



Rethinking the Value of Premium Lightweight Materials in EVs

As the cost of EV batteries and kilowatt hours decreases, will premium lightweight materials become less important in extending vehicle range?

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  **It no longer is a question of taking weight out of structure. It is about getting more energy density into the battery."**

Understanding Materials/Architecture Strategies

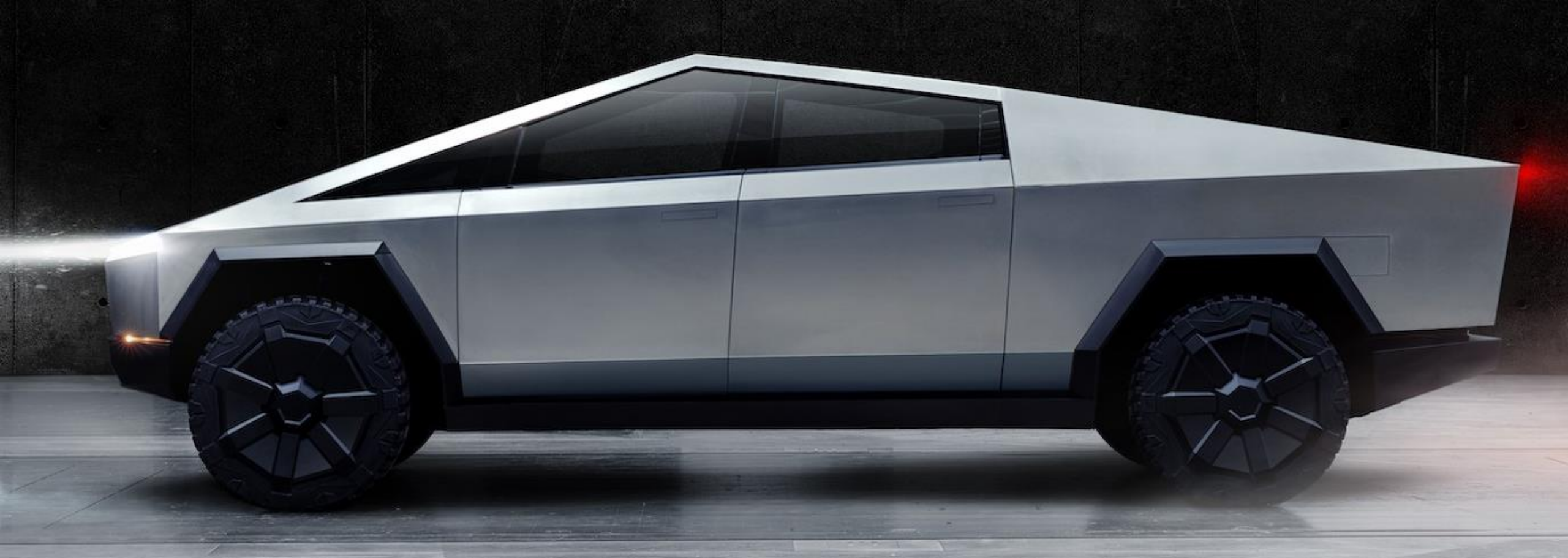
Key consumer issues with EVs today

How weight and emissions issues have been dealt with in the past

What we can learn from past strategies

How important cost and weight is in materials/emissions strategies

Is the Tesla Cybertruck a stunt or a game changer?



What is the Tesla Cybertruck?

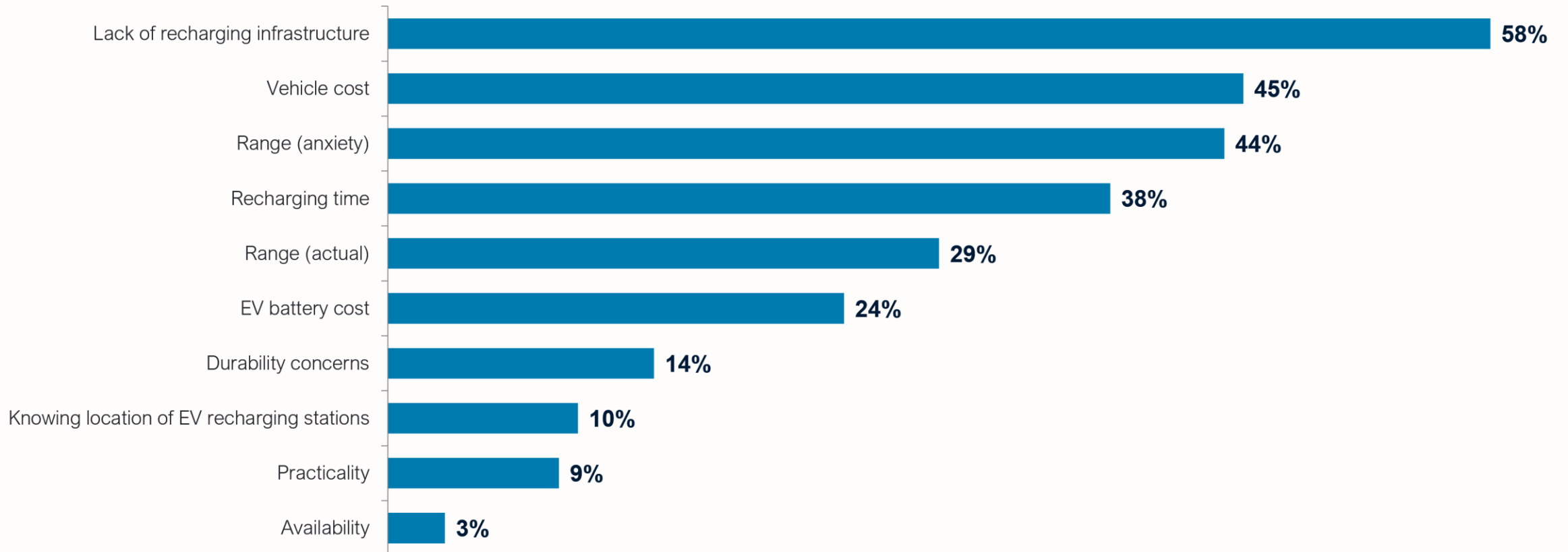
- A publicity stunt.
- A totally new approach to the pickup truck.
- An extremely polarizing new design that will appeal to a limited number of buyers.

Poll Question: What Is the Tesla Cybertruck?

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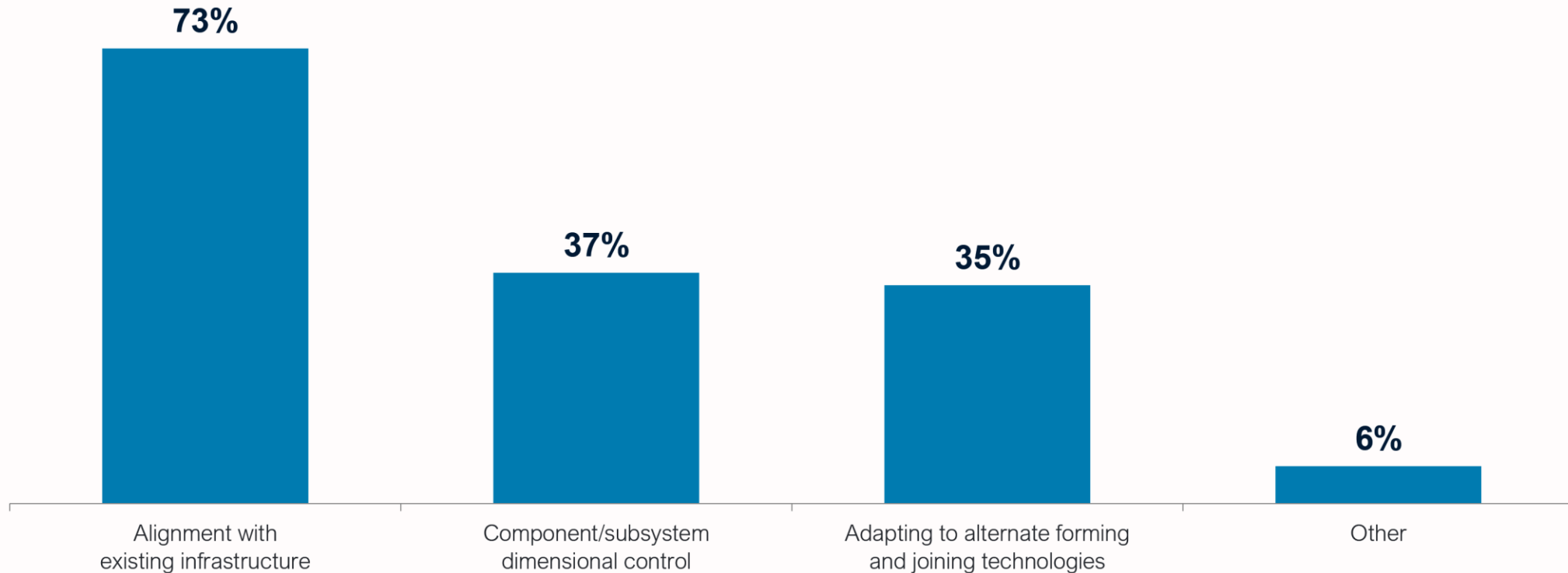
Impediments to Consumer Acceptance of Battery-Electric Vehicles

The primary impediment to consumer acceptance of BEVs is lack of recharging infrastructure (58%), followed by vehicle cost (45%), range (anxiety) (44%), and recharging time (38%).



