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Consumer Interview

1. **What Is your name?**

   Mohammed Qureshi

2. **What type of Tesla do you have?**

   I have a 2020 Tesla Model 3.

3. **Are you satisfied with your EV?**

   Yes, because there is not a lot of maintenance, there is no transmission, there are less moving parts which means less maintenance, and I do not have to pay for gas which makes it cheaper.

4. **Are you satisfied with your EV battery?**

   Yes, I haven't had any issues so far and it has been working fine.

5. **What type of battery does your EV use and what is the voltage?**

   I think my Tesla has a Lithium-ion battery but I am not sure about the voltage. Of course, it is rechargeable and the software monitors the charging so it charges only up to 80% and lowers only until 10% because that slows down the rate at which it degrades. I also know that the battery has multiple cells that are located under the floor. I charge it with a 110-volt cord but the bigger the cord, the faster the charge. That is how a Supercharger works.

6. **How far does your battery last after one charge?**

   If it is charged to 100% then the max it can travel is 500km but since I charge it up until 80%, it lasts until about 400km. In winter though, the range decreases because you are using the battery for heating and all that other stuff.

7. **How long does it take for your EV to charge?**

   It depends on the power source. For a 110-volt cable, it takes 24 hours to charge but if it goes low then I take it to a Supercharger, it takes 30 minutes to charge from 15%-80%.

8. **If you could change something about the battery, what would it be?**

   I am okay with the range but I would want faster charging.

9. **How long will it be until your battery goes bad and you would need to change it? How do you know?**

   I am not sure when it will go bad but I do not think it will be soon. It also depends on how much I use it but I think I will outlive this car. Also, Tesla gives an 8-year or 192 000km (whichever comes first) warranty for the battery so if it breaks or completely degrades, they will replace it with no charge. I think that even if I keep it for long enough that the battery degrades fully, the software will tell if anything is wrong or it stops charging properly.

10. **How often do you need to charge your EV?**

    I keep it plugged on in the garage all the time when I am not using it and the software manages all of the charging things.

Tesla Technician Interview Report

1. **What is your name?**

   Chris M.

2. **How long have you been working for?**

   I have been working as a technician at Tesla for 4 years

3. **Whare did you get your training?**

   First, I went to SAIT (Southern Alberta Institute of Technology), then I went to Toyota for 14 years, and now I have been at Tesla for 4 years.

4. **What Batteries are used in Tesla's?**

   We use 18650 (size number), 2170, 4680. The types of batteries we use are lithium-ion, lithium-polymer, and lithium-iron phosphate.

5. **What can you tell me about batteries like which ones are better?**

   Lithium-ion batteries are great because of their boost and high energy density but they have limitations like capacity and weight.

6. **In your opinion how can we make batteries last longer?**

   We can make them last longer ideally by controlling the temperature so the battery is at its peak performance all the time. The ideal temperature for the battery to function the best is 40°C and the software makes sure that it stays at ideal temperature.

7. **In your opinion how can we develop a way to charge Tesla's faster?**

   The Cybertruck has already developed a way to do that which is instead of having one 48v battery, it has two 24v batteries so that way you still get the same voltage but it charges faster because the current goes to both batteries at the same time. Also, since 24x2=48, you do not have to convert the voltage.

8. **Is there a way to make batteries self-healing?**

   Kind of, if the software in the car senses that one of the batteries cells have degraded, it stops using that cell so all the other cells don't start to stop working properly and the battery is still at its peak performance. Also, it is very hard to fix it physically but let's say that you have 5 cells. You can use the materials in the 5 cells to make 3 good cells that can be used again instead of buying 3 completely new cells which is also cheaper for the customer.

9. **Is there a way to fix batteries after they have fully degraded so you don't have to get a new one?**

   Yes, it is possible but we don't because of bylaws (fire, chemicals, etc.). To replace the battery, it costs something between 38, 000$ - 14, 000$ and the life of the battery is 10-15 years.

10. **Which batteries that Tesla uses are the best?**

    My favorite is the lithium-ion because of the boost and the good performance.

11. **How are your batteries different than other companies?**

    We use cell-based batteries which are larger and more energy dense. Toyota, for example, uses plates of nickel-metal cadmium.

Science Fair Logbook
2023-2024

Dec 15th 2023 - Jan 28th 2024:
- start my background research
- finish my background research
- fully understand how a rechargeable battery (secondary cell) works
- websites I use: www.tesla.com, www.energy-storage.news, www.aquametals.com, study.com, www.linkedin.com, ul.org, energyeducation.ca, batteryuniversity.com, www.mdpi.com, google.com

Jan 29th 2024:
- finish all of my main research on Google Docs
- complete my understanding of electrolysis
- websites I use: www.sciencedirect.com, www.energy.gov, google.com

Jan 30th 2024 - Feb 3rd 2024:
- catagorize all of my research on Google Docs under questions
- add references
- I also look up any additional questions
- websites I use: energyeducation.ca, batteryuniversity.com, google.com, sciencedirect.com, www.mdpi.com, www.tesla.co

