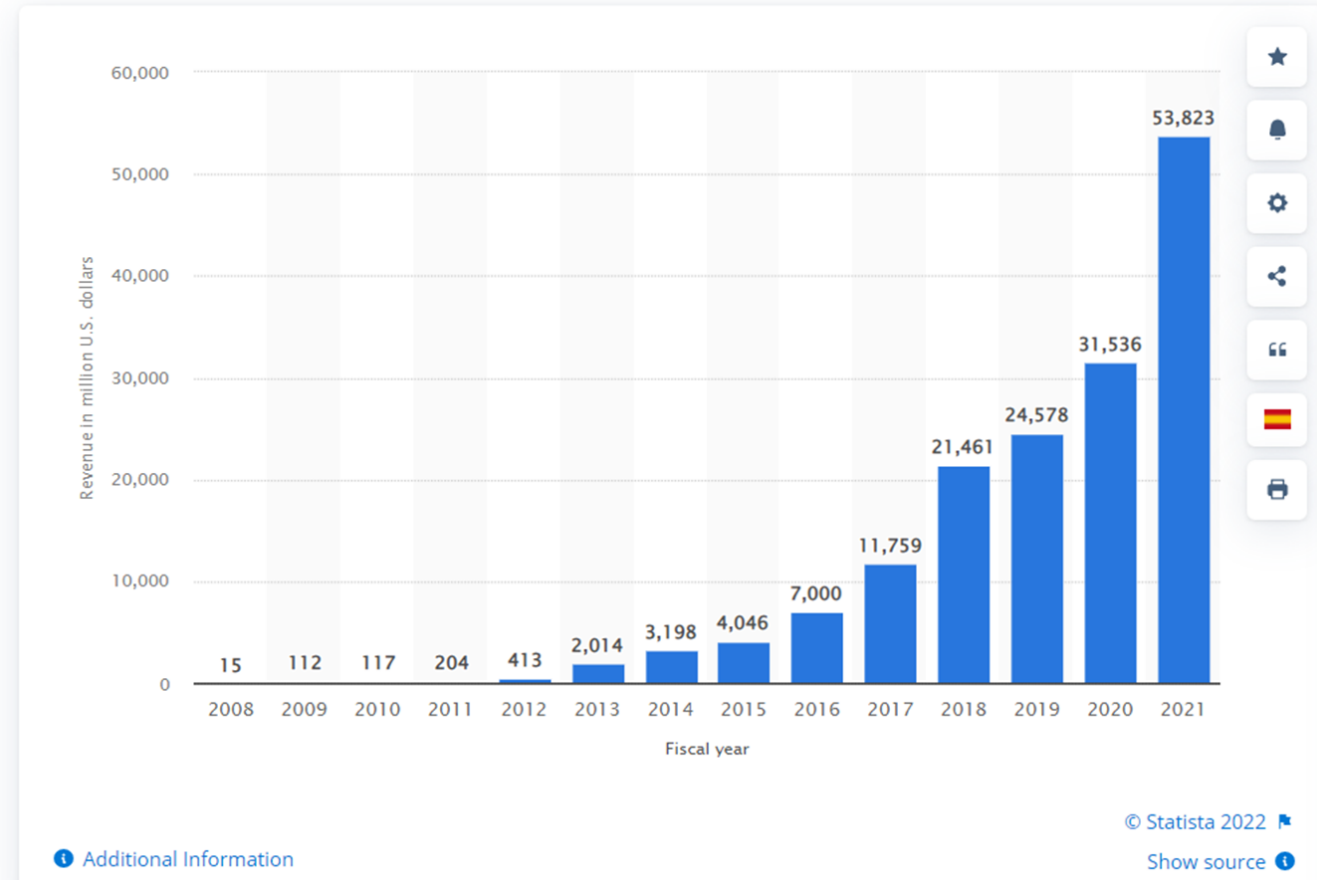
- Tesla's research and development spending increased to almost 1.5 billion U.S. dollars in 2020. The intensity of investment in recent years has made Tesla the leading electric vehicle manufacturer in the United States. Globally, the company sold just under half a million vehicles in 2020.