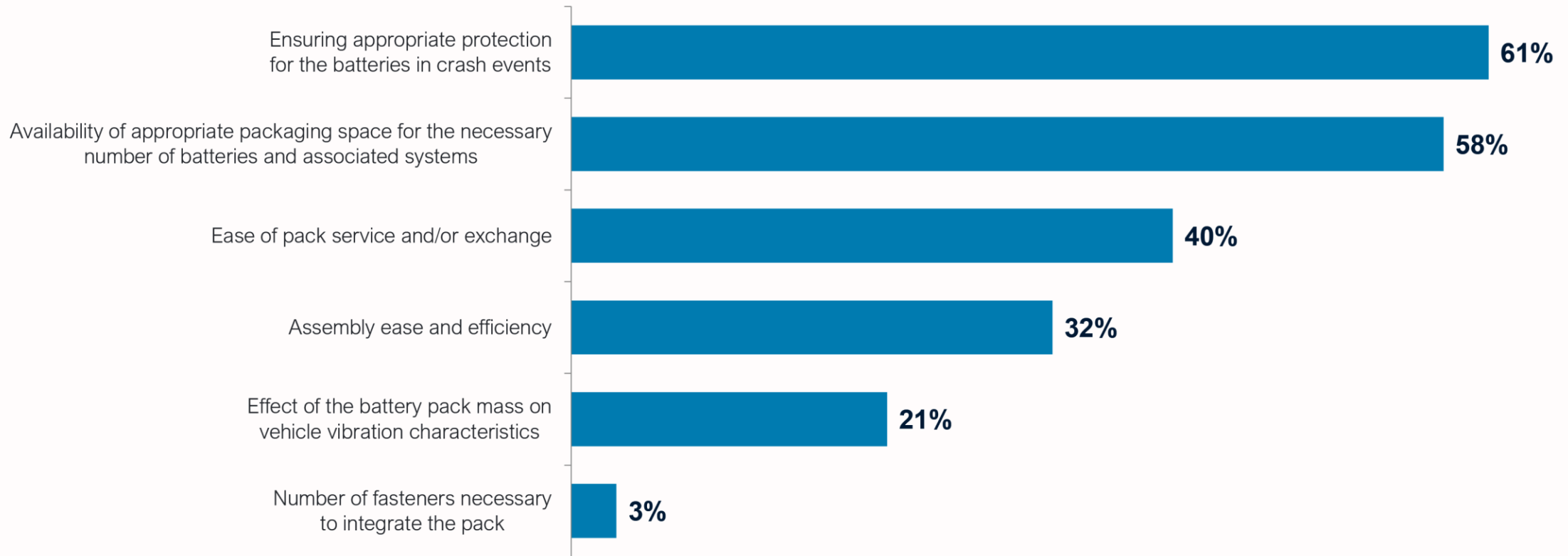
Challenges with Adapting to Flexible/Modular Architectures for EV

The primary challenge faced by manufacturers/suppliers with adapting to flexible/modular architectures for EV is alignment with existing infrastructure, followed at a distance by component/subsystem dimensional control and adapting to alternate forming and joining technologies.



Challenges of Integrating EV Battery Packs into Vehicle Structures

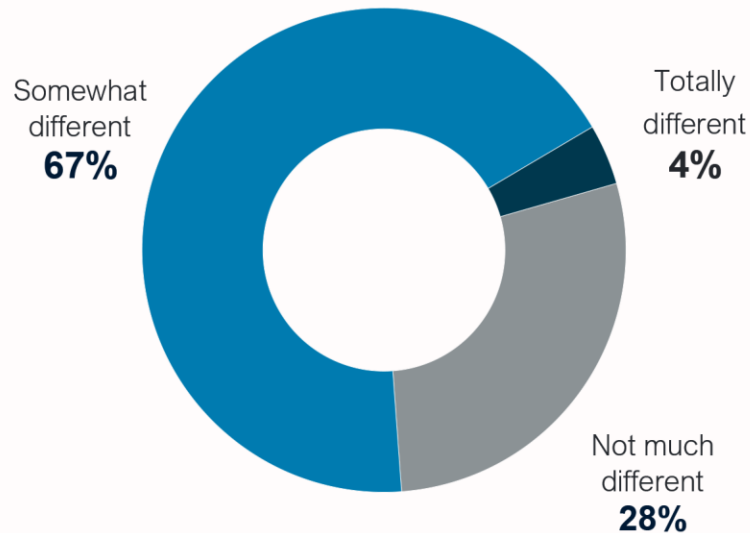
The two most common challenges associated with integrating EV battery packs into vehicle structures are (1) ensuring appropriate protection to the batteries in crash events, and (2) the availability of appropriate packaging space for the necessary number of batteries and associated systems.



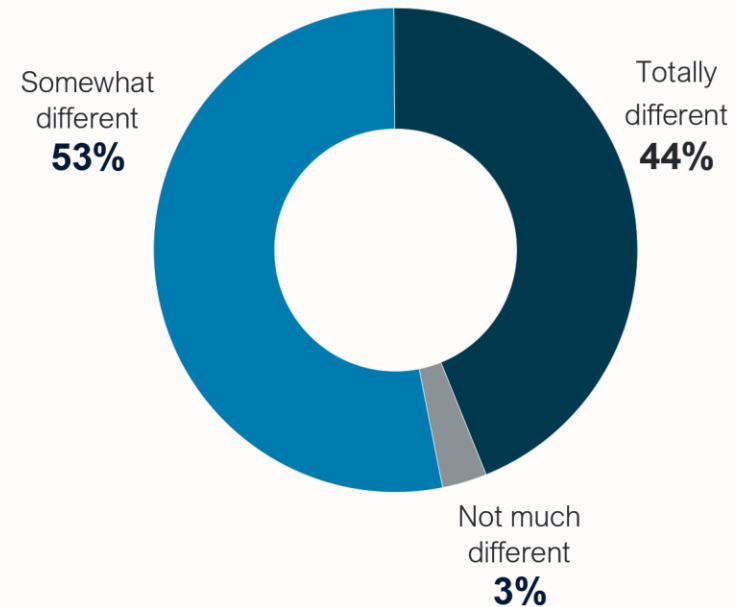
Difference in Vehicle Materials & Architectures over Time

Within five years, three in four respondents (72%) anticipate at least some difference in vehicle materials and architecture, with just 4% anticipating these will be “totally different”. Within ten years, virtually all respondents (97%) anticipate at least some difference in vehicle materials and architecture, with 44% anticipating these will be “totally different”.

5 Years from Now



10 Years from Now



The History of Automotive Materials Innovation



New materials always have been considered disruptive technologies that enable automakers to meet government mandates for fuel economy, emissions and safety.



Steel historically has been regarded as old material that is too heavy, rust-prone and difficult to form into new shapes.



The need to solve these issues has resulted in huge programs employing plastics, composites, aluminum and carbon fiber to reinvent vehicle designs, architectures and manufacturing techniques.



Most were engineering triumphs but sales disasters.



What went wrong?

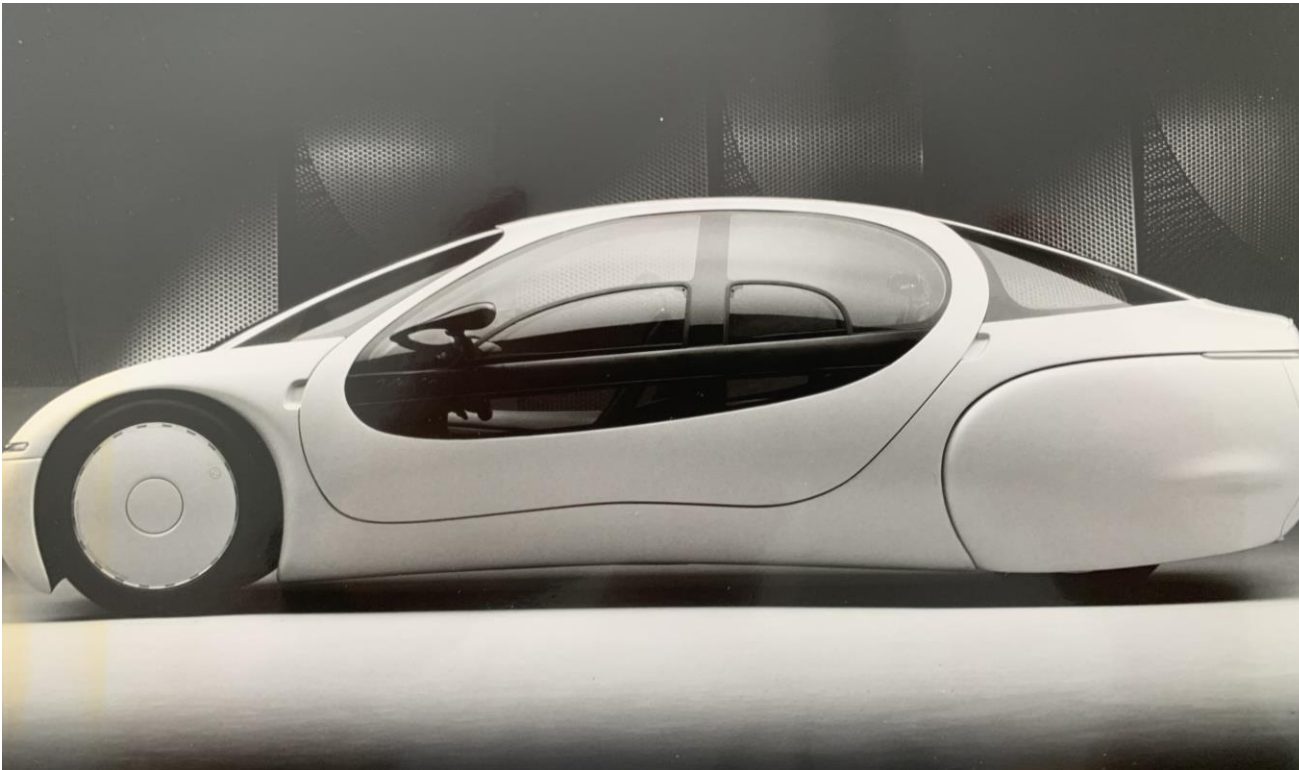
1977: Carbon Fiber, the Material of the Future



1977 Ford Galaxy Concept

- Stung by soaring fuel prices and new fuel-efficient competition, Ford shows off CFRP Galaxy, 1,250 lbs. lighter than planned '79 mid-size cars.
- CFRP cost ranged from \$25 to \$100 per lb. but engineers were confident price would come down in five or 10 years.