Science Fair Logbook
2023-2024

Feb 4th - Feb 11th 2024:
- make sure all my research is in my ow words
- make sure that everything is properly referenced
- move all research to Microsoft Word
- add some more research on different rechargeable EV batteries
- Websites I use: adfc.energy.gov, firstphosphate.com

Feb 12th 2024:
- research pictures to put on the trifold that are relevent to my topic
- make questions for consumer interview
- finalize title completely
- make my own chart based on my research comparing lithium-ion batteries to other batteries
- no websites to use

Feb 13th 2024:
- conduct interview with consumer
- after interview, type up questions and exact answers
- after interview, make a summary of the interview to put on the board/trifold
- make questions for Tesla technicion interview
- no websites to use
- get supplies for board/trifold

Science Fair Logbook
2023-2024

Feb 14th 2024:
- conduct interview with Tesla technician
- after interview, type up questions and exact answers
- after interview, make a summary of the interview to put on the board/trifold
- conduct test drive with Tesla Model 3 to see how well lithium-ion battery works

Feb 15th 2024:
- Fill out most of the forms on CYSF
- no websites to use
- do some more extra research
- start to format research so I can print and put it on the trifold/board.
- write down all research to put in logbook

Feb 16th 2024:
- go to get pictures printed
- continue to format research
- mabye start printing formatted research
- start adding stuff to trifold/board
- no websites to use

Feb 17th 2024:
- if research is not printed, then print it
- add more stuff to the board/trifold
- write the presentation on index cards
- no websites to use

Science Fair Logbook
2023-2024

Feb 16th 2024:
- finish half of the work for the trifold like putting on the research
- print pictures (if not done already)
- have all of the forms on the CYSF platform done

Feb 17th 2024:
- (if possible) finish the trifold/board
- practice for presentation using index cards
- (if possible) record video presentation and attach to CYSF form
- no websites to use

Feb 18th 2024:
- (if not done already) finish trifold/board
- keep practicing presentation using index cards
- no websites to use
- (if not done already) record video presentation and add to CYSF form

Feb 19th 2024:
- keep practicing oral presentation
- no websites to use

Feb 20th 2024:
- double check to see if I missed anything
- keep practicing oral presentation

Feb 21st 2024: At school judging day

More Research on Other Rechargeable Batteries Used in EVs

1. Lead Acid:

Materials: Lead peroxide (PbO2): Dark brown, hard and brittle substance to form the positive plate. Sponge lead (Pb): The pure lead in soft sponge conditions creates the negative plate. Dilute sulfuric acid (H2SO4): A strong acid and a good electrolyte. It is highly ionised, and most of the heat released in dilution comes from the hydration of the hydrogen ions.

How it works: A lead acid battery works by dipping a lead peroxide plate and sponge lead plate in dilute sulfuric acid. There is an electric current is connected to the plates from the outside. Since it is in diluted sulphuric acid, the acid molecules split into positive hydrogen ions and negative sulfate ions. When the hydrogen ions reach the lead peroxide plate, the hydrogen ions receive the electrons from it and become hydrogen atoms which again attacks the lead peroxide plate and forms lead oxide and water. The lead acid then reacts with the hydrogen sulfate and forms lead sulphate and water.

When it is charged: When the lead acid battery is charged, the sulfuric acid in the electrolyte keeps increasing, water gradually decreases, and the gravity of the solution rises.

When it is discharged: When the lead acid battery is discharging, the sulfuric acid in the electrolyte decreases continuously, the water gradually increases gradually and the specific gravity of the solution falls.

Self-discharge: One of the cons of a lead acid battery is that they self-discharge all by themselves even if they are not being used. A general way to express the self-discharge rate of a lead acid battery is that one percent a day self discharge. This rate, however, increases at places with high temperature and decreases at places with lower temperature.

(https://batteryaccessories.net/blogs/news/what-is-a-lead-acid-battery)

2. Ultracapacitors:

Materials and their jobs: The electrolyte is made of water and it facilitates the movements of the ions. The electrodes (one positive and one negative) are usually made of a high-surface-are a conductive material like activated carbon or other carbon-based materials and they provide the surfaces where electrical energy is stored through the accumulation of charges. The separator is a non-conductive material placed between the two electrodes to prevent direct electrical contact while allowing the movement of ions and it also helps to maintain the separation of charges which prevents short circuit and ensuring the proper functioning of the ultracapacitor. The current collectors are conductive materials that collect the electrical charge generated during the charge and discharge processes. They just connect the electrodes to the external circuit and allow the flow of electrical energy between the ultracapacitor and the connected device. The cell casing encloses the ultracapacitor components and ensures the safety of the device.

Charging: When a voltage is applied across the electrodes (positive voltage to one electrode and negative voltage to the other), electrons are driven out of one electrode and onto the other. This accumulation of electrons on the surface of the electrodes creates a double layer of charges – one layer of positive ions at the negative electrode and a corresponding layer of negative ions at the positive electrode. This is known as the electric double layer.

Energy storage: The energy is stored primarily in the electric double layer and is proportional to the surface are of the electrodes and the square of the voltage applied. Due to the high surface area of the porous electrode materials and the very small separation between them, ultracapacitors can store a significant amount of energy in this electric double layer.

