PENGUASAAN TEKNOLOGI BATERAI UNTUK MENYAMBUT REVOLUSI KENDARAAN LISTRIK

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Focus Group Discussion

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FTMD ITB
Fakultas Teknik Mesin dan Dirgantara
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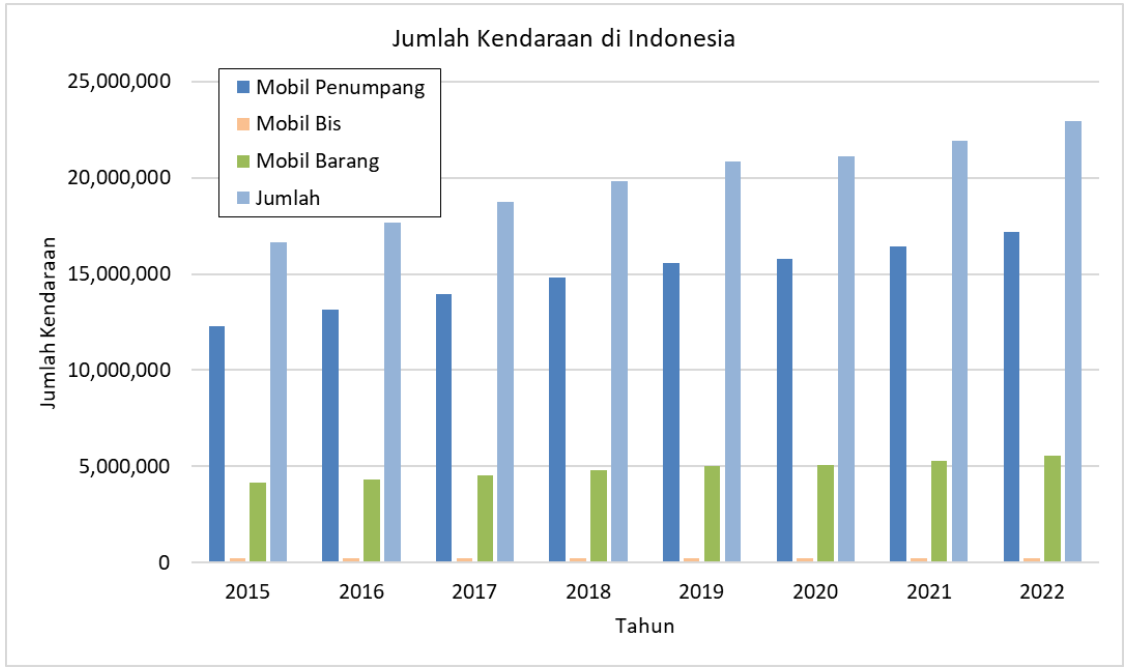
National Center for Sustainable Transportation Technology

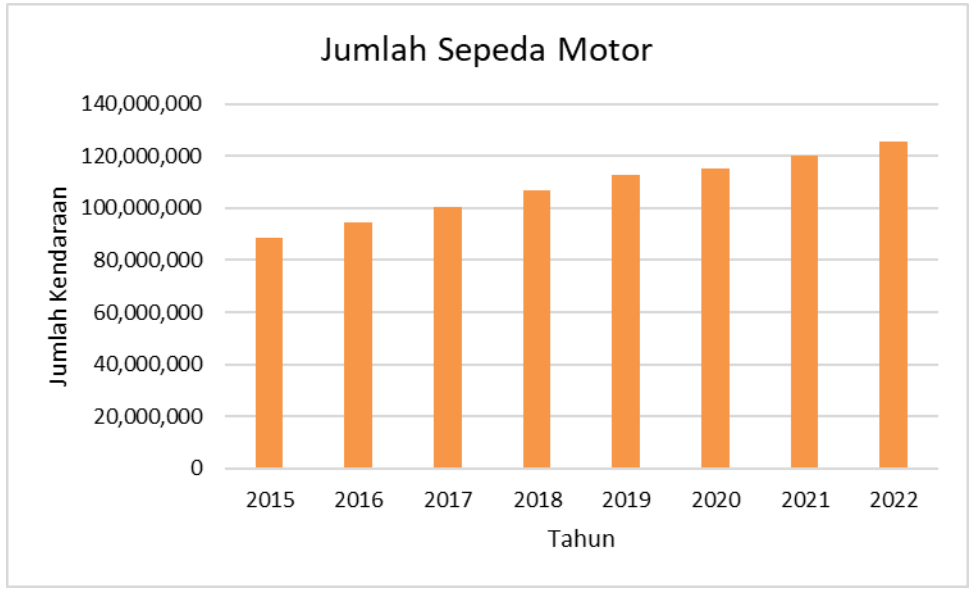
Outline

- Urgensi Mengelola Industri Otomotif
- Penelitian Baterai Kendaraan Listrik
- Teknologi Integrasi Kendaraan Listrik
- Baterai Masa Depan