1992: Ultralite Debuts at NAIAS



- 45/81 mpg City/Hwy
- 0-60 7.8 seconds
- Top speed: 135 mph
- 420-lb. Body structure
- Structure cost: \$13,000

2014 BMW Launches New I Division



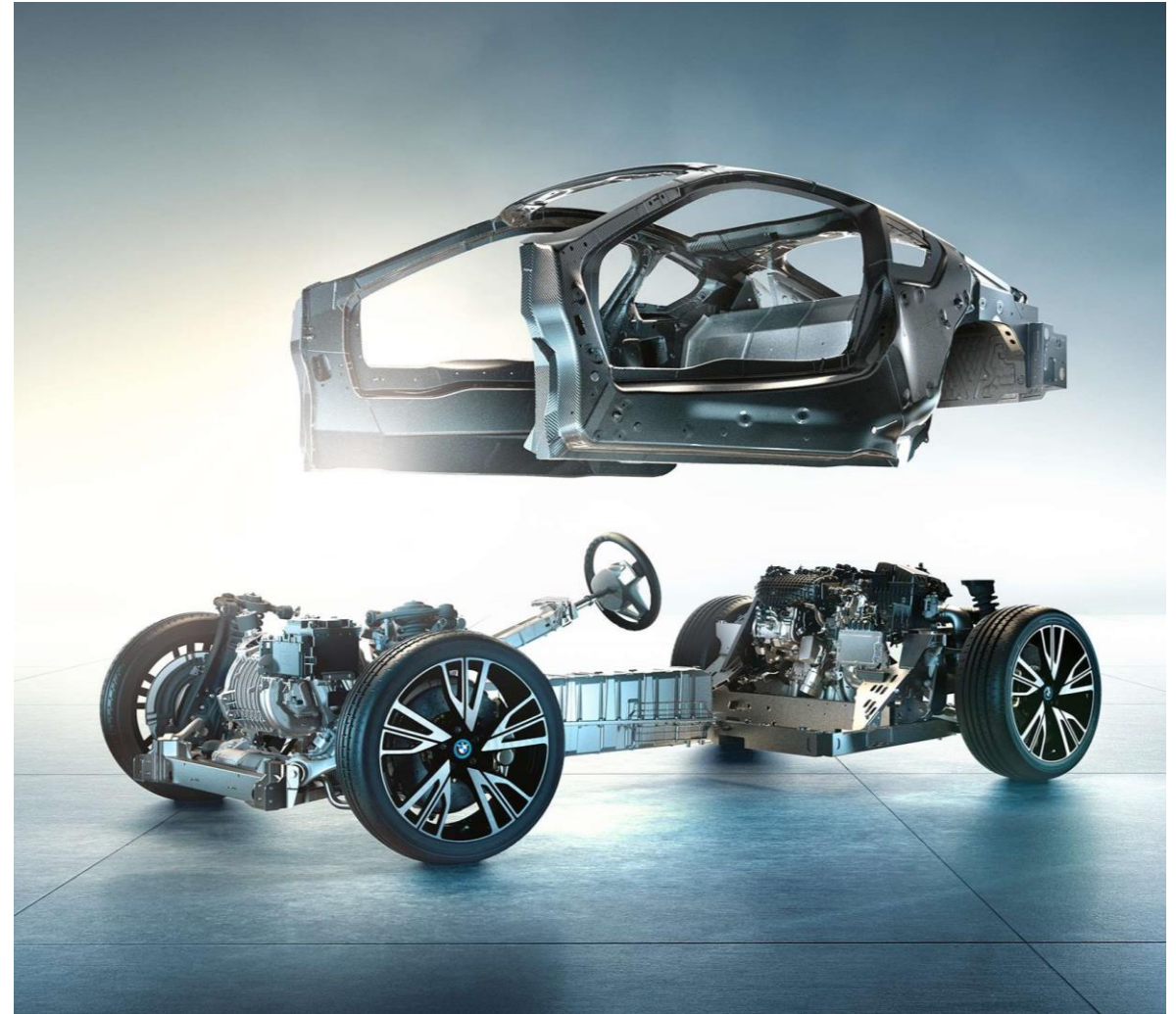
First Mass-Produced Carbon Fiber Body Structures



- i3 and i8 models built around carbon-fiber tubs.
- Large global carbon-fiber supply chain created, \$300 million investment in U.S. Mfg. site.
- High GHG mfg. emissions countered by hydro power.

Gorgeous Design, Impressive Engineering Unappreciated

- Hybrid powertrain turned off Tesla and ICE fans like half-vegan hamburger
- \$147,000 pricetag
- Short EV range
- Noisy range-extender a turnoff
- Elaborate supply chain not worth small sales volumes



2018: BMW Moves Away From CFRP



- ▲ ▼ At the time of the BMW i3, the capacity of batteries was still quite low, and so we tried to get every kilogram out of the car to reduce the amount of energy we needed [to power it]. But, with the improving energy capacity of batteries, you don't need to look for the last 500 grams."

Robert Irlinger, head of BMW's i Division

BMW's Latest iNEXT to be on Conventional Platform



To be built in Dingolfing

Same line as conventional cars

Sharing Fifth Gen Architecture

New Mid-Engine Corvette Has Two Carbon Fiber Parts



GM's Massive Push into Spaceframe/Plastic Architectures

- Three brands with differentiated styling
- Pontiac, Chevy, Oldsmobile
- Bolt-on body panels enabled them to look different.
- GM's first front-drive minivans aimed to challenge Chrysler's dominance with technology and styling.



Innovative Styling and Great Engineering Don't Always Work



- GM spared no expense on 1990 trio of APV minivans in challenge to Chrysler dominance.
- Innovative space frame design with polymer panels enabled dramatic design, model differentiation.
- Radical design turned off consumers.

Saturn's Bold Promise of Plastic Side Panels

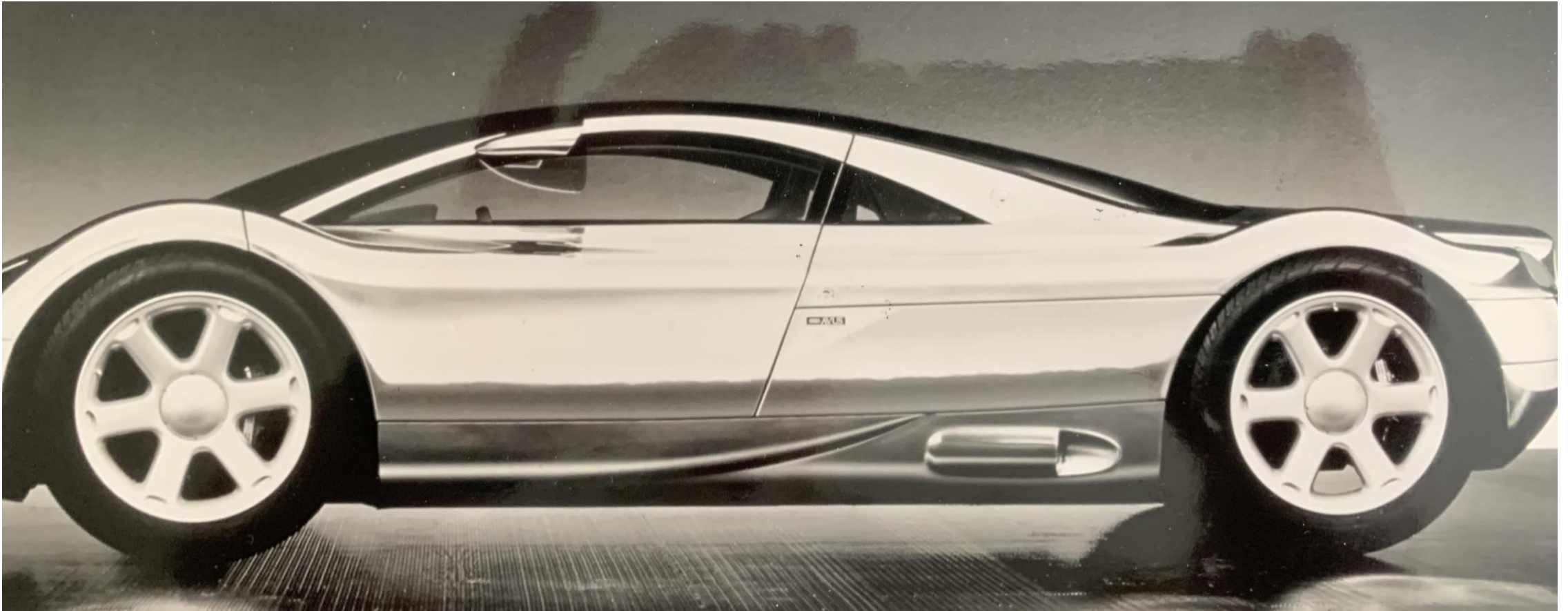


- GM touts Saturn's thermoplastic side panels as rustproof and dent-resistant.
- Saturn buyers recognize the value, but critics attack wide panel gaps required for thermal expansion.
- High costs, steel improvements take toll.