Quick charge and discharge: The energy stored in an ultracapacitor can be quickly released when needed. Unlike batteries that involve chemical reactions, ultracapacitors release energy through the movement of ions within the electrolyte and the redistribution of charges across the double layer. This enables ultracapacitors to deliver high power outputs and rapid charge and discharge cycles.

Cycling: Ultracapacitors are designed to withstand a large number of charge and discharge cycles without significant degradation. This is because there are no chemical reactions taking place that degrade the electrode materials over time, as is the case in batteries.

(https://hyfindr.com/ultracapacitor/)

3. Nickel Cadmium:

Materials and parts: The parts and materials of a nickel cadmium battery are the positive and the negative plates, separators, electrolyte, cell vent, and cell container. The positive plates are made from a porous plaque on which nickel-hydroxide has been deposited. The negative plates are made from similar plaques on which cadmium-hydroxide is deposited. In both cases the porous plaque is obtained by sintering nickel powder nickel powder to a fine-mesh wire screen.

Sintering is a process which fuses together extremely small granules of powder at a high temperature. After the active positive and negative materials are deposited on the plaque, it is formed and cut into the proper plate size. A nickel tab is then welded to a corner of each plate and the plates are assembled with the tabs welded to the proper terminals. The plates are separated from each other by a continuous strip of porous plastic.

The electrolyte used in the NiCad battery is a 30 percent solution of potassium hydroxide (KOH) in distilled water. The specific gravity of the electrolyte remains between 1.240 and 1.300 at room temperature. It must be noted that no appreciable changes occur in the electrolyte during charge or discharge. Because of this, the battery charge cannot be determined by a specific gravity check of the electrolyte. The electrolyte level should be maintained just above the tops of the plates.

Charging: When a charging current is applied to a nickel cadmium battery, the negative plates lose oxygen and begin forming metallic cadmium. The active material of the positive plates, nickel-hydroxide, becomes more highly oxidized. This process continues while the charging current is applied or until all the oxygen is removed from the negative plates and only cadmium remains. Toward the end of the charging cycle the cells emit gas. This will also occur if the cells are overcharged. This gas is caused by decomposition of the water in the electrolyte into hydrogen at the negative plates and oxygen at the positive plates. The voltage used during charging, as well as the temperature, determines when gassing will occur. To completely charge a nickel cadmium battery, some gassing, however slight, must take place; thus, some water will be used.

Discharging: The chemical action is reversed during discharge. The positive plates slowly give up oxygen, which is regained by the negative plates. This process results in the conversion of the chemical energy into electrical energy. During discharge the plates absorb a quantity of the electrolyte. On recharge the level of the electrolyte rises and at full charge the electrolyte will be at its highest level. Therefore, water should be added only when the battery is fully charged.

Changing from lead acid to nickel cadmium: The NiCad battery is usually interchangeable with lead-acid batteries. When replacing a lead-acid battery with a NiCad battery, the battery compartment must be clean, dry, and free of all traces of acid from the old battery. The compartment must be washed out and neutralized with ammonia or boric acid solution, allowed to dry thoroughly, and then painted with an alkali-resisting varnish.
The pad in the battery sump jar should be saturated with a 3 percent (by weight) solution of boric acid and water before the battery vent system is connected.
(https://www.aviationpros.com/engines-components/article/10387569/nickel-cadmium-batteries-basic-theory-and-maintenance-procedures)

4. Lithium-iron phosphate:
   Materials, parts and how it works: The lithium-iron phosphate battery consists of an anode, cathode, separator, electrolyte, and positive and negative current collectors. The positive terminal of a battery is called the cathode, whereas the negative terminal is termed as the anode. The anode terminal acts as the source of lithium ions. The electrolyte carries positively charged lithium ions from the anode to the cathode and vice versa through the separator. The movement of the lithium

ions creates free electrons in the anode and as a result, electrons will flow through an external circuit to the cathode i.e. positive terminal, and accordingly, a current will flow from the positive terminal to the negative terminal when an electric load is connected across the battery. The cell consists of concentric alternating layers of the negative and positive electrode materials between which separator layers are situated. The cell is then filled with electrolyte to allow ion conduction. The cathode terminal must be manufactured in such a way that it can release a vast amount of lithium ions during the battery operation. The most common cathode material is LiCoO2, however, there are some disadvantages associated with the material. As a result, LiFePO4 finds its application as a replacement for LiCoO2. In recent times, the anode terminal is made from natural or synthetic graphite. However, with the advancement in technology, Lithium Titanate (LTO) has become a promising candidate for anode material as a substitute for graphite. The most commonly used electrolyte is comprised of lithium salt, such as LiPF6 in an organic solution.

Charging: The positive electrode i.e. the cathode is constructed from lithium-iron-phosphate. The iron and phosphate ions form grids where the lithium ions are loosely trapped. When the battery is getting charged, these lithium ions get pulled through the membrane and reach the negative graphite electrode that can trap and hold these cross over lithium ions. The membrane is made of a type of polymer (plastic) that has lots of tiny little pores to make it easy for the lithium ions to pass through. The battery will be fully charged when all the positive lithium ions available in the cathode terminal reach the anode terminal and are stored between layers of graphene accordingly.