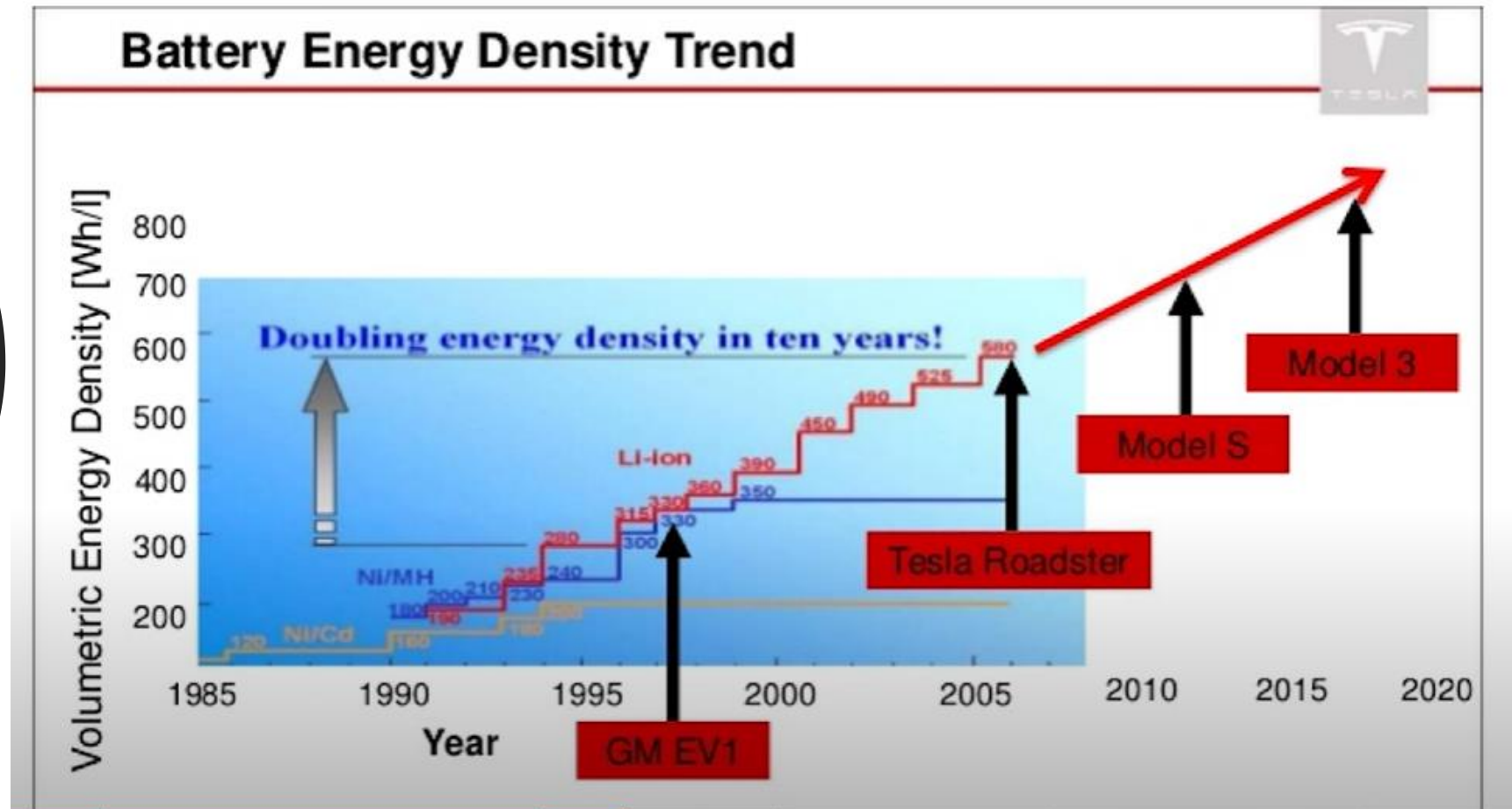
TESLA's Revenue

Tesla's revenue grew to around 53.8 billion U.S. dollars in the 2021 fiscal year, a 71 percent increase from the previous year. The United States is Tesla's largest sales market.