Audi's Tragic Love Affair with Aluminum



It Begins with Eye-Catching Concept and High-Volume Plans



Audi Makes Aluminum Part of its Brand Image



- Aiming to win market share from Mercedes S-Class, Audi touts high-tech aluminum body of its A8 flagship.
- Pioneering lightweight construction is part of its branding and business strategy.

Audi A8 Aluminum Flagship

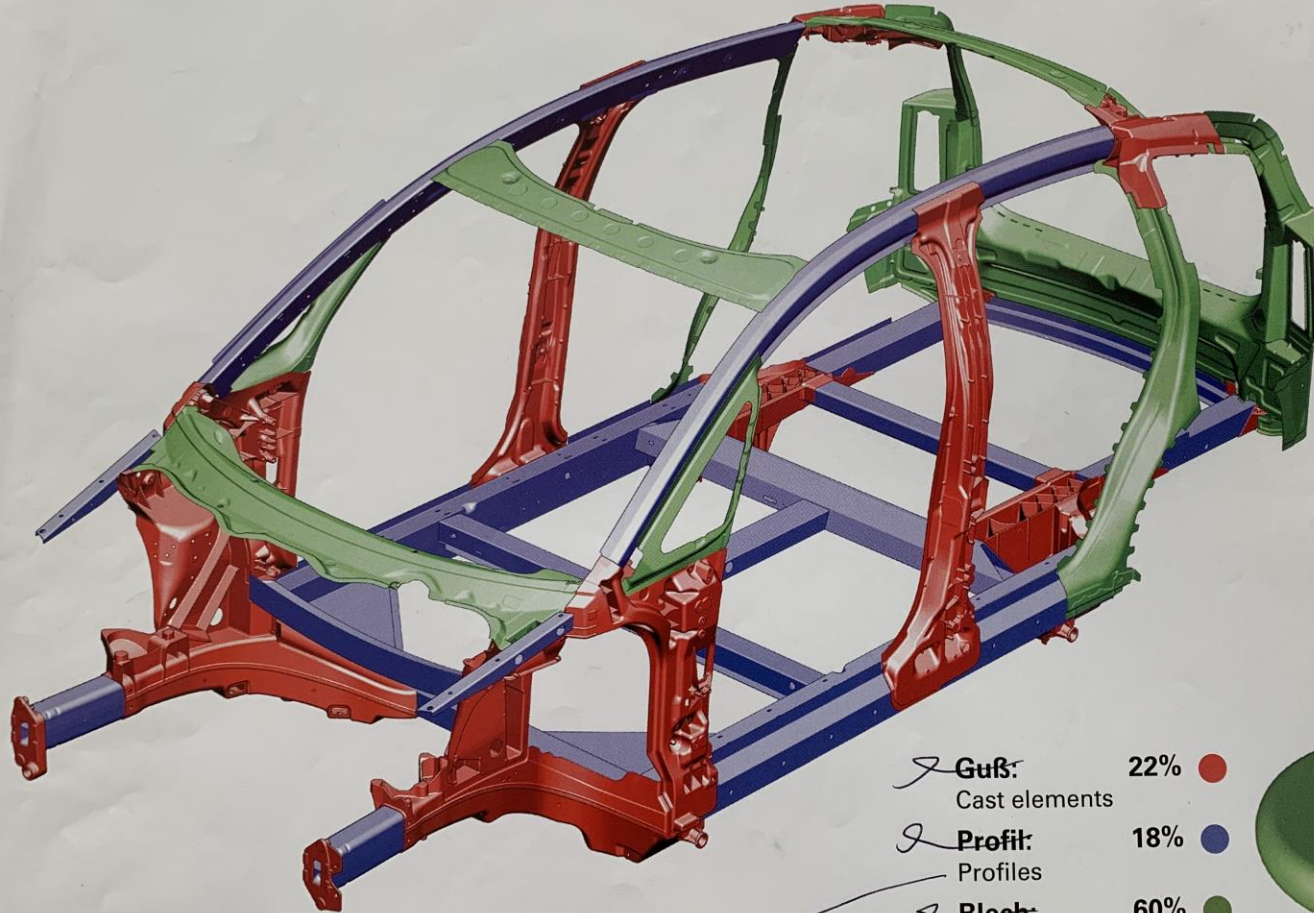


INSET

Audi A2 Space Frame

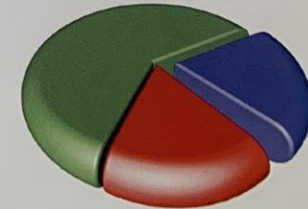
Audi A2 Space Frame

09/99



- Guß:* 22% ●
Cast elements
- Profil:* 18% ●
Profiles
- Blech:* 60% ●
Panels

Extrusions



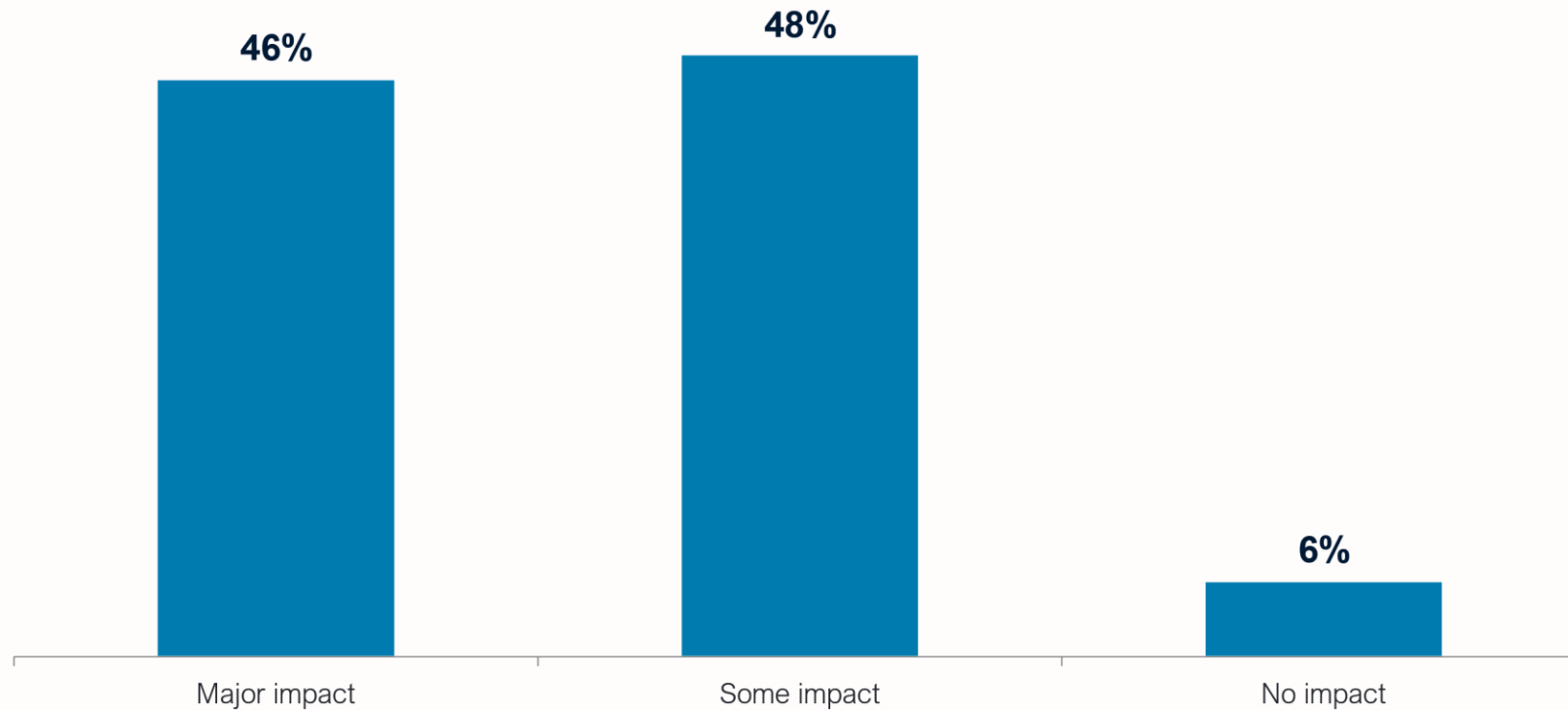
A2, World's First Volume-Production Aluminum Car



40% lighter than steel car	0.28 drag coefficient
Up to 80 mpg with small diesel engine	Advanced aluminum spaceframe construction
Agile handling	Competition: Mercedes A-Class
Displayed at 1999 Frankfurt Motor Show	Production ended 2005
Total sales 176,000, vs. 1 million Mercedes A-Class	