Discharging: As discussed earlier, during the charging cycle of a LiFePO4 battery, the released positive lithium ions from the positive electrode move to the negative electrode through the electrolyte and remain stored there. When all the available lithium ions reach the negative terminal, the battery is said to be completely charged. When the charged battery is connected across an electrical load, the positive ions move back to the positive electrode from the negative electrode through the separator. At the same time, electrons flow through the outer circuit, resulting in a current flow through the electrical load circuit and the battery will discharge its stored energy. Due to the presence of an insulating barrier (i.e. the separator), the electrons cannot flow through the electrolyte. When the battery is fully discharged, all the lithium ions have moved back to the lithium-iron-phosphate electrode.

Conclusion: The charging and discharging of lithium-ion batteries is the key to their operations and long-term performances. Therefore, it is essential to ensure that the batteries are charged and discharged in an appropriate manner. In such context, the following safety measurements such as charging current (maximum value is 0.8C), charging temperature (in the range between 00C to 450C), discharging current protection, over-voltage protection, over-charge protection, reverse polarity protection and over-discharge protection must be considered. To safely manage the charging and discharging of LiFePO4 batteries, a battery management system is integrated into the battery packs. If a user forgets to unplug the charging system, this system will automatically stop charging the battery to prevent overcharge and on the other hand, this system will also ensure the battery is not discharged beyond the specified limit.

(https://rebelbatteries.com/blogs/lithium-iron-phosphate/how-do-lithium-iron-phosphate-batteries-work)

Electric Car Dealers and Which Batteries They Use for Their EVs

Tesla:
Model S: The Tesla Model S uses lithium-ion batteries.
Model 3: The Tesla Model 3 uses lithium-iron phosphate.
Model X: The Tesla Model X uses lithium-ion batteries.
Model Y: The Tesla Model Y uses lithium-ion or lithium-iron phosphate
Cybertruck: The Tesla Cybertruck uses lithium-ion batteries.
Roadster: The Tesla Roadster will use lithium-ion batteries.

(https://servicems.eu/en/news/post/1255-Type-and-chemical-composition-of-lithium-ion-.html, https://ev-database.org/car/1743/Tesla-Model-Y, https://www.findmyelectric.com/blog/what-kind-of-battery-does-my-tesla-have/)

Rivian:
R1T: The Rivian R1T uses lithium-ion batteries.
R1S: The Rivian R1S uses lithium-ion batteries.
R2: The Rivian R2 will use lithium-iron phosphate batteries.

(https://rivian.com/)

Which Battery is the Best Option for EV Companies

According to afdc.energy.gov, The lithium-ion battery is the best battery for EVs right now. This is because they have a high power-to-weight ratio, high energy efficiency, good high-temperature performance, long life, and low self-discharge.

Recycling Batteries

Electric-drive vehicles are relatively new to the U.S. auto market, so only a small number of them have approached the end of their useful lives. As electric-drive vehicles become increasingly common, the battery-recycling market may expand.

Widespread battery recycling would help keep hazardous materials from entering the waste stream, both at the end of a battery's useful life and during its production. The U.S. Department of Energy is also supporting the Lithium-Ion Battery Recycling Prize to develop and demonstrate profitable solutions for collecting, sorting, storing, and transporting spent and discarded lithium-ion batteries for eventual recycling and materials recovery. After collection of spent batteries, the material recovery from recycling would also reintroduce critical materials back into the supply chain and would increase the domestic sources for such materials. Work is now underway to develop battery-recycling processes that minimize the life-cycle impacts of using lithium-ion and other kinds of batteries in vehicles. But not all recycling processes are the same and different methods of separation are required for material recovery:

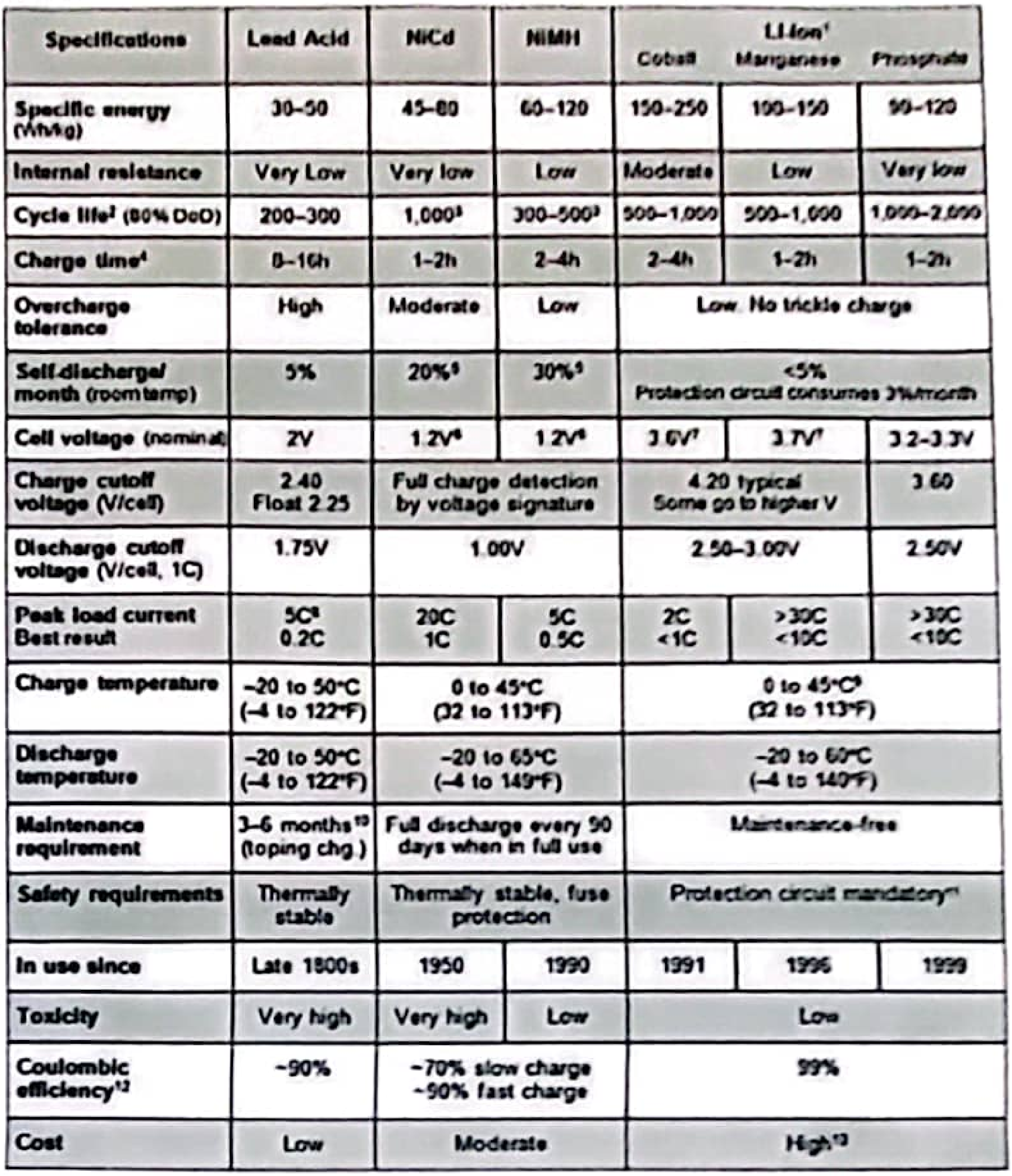
- **Smelting**: Smelting processes recover basic elements or salts. These processes are operational now on a large scale and can accept multiple kinds of batteries, including lithium-ion and nickel-metal hydride. Smelting takes place at high temperatures where organic materials, including the electrolyte and carbon anodes, are burned as fuel or reductant. The valuable metals are recovered and sent to refining so that the product is suitable for any use. The other materials, including lithium, are contained in the slag, which is now used as an additive in concrete.

- **Direct recovery**: At the other extreme, some recycling processes directly recover battery-grade materials. Components are separated by a variety of physical and chemical processes, and all active materials and metals can be recovered. Direct recovery is a low-temperature process with minimal energy requirement.
- **Intermediate processes**: The third type of process is between the two extremes. Such processes may accept multiple kinds of batteries, unlike direct recovery, but recover materials further along the production chain than smelting does.

Separating the different kinds of battery materials is often a stumbling block in recovering high-value materials. Therefore, battery design that considers disassembly and recycling is important in order for electric-drive vehicles to succeed from a sustainability standpoint. Standardizing batteries, materials, and cell design would also make recycling easier and more cost-effective.

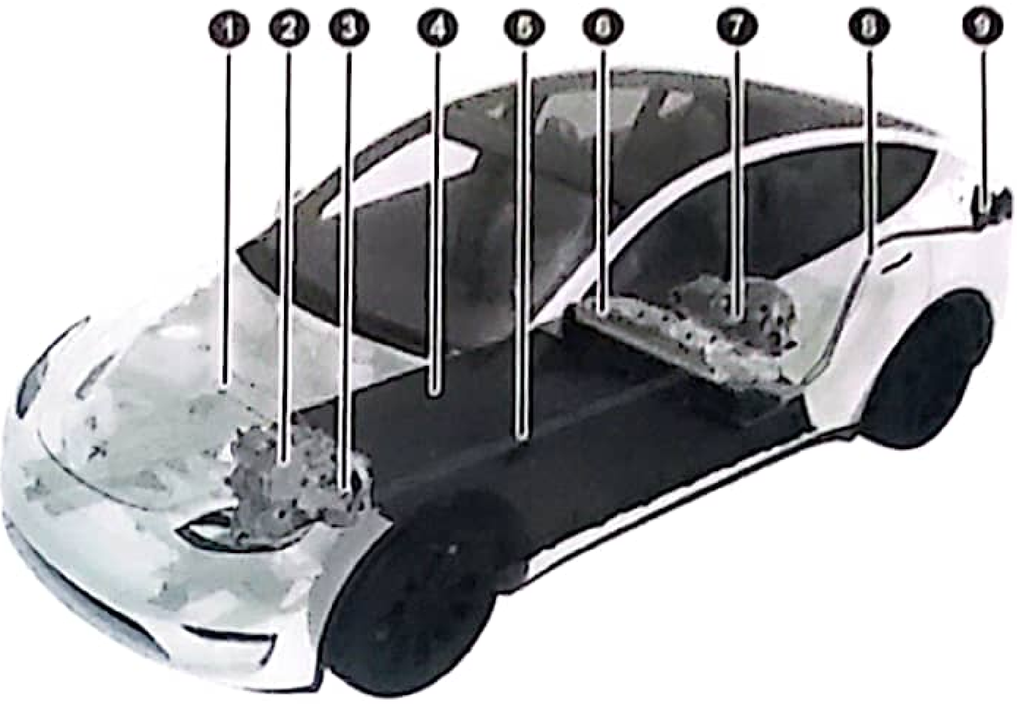
(https://afdc.energy.gov/vehicles/electric_batteries.html)