Tesla's revenue from FY 2008 to FY 2021
(in million U.S. dollars)



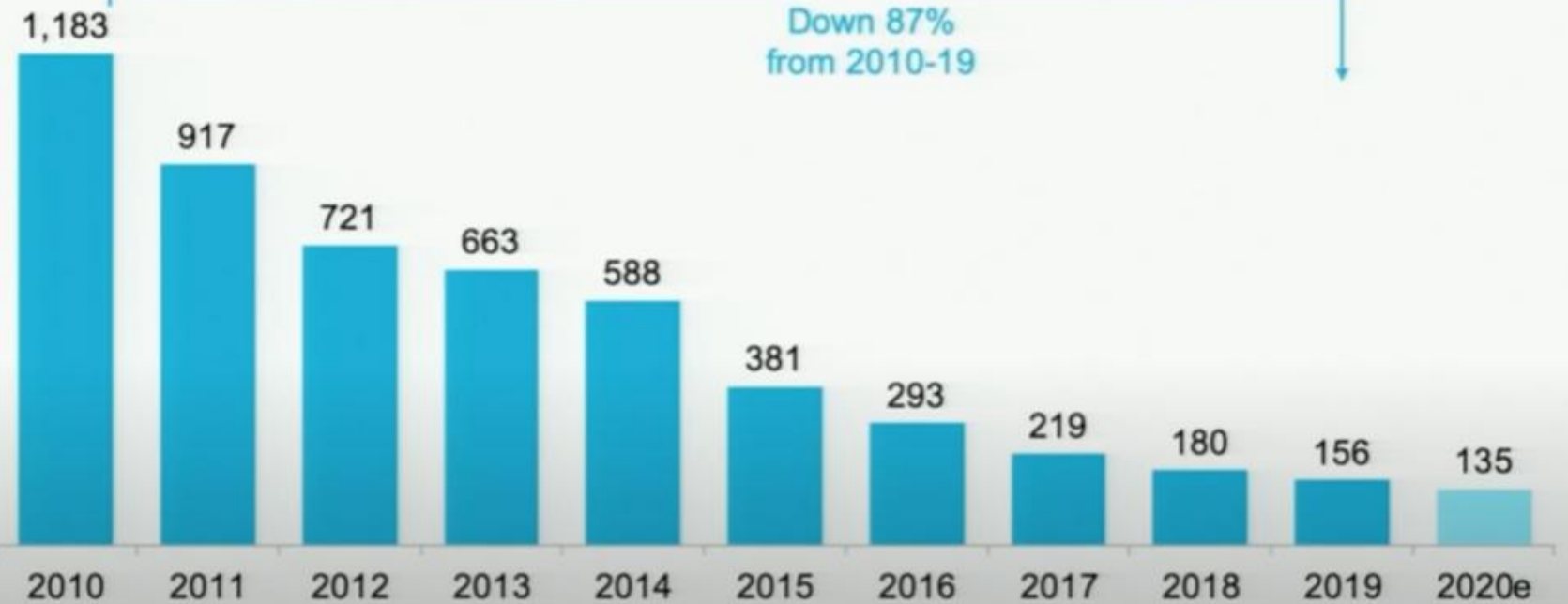
Battery capacity-is going up



Battery cost-
is going
down

Lithium-ion battery prices keep falling

Battery pack price (real 2019 \$/kWh)



Source: BNEF 2019 lithium-ion battery price survey

Tesla Batteries Innovations

Powerwall

- Powerwall is an integrated battery system developed by Tesla, which stores solar energy for backup protection and reduces reliance on the grid. The device automatically recharges with sunlight and detects power outages.
- Using the Tesla app, the user can monitor the system in real-time and set their preferences to optimise energy independence, outage protection, or savings. “Solar + Powerwall battery ensures that your home never loses power,” said Tesla’s chief Elon Musk in a Twitter post.