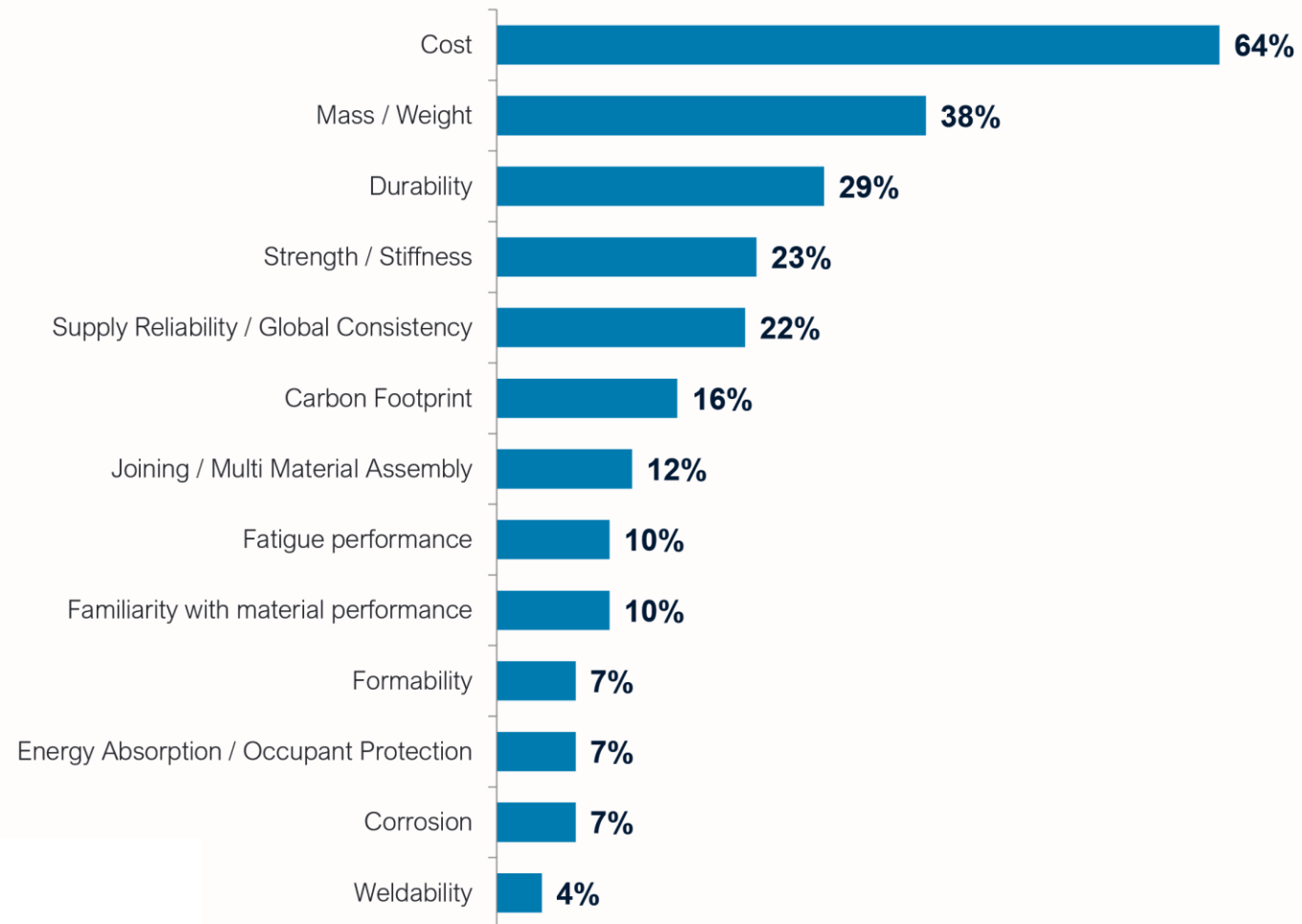
Impact of Electrification & Self-Driving Technologies on Funding of Other Focus Areas

Almost all respondents (94%) report the new focus on making electrification and self-driving technologies has had an impact on the funding of activities like body & chassis engineering and R&D, including 46% who report it has had a major impact.



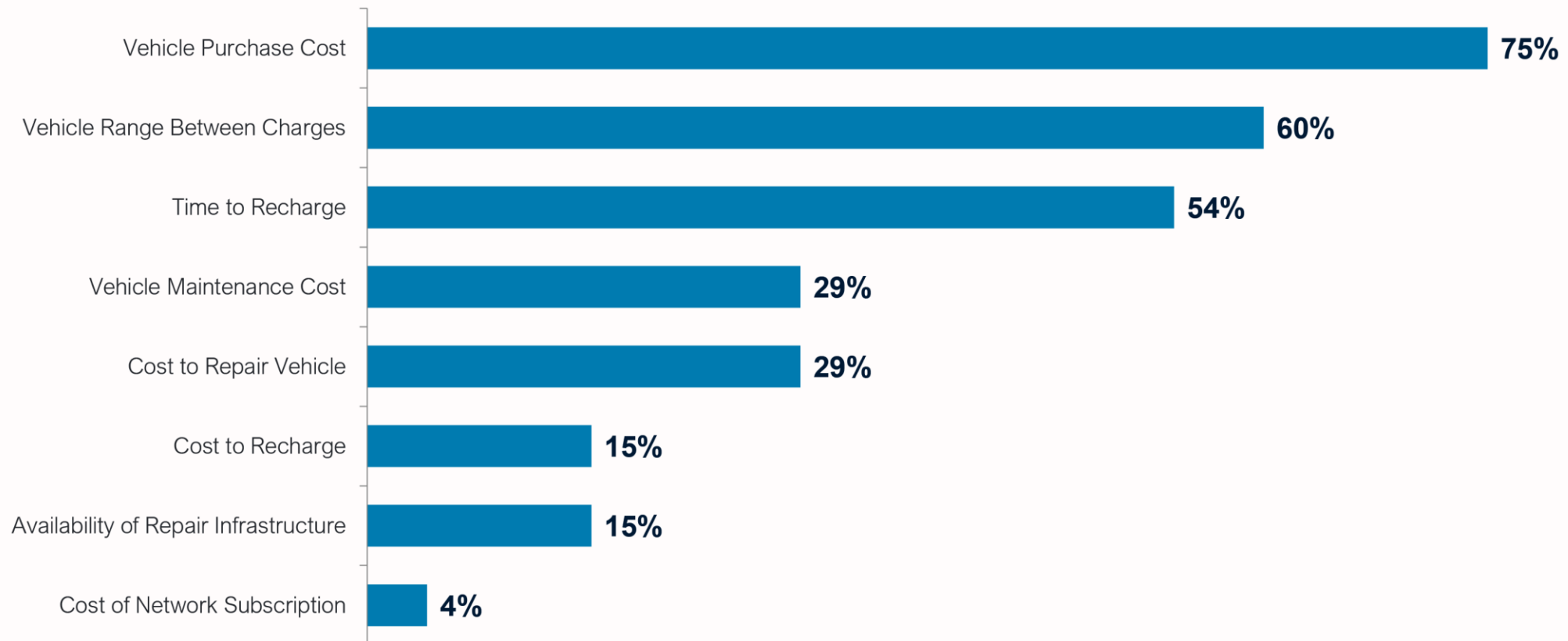
Drivers of Company's Material Portfolio

The primary driver of respondents' companies' material portfolios is cost, followed by mass/weight, durability, strength/stiffness, and supply reliability/global consistency.



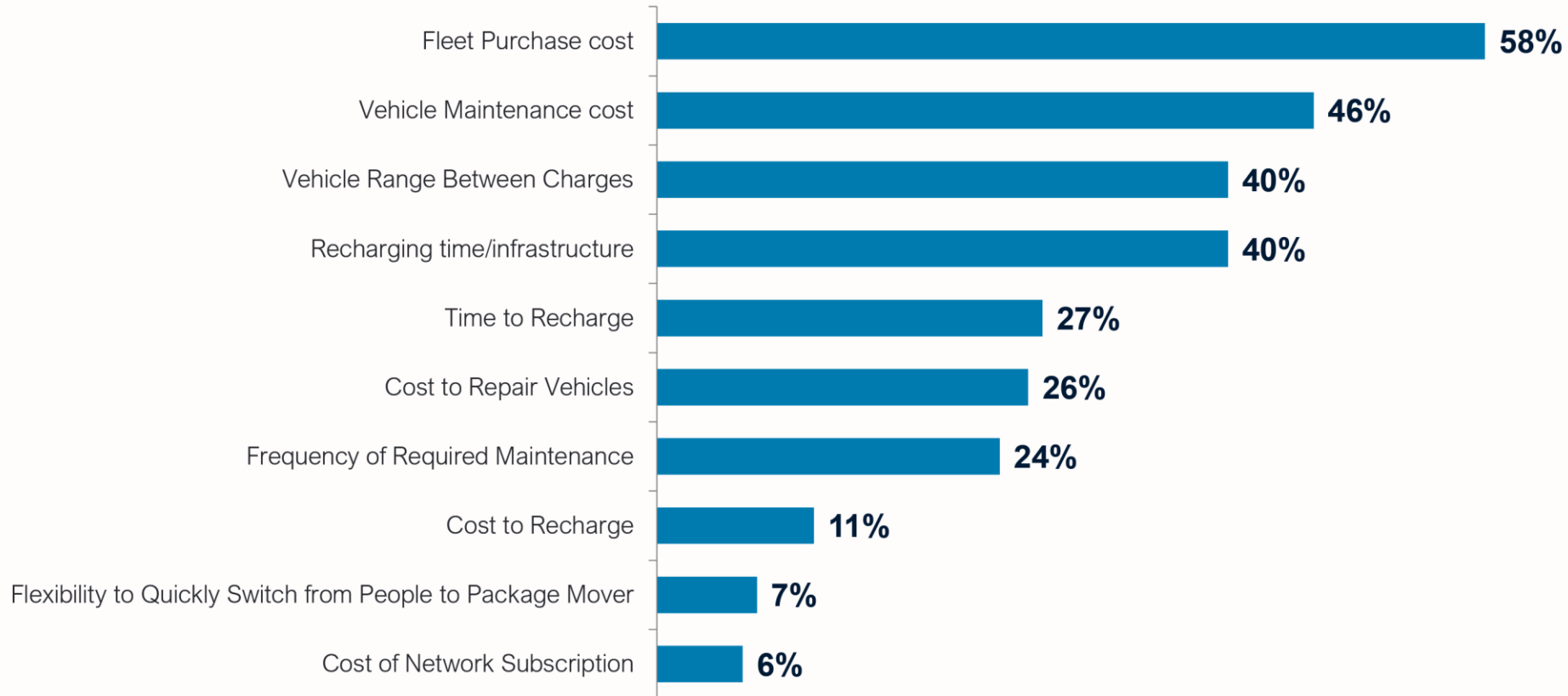
TCO-Related Considerations for Private Vehicle Owners