Chart Comparing Different Rechargeable Batteries



Specifications	Lead Acid	NiCd	NiMH	Li-ion[1]		
				Cobalt	Manganese	Phosphate
Specific energy (Wh/kg)	30–50	45–80	60–120	150–250	100–150	90–120
Internal resistance	Very Low	Very low	Low	Moderate	Low	Very low
Cycle life[2] (80% DoD)	200–300	1,000[3]	300–500[3]	500–1,000	500–1,000	1,000–2,000
Charge time[4]	8–16h	1–2h	2–4h	2–4h	1–2h	1–2h
Overcharge tolerance	High	Moderate	Low	Low. No trickle charge		
Self-discharge/ month (room temp)	5%	20%[5]	30%[5]	<5% Protection circuit consumes 3%/month		
Cell voltage (nominal)	2V	1.2V[6]	1.2V[6]	3.6V[7]	3.7V[7]	3.2–3.3V
Charge cutoff voltage (V/cell)	2.40 Float 2.25	Full charge detection by voltage signature		4.20 typical Some go to higher V		3.60
Discharge cutoff voltage (V/cell, 1C)	1.75V	1.00V		2.50–3.00V		2.50V
Peak load current Best result	5C[8] 0.2C	20C 1C	5C 0.5C	2C <1C	>30C <10C	>30C <10C
Charge temperature	–20 to 50°C (–4 to 122°F)	0 to 45°C (32 to 113°F)		0 to 45°C[9] (32 to 113°F)		
Discharge temperature	–20 to 50°C (–4 to 122°F)	–20 to 65°C (–4 to 149°F)		–20 to 60°C (–4 to 140°F)		
Maintenance requirement	3–6 months[10] (toping chg.)	Full discharge every 90 days when in full use		Maintenance-free		
Safety requirements	Thermally stable	Thermally stable, fuse protection		Protection circuit mandatory[11]		
In use since	Late 1800s	1950	1990	1991	1996	1999
Toxicity	Very high	Very high	Low	Low		
Coulombic efficiency[12]	~90%	~70% slow charge ~90% fast charge		99%		
Cost	Low	Moderate		High[13]		