Solar Roof

- Tesla’s Solar Roof tiles are the first of its kind product in the market. Its solar roof tiles are more than thrice stronger than standard roofing tiles and are engineered for all-weather protection. It comes with a 25-year warranty. “Our in-house team of energy professionals have installed more than 3.6 GW of clean solar energy across 4 lakh roofs — the equivalent of 10 million traditional solar panels,” according to Tesla.
- Tesla said users could power their homes at the lowest price per watt of any national provider and take control of their monthly electricity bill.

Megapack

- Tesla Megapack is transforming how we power the grid — delivering giga-scale capacity, enabling the world’s largest energy projects. For instance, its 1 GWh (Gigawatt hour) project can provide record energy capacity — enough to power every home in San Francisco for six hours.

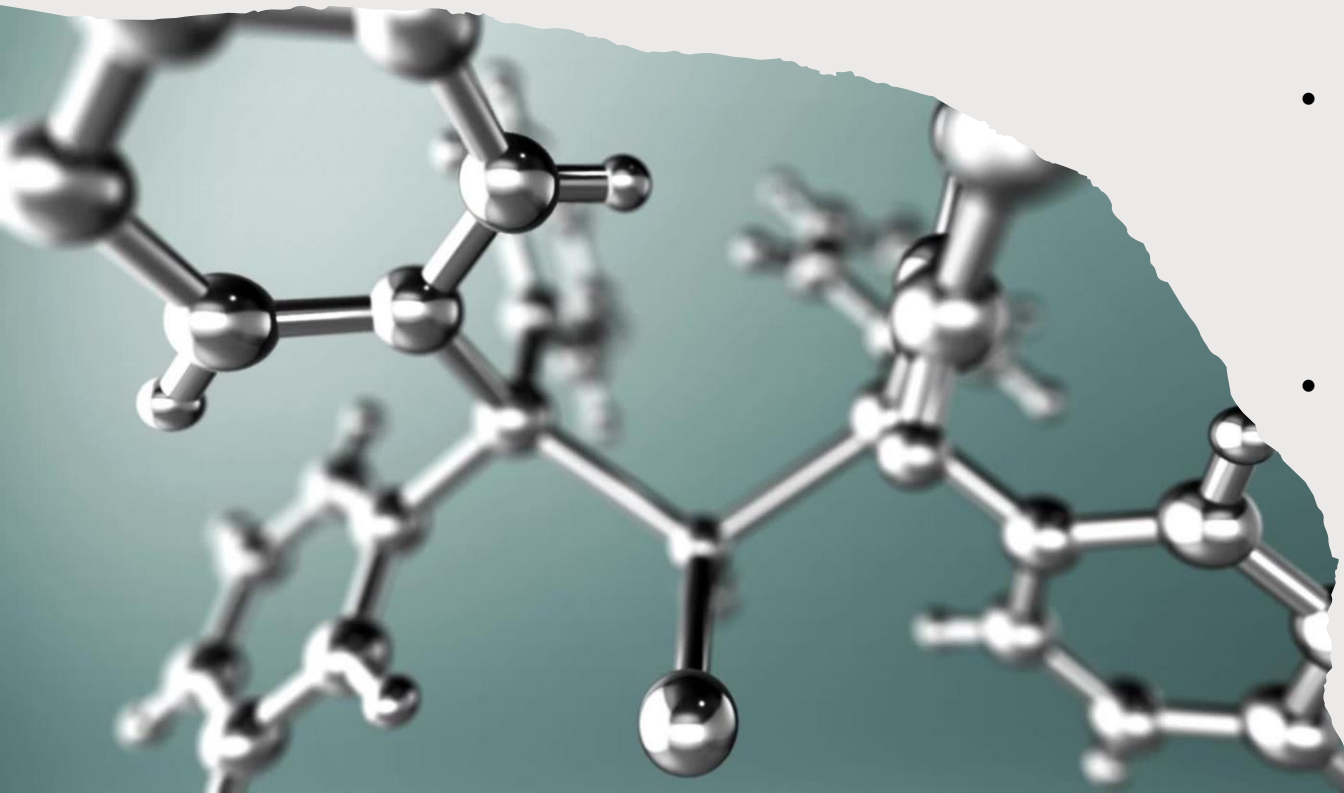
Electric vehicles charging stations

- While the demand for electric vehicles continues to rise, setting up charging infrastructure has become paramount. Tesla is currently leading the race by developing state-of-the-art chargers to power its electric vehicles.
- The company has released innovative chargers, including home charging(wall connector), Supercharger, and destination charging. Today, Tesla owns and operates the largest global, fast-charging network in the world, where it has installed close to 35,000+ Superchargers.