Respondents believe the most important TCO-related consideration for private vehicle owners is the vehicle purchase cost, followed by vehicle range between charges, and time to recharge.



TCO-Related Considerations for Fleet/Service Provider Vehicle Owners

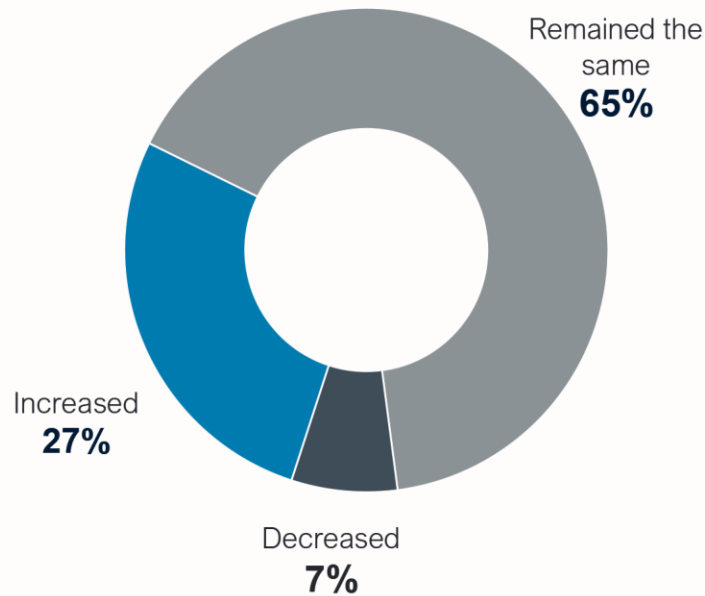
Respondents believe the most important TCO-related consideration for the owners of fleet/service vehicles is fleet purchase cost, followed by vehicle maintenance cost, vehicle range between charges, and recharging time/infrastructure.



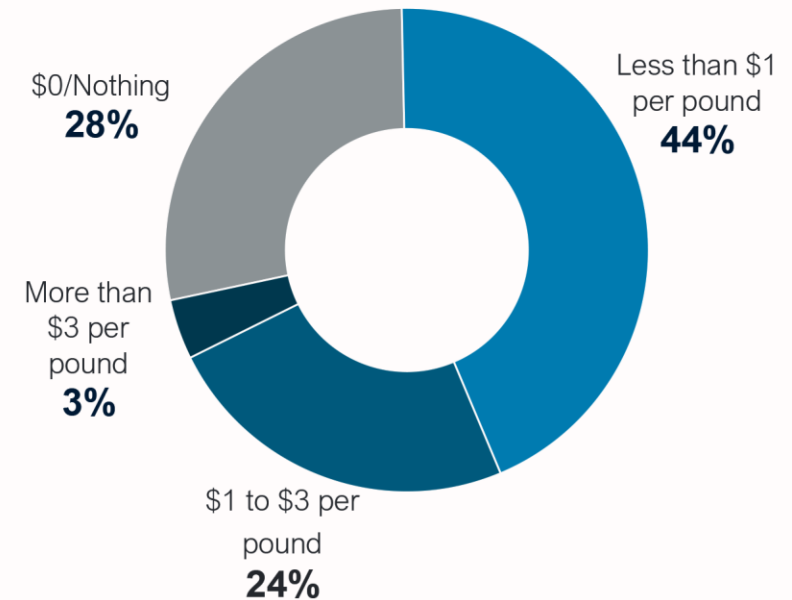
Weight Savings Premiums

A majority of respondents report the premiums their companies are willing to pay for weight savings has not changed meaningfully. On in four respondents report their companies are unwilling to pay any premiums for weight savings; 44% are willing pay less than \$1 per pound.

Change in Premium

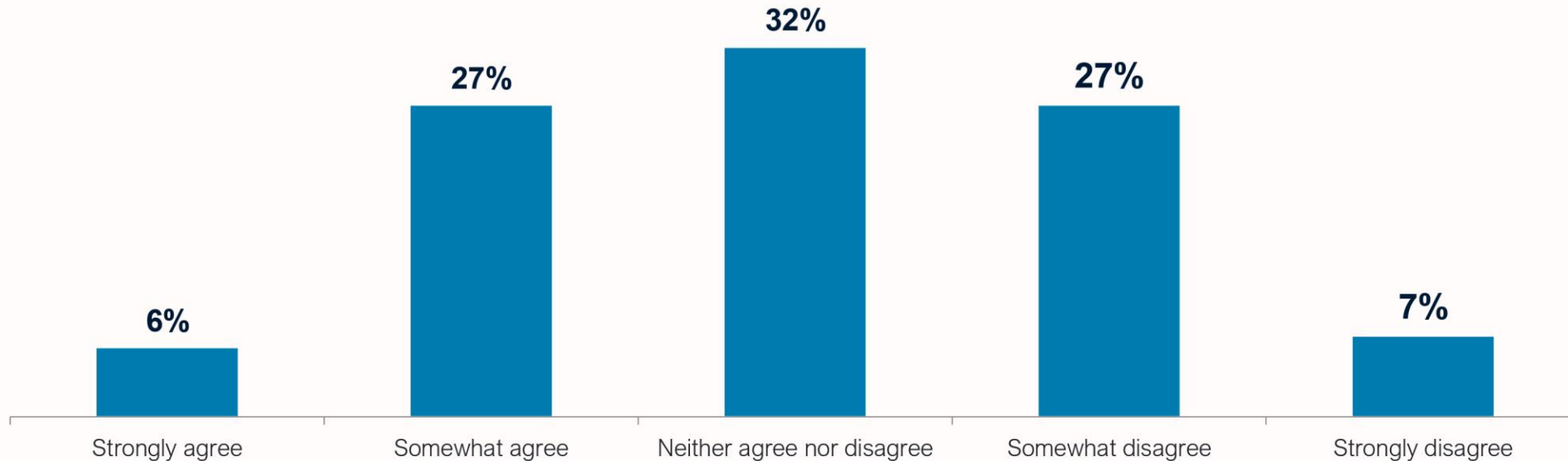


Premium Willing to Pay



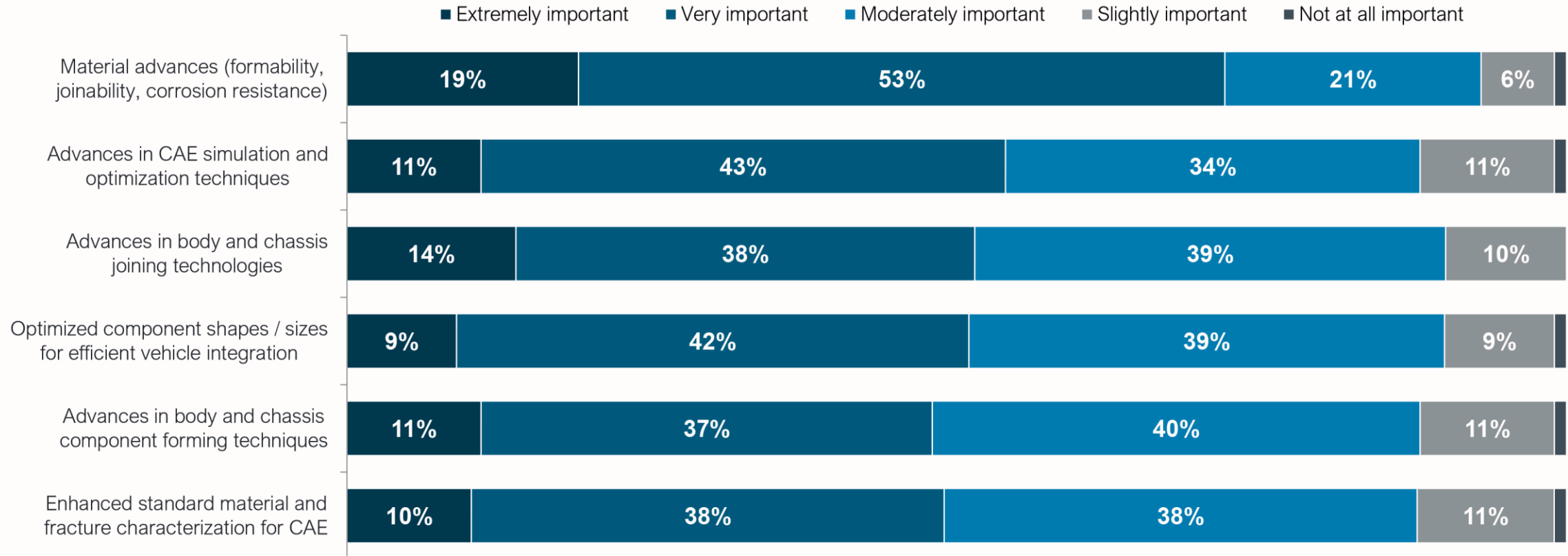
Has Lightweighting Reached Its Cost-Efficiency Limit?