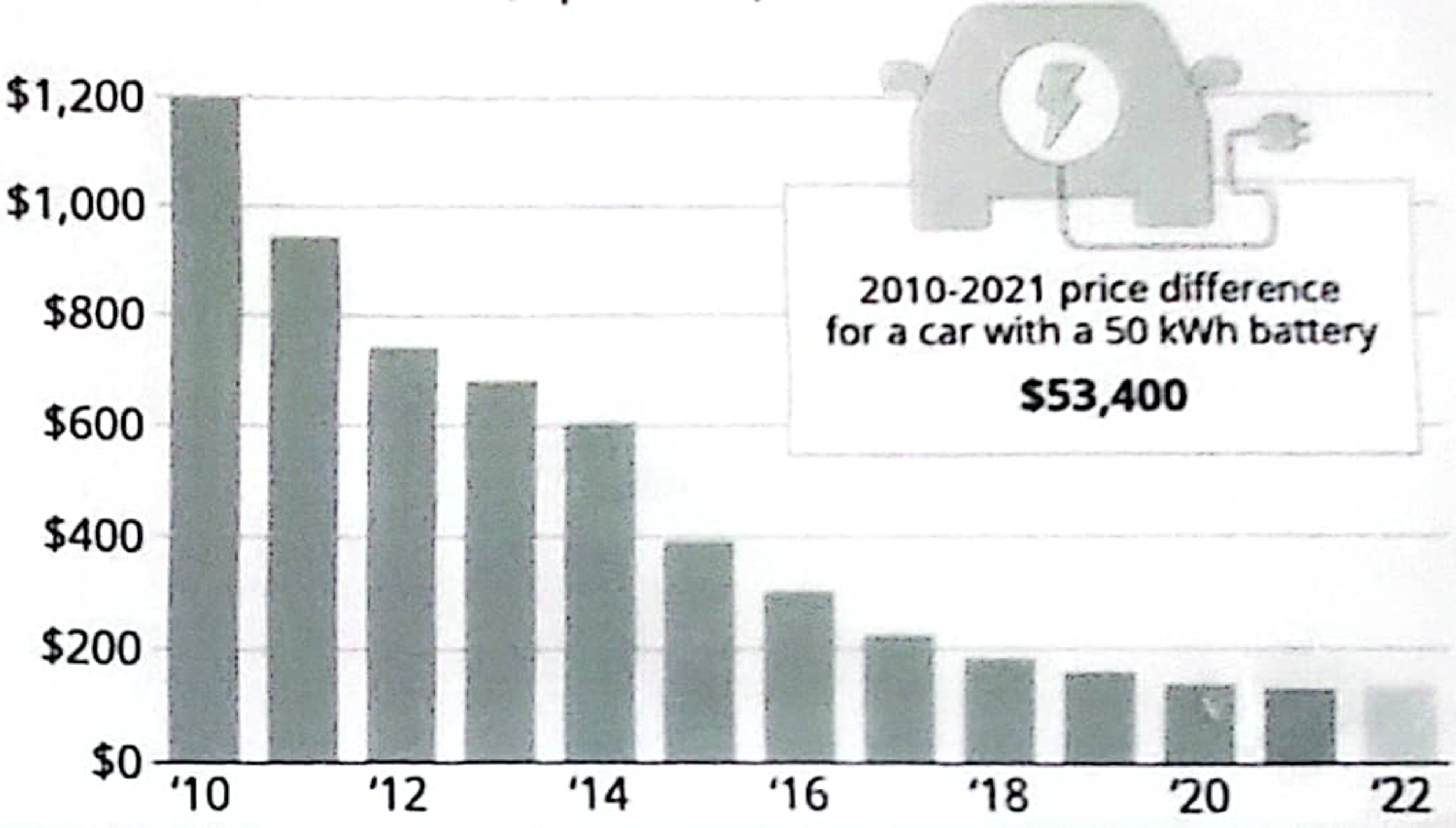
Tesla Model Y



1. High Voltage Cabling
2. Heat Pump Assembly
3. Front Motor (Dual Motor vehicles only)
4. High Voltage Battery
5. High Voltage Cabling
6. Service Access Panel for High Voltage Components (Penthouse)
7. Rear Motor
8. High Voltage Busbars
9. Charge Port

Rising Commodity Prices Slow EV Battery Price Drop

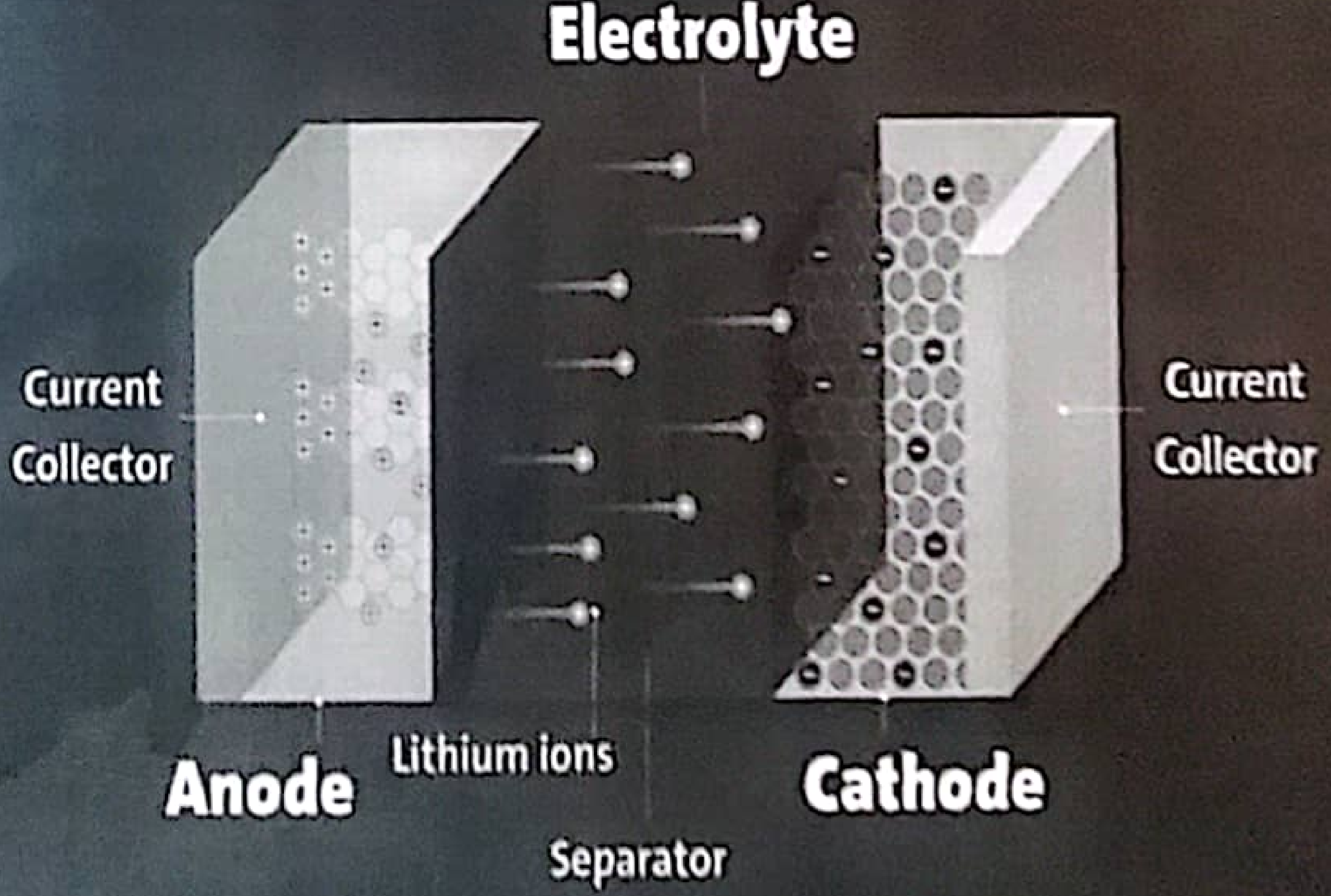
Volume-weighted average price of battery packs for electric vehicles ($ per kWh)*