Battery Recycling Facility

- Tesla is building capacity to recycle manufacturing scrap and end of life batteries raw materials. By the end of 2021 our battery recycling facility at Gigafactory Nevada achieved a production rate of 50 tons of recycled material per week

Understanding innovation-Mindset



- Musk has an ability to look at the bigger picture when setting ambitious goals, and in equal measure can look at any situation at a molecular level to challenge the status quo.
 - (a) He asks himself what is the solution to the problem?
 - (b) What needs to happen to achieve the desired outcome?
- He recognises the benefits of maintaining constant improvements to everything relating to the business and innovation.
- By looking at what has been done, you are able to more effectively build what could, or even should, be done in the future. In doing so he believes you don't even need to be the first to do something; you just need to be the first to do it well or at the right time,
- e.g. the first EV was invented in 1884 when Thomas Parker built the first electric production car in London.

Understanding innovation-Outcomes

- Started manufacturing upstream (inhouse batteries)-Manufacturing their own batteries. Set up Gigafactory 1 facility designed to significantly reduce battery cell costs, by bringing production costs in house. Vertical intergration.
- They are also aiming to supply direct to their customers
- Recycling the batteries
- Tesla to Manufacture batteries at the volumes required to meet production goals, while creating thousands of jobs



Outcome: Product Innovation Strategy



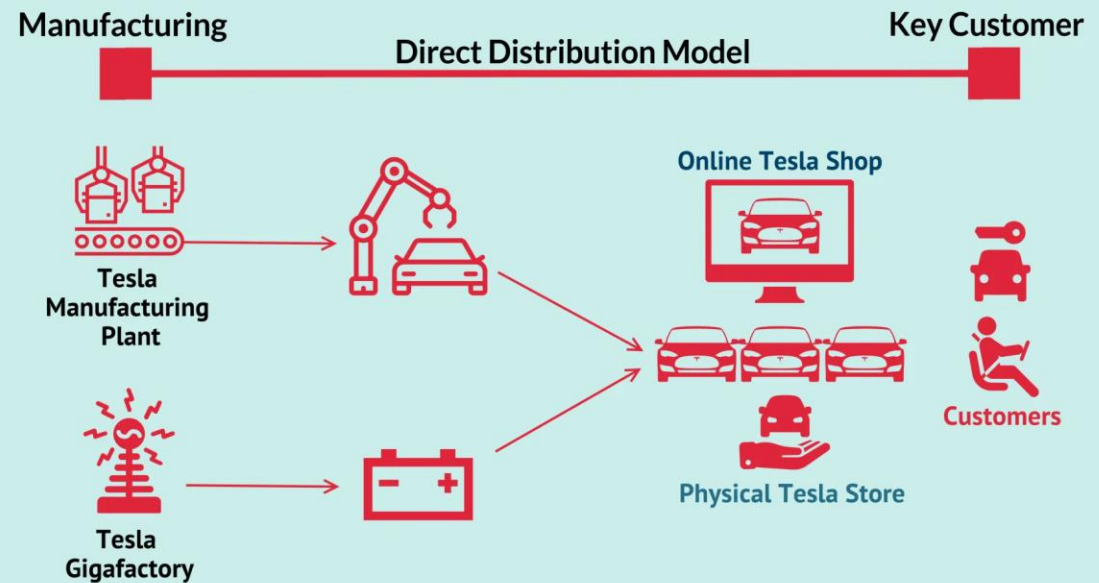
- Create an entire sustainable energy ecosystem
- enable homeowners , businesses and utilities to manage renewable energy generation, storage and consumption.
- Set up Gigafactory 1 facility designed to significantly reduce battery cell costs, by bringing production costs in house.
- Tesla to Manufacture batteries at the volumes required to meet production goals, while creating thousands of jobs
- Tesla to produce products accessible and affordable