Respondents are evenly divided with regard to whether or not lightweighting has reached its cost-efficiency limit: 33% agree it has; 32% are neutral; and 34% disagree it has.



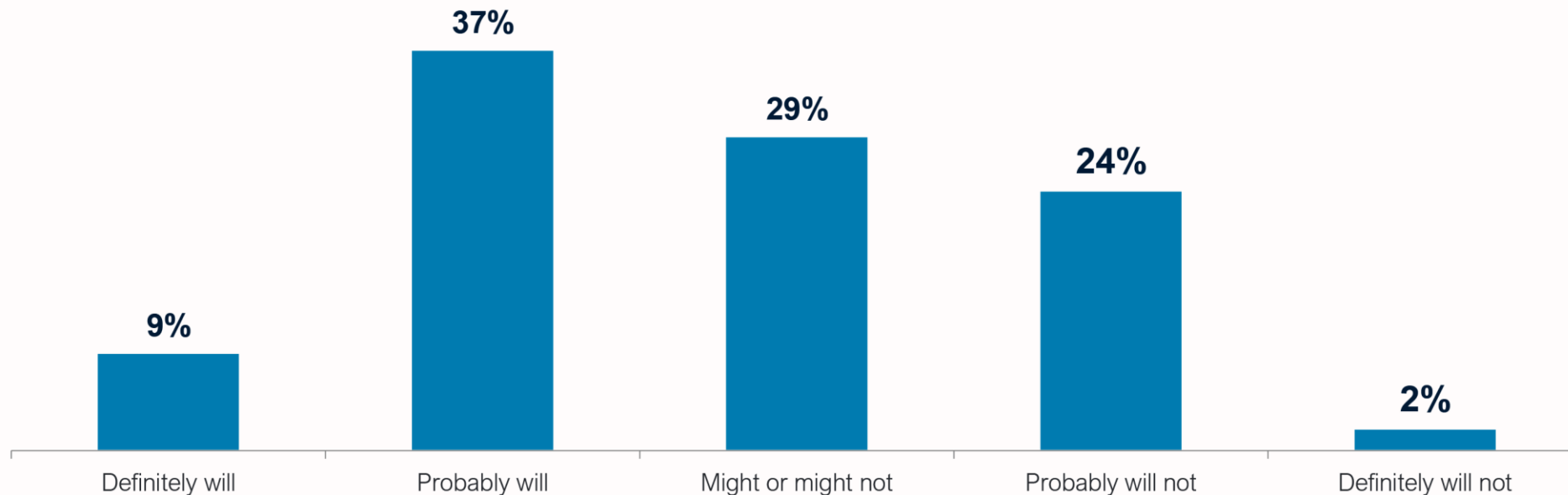
Importance of Advances to Further Optimize Mass Efficiency

Respondents consider the most important advances for further optimizing mass efficiency are material advances (72% indicating either “very” or “extremely important”).

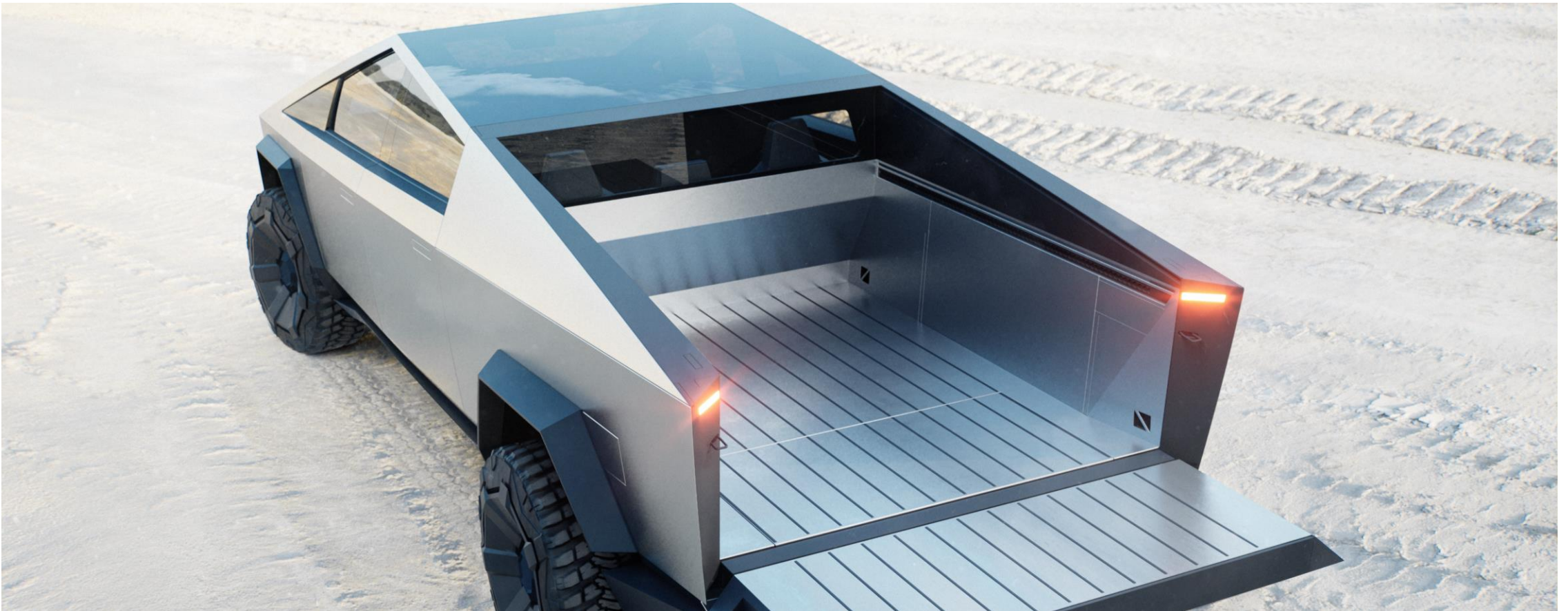


Decreasing Cost of EV Batteries & Watts per kW Hour and Automakers' Willingness to Pay a Premium for Lightweighting

Just under half of respondents (46%) believe continued decrease in the cost of both EV batteries and watts per kilowatt hour will drive automakers to stop paying a premium for lightweighting to increase range. One in four (26%) do not believe this would be the case.