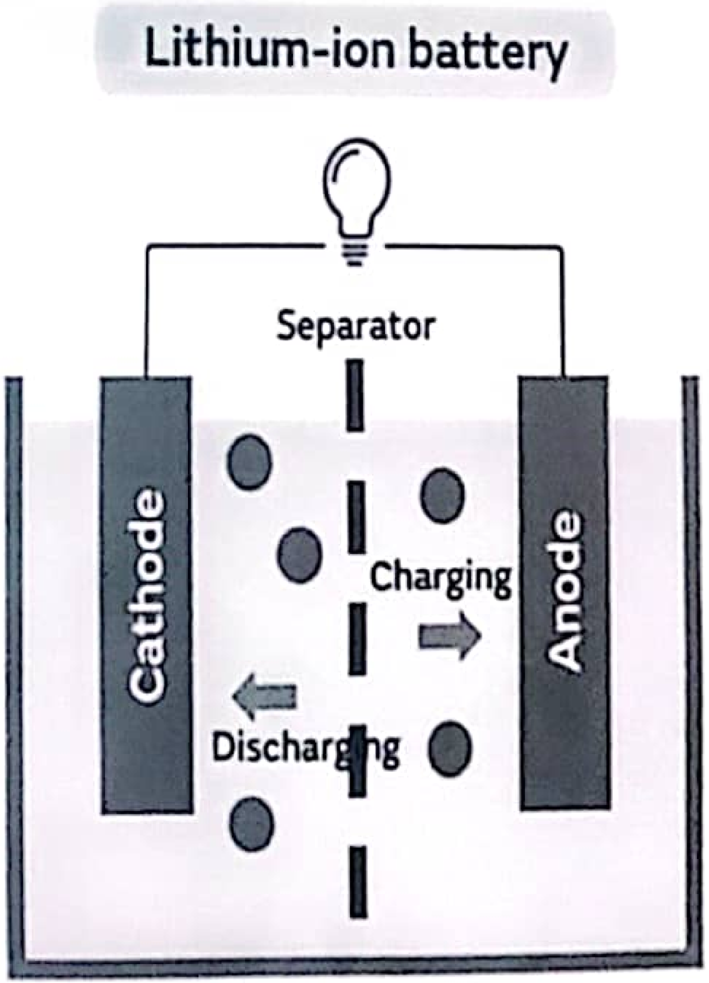
2010-2021 price difference for a car with a 50 kWh battery

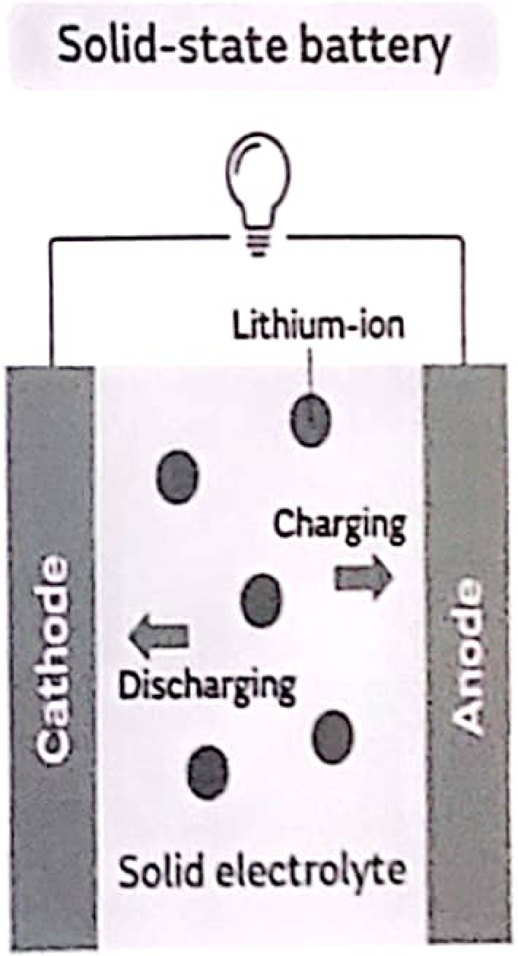
$53,400

Lithium-ion Cell




Volkswagen


Lithium-ion battery
Separator
Cathode
Charging
Anode
Discharging


Solid-state battery
Lithium-ion
Charging
Cathode
Discharging
Anode
Solid electrolyte