Understanding innovation Process

- High speed continuous motion assembly to maximise output
- Vertical integration to build their own batteries
- Streamline operations
- Utilise advanced technology including
 - Robotics
 - IOT
 - SMART Technology
 - Cameras
 - Automation
 - Sensors
 - Lean Manufacturing
 - Agile
 - Recycling

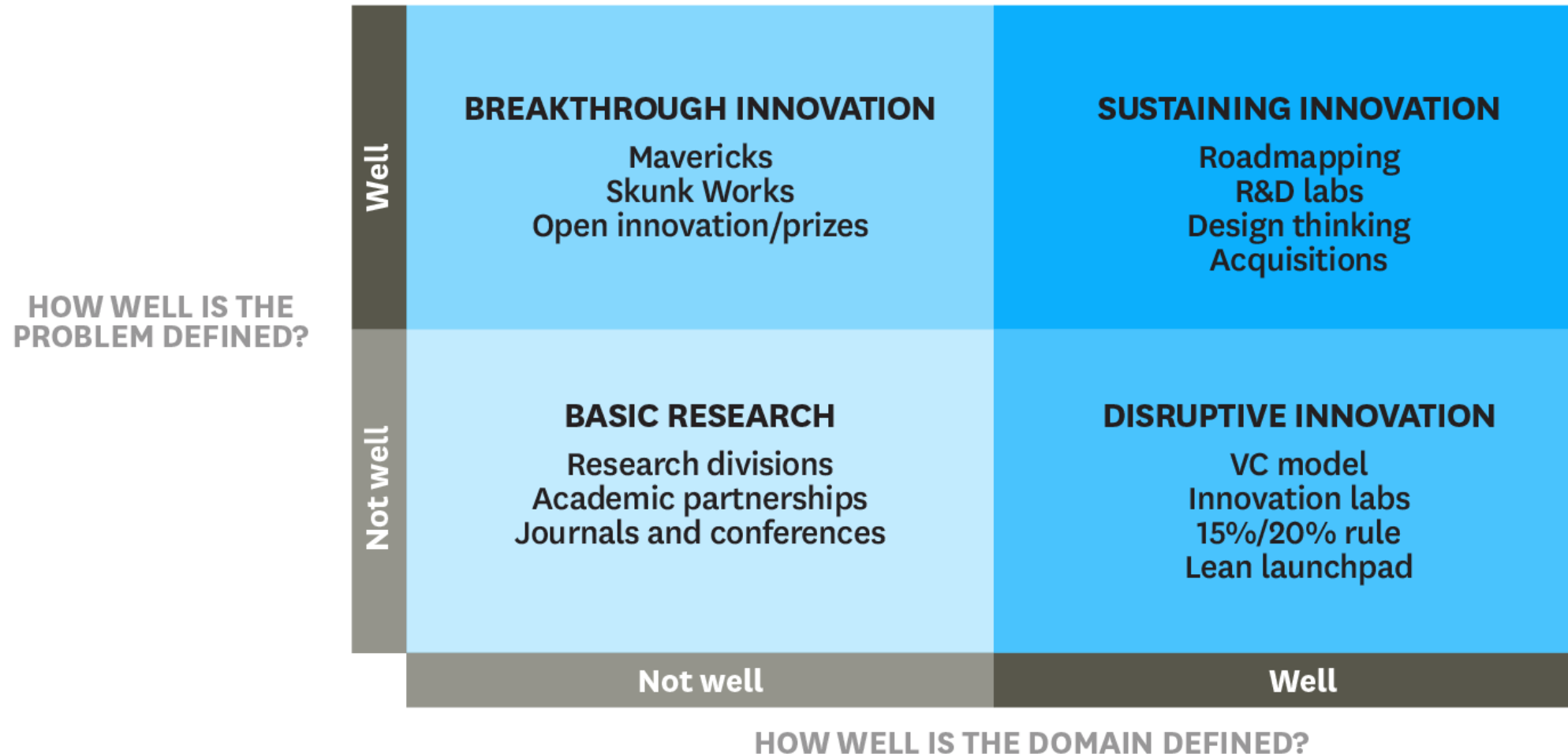
Tesla Business Model In A Nutshell

Tesla is vertically integrated. Therefore, the company runs and operates the Tesla's plants where cars are manufactured and the Gigafactory which produces the battery packs and stationary storage systems for its electric vehicles, which are sold via direct channels like the Tesla online store and the Tesla physical stores.