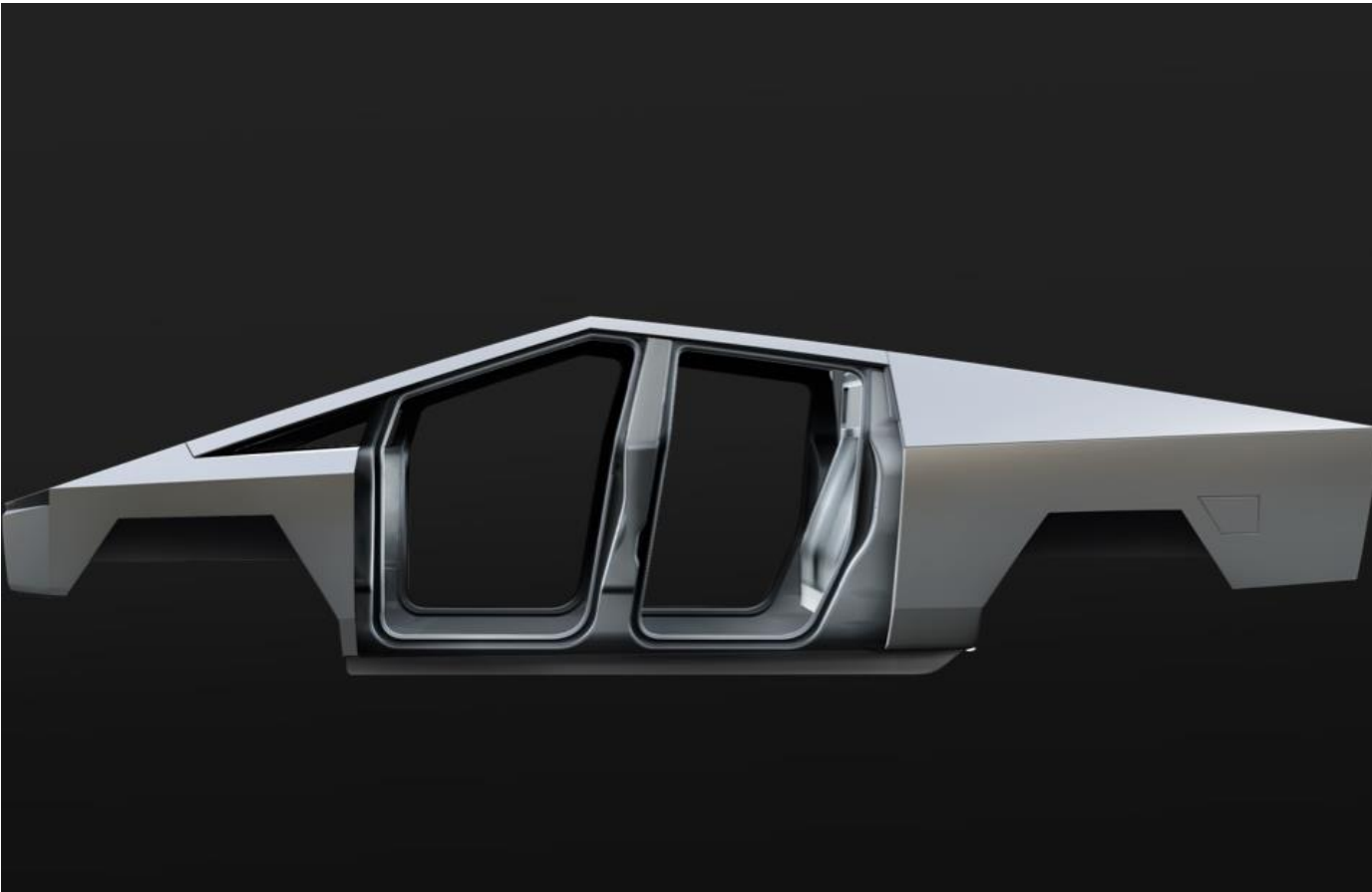


Is This for Real?



Poll Question Results

Something New on Many Levels



- New architecture uses stainless steel from SpaceX.
- Caters to millennial need to abandon Boomer-generation's ideas, conventions.
- “We want to be a leader in apocalypse Technology.”

Tesla's Franz von Holzhausen designed GM Solstice and Sky



Method to the Madness: No tooling costs or paint shop

- According to manufacturing expert Sandy Munro:
- Eliminating paint with stainless steel panels eliminates need for paint plant costing \$150 million to \$500 million depending on volume.
- Eliminating paint also eliminates costs associated with paint plant emissions mitigation.
- Flat body panels and straight lines enable Tesla to save \$60 million in tooling costs assuming 50,000-unit run.

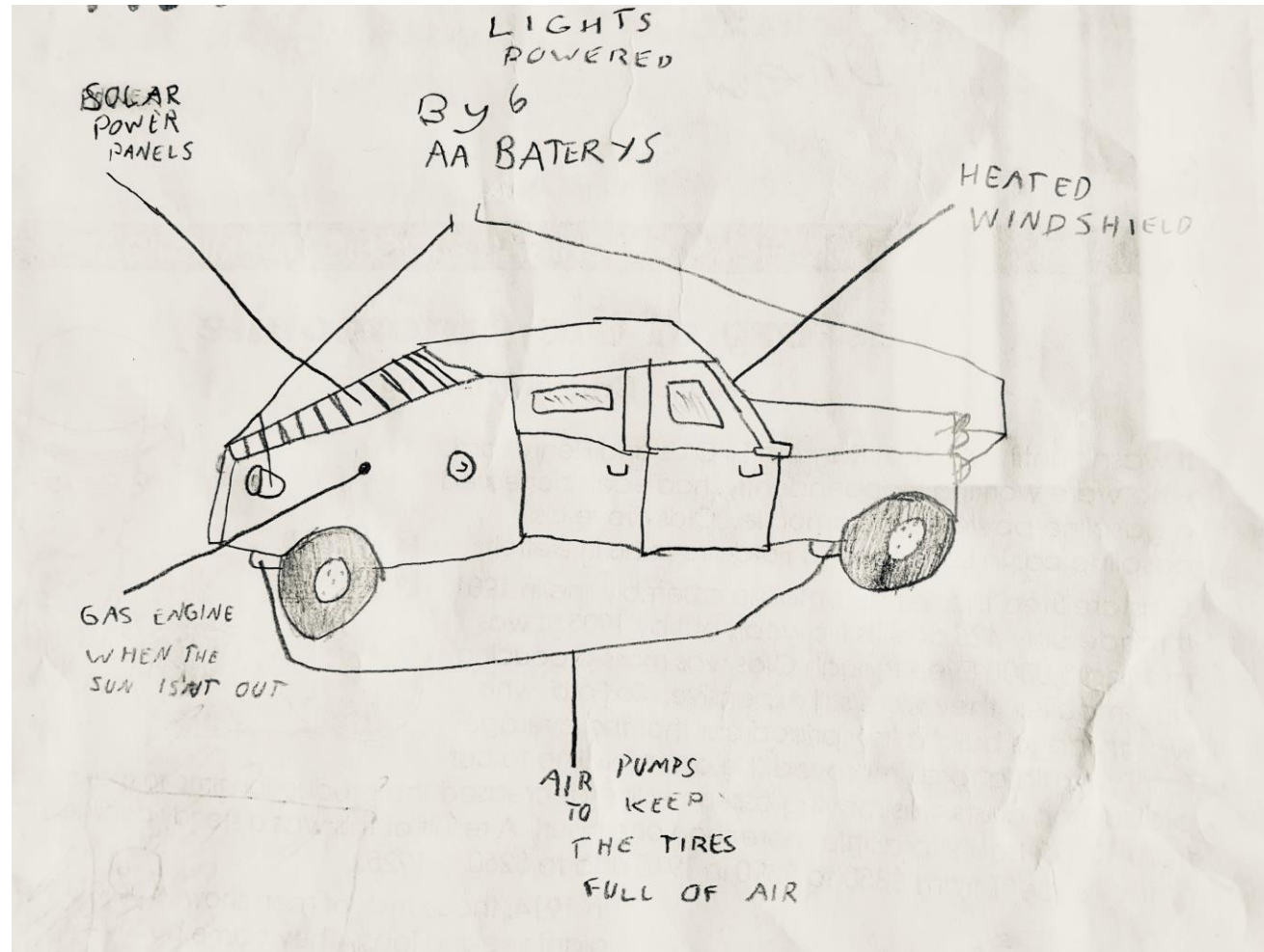
Out with the Old, in with the New



- 1974's Cadillac Ranch dedicated to desecrating everything previous generation liked.
- Cadillac tailfins embodied everything Boomers disliked.
- Every generation wants new ways to define themselves.



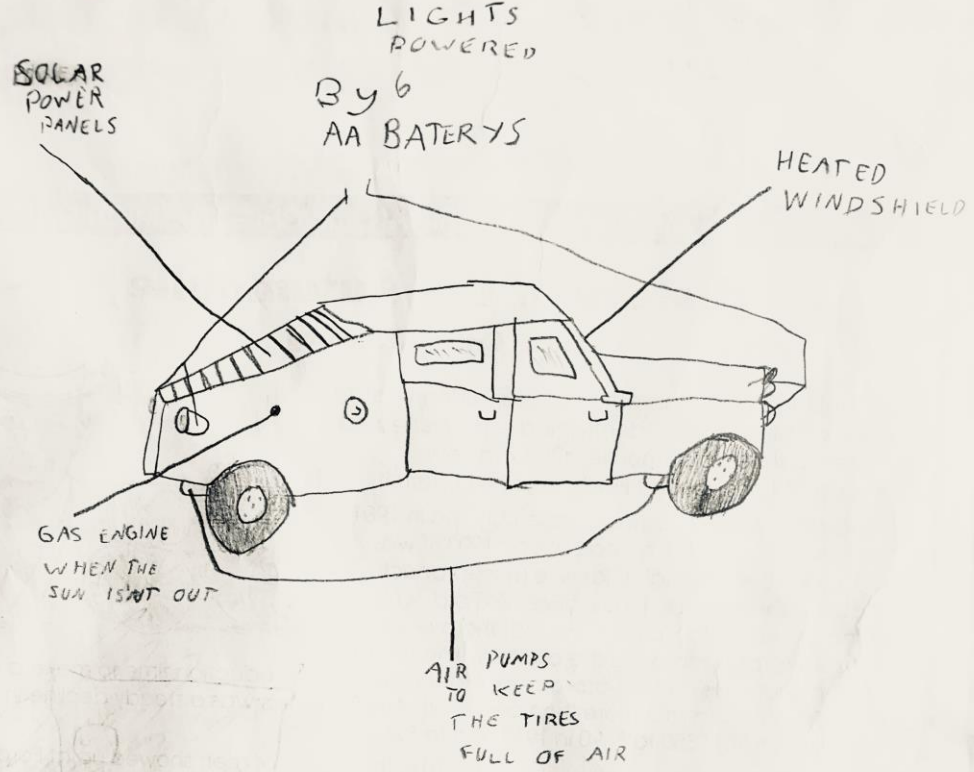
“My Dream Car” Drew Winter Jr. Age 7, circa 1992







MY DREAM CAR



















Okay Grandpa, these are cars with tailfins.



Okay Boomer, this is what a real pickup truck looks like





Thank you

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