Mapping TESLA Battery technology onto Satell's typology Matrix

4 Types of Innovation



Innovation matrix

Sustaining Innovation

- By looking at what has been done, you are able to more effectively build what could, or even should, be done in the future. In doing so he believes you don't even need to be the first to do something; you just need to be the first to do it well or at the right time, e.g. the first EV was invented in 1884 when Thomas Parker built the first electric production car in London.
- Looking purely at the core technologies of Tesla's vehicles, both electric motors and lithium-ion batteries have been around for quite some time and an argument can be made that even though Tesla has clearly refined these technologies, the innovations have been incremental in nature.

Breakthrough Innovation

- The Tesla Roadster was the first production all-electric car to be able to travel more than 200 miles per charge.
- Therefore, electric cars such as the Tesla Roadster are an example of a breakthrough product in the automobile sector.

Disruptive Innovation

- The new Infostructure & ecosystem Tesla has brought to being has disrupted the auto industry. The use of innovation, a reputation for being amazingly innovative, continuously reducing costs, and massively contributing to towards net zero, along with hitting innovative milestones having a good story and the power of word of mouth and technology such as social media has allowed for a shift in the automotive industry. Manufacturing batteries inhouse and developing vertical Integration has resulted in tighter control over reducing costs and contributes to the bigger picture.
- Has its own proprietary supercharger network net worth 35000 charging stations. Manufactures solar power etc. Tesla are dominating the lead in the Electric battery market
- Tesla supplies direct to the end user either via the internet or a distribution network that Tesla owns.
- Every sale of a Tesla vehicle then represents a loss of margin for a traditional car dealer and therefore a threat to a century old industry structure in which vehicles are sold through dealers who maintain large lots and inventory.

Basic innovation

- As much it is evident that Tesla have, historically, invested heavily in R&D, we can't find any evidence to suggest it was invested in basic innovation directly.

Conclusion

- All elements of innovation, mindset, outcomes and process are important in developing a roadmap and strategy to achieve objectives.
- The use of innovation, a reputation for being amazingly innovative, continuously reducing costs, and massively contributing towards net zero, along with hitting innovative milestones having a good story and the power of word of mouth and technology such as social media has allowed for a shift in the automotive industry.
- Musk willingness to see common objects and technologies as worthy of critique has allowed him to innovate in areas that few have imagined.
- There are constant improvements to all elements of the battery, including the anode & Cathode (silicon vs. graphite content) and the electrolyte.
- Tesla uses NCA chemistry, or Nickel, Cobalt, and Aluminium (LiNiCoAlO_2). They use this particular chemistry because it offers great energy density, long cycle life, and great charge performance. This makes Tesla's batteries the absolute top of the line in the EV world. They weigh less, last longer, and power the performance of things like Ludicrous mode.
- Tesla is now dependent on SMART technologies to achieve competitiveness and maintain innovative benefits.
- Tesla have applied innovation to the extent of repositioning themselves as the EV market leader.

What We Learnt

- *To attain successful innovation the mindset of the leader is paramount and that he possesses the passion needed to drive innovation forward.*
- *The leader needs to ensure a management structure is in place to allow innovation to flourish.*
- *Looking backwards at existing innovations before developing new ideas, is not only less risky, but more cost effective and efficient. You don't need to be the first to do something; you just need to be the first to do it well or at the right time.*
- *It's difficult to define and categorise innovation.*
- *The value of a clear vision and strategy in developing a clear strategy.*
- *By investing in R&D results in allows innovation to flourish.*

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