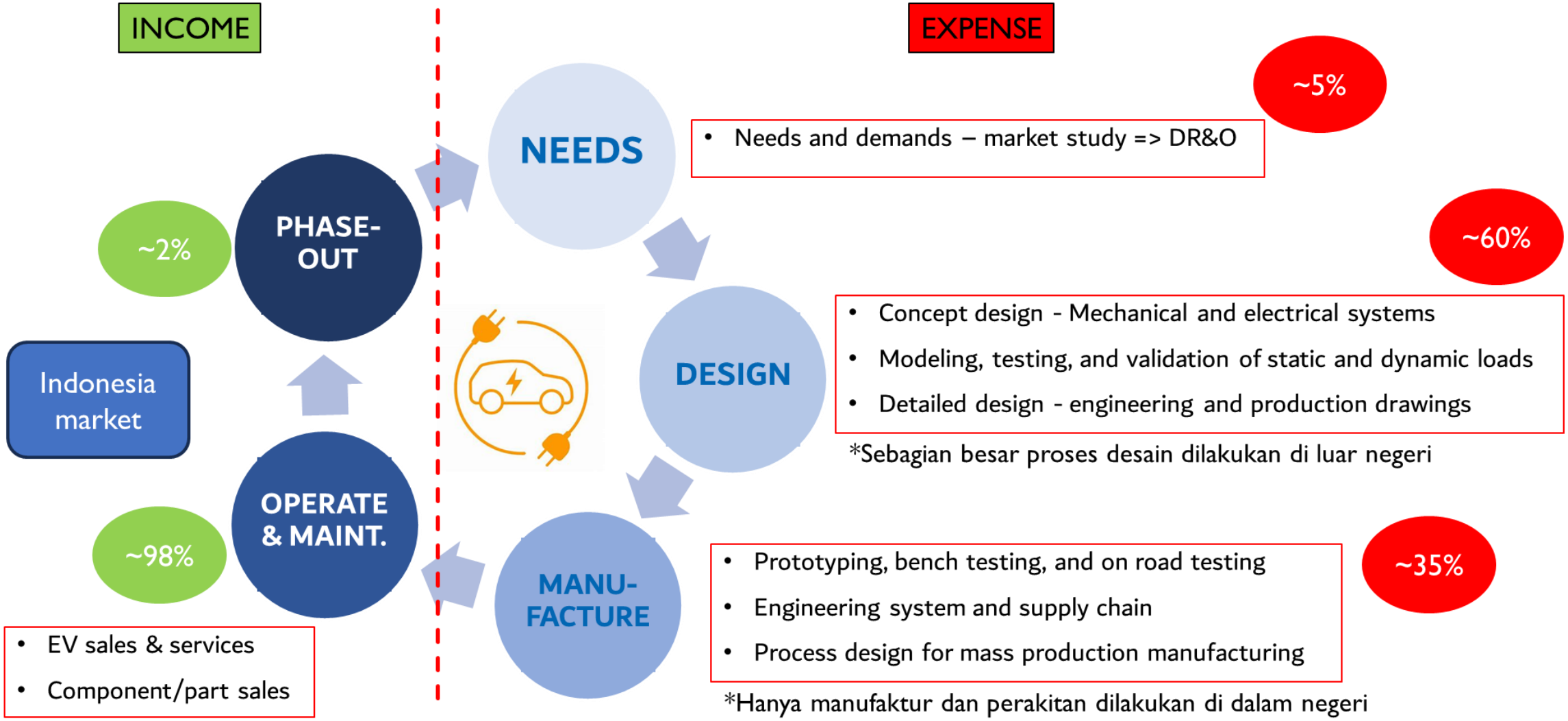
Urgensi Mengelola Industri Otomotif

- Pertumbuhan ekonomi suatu negara bergantung pada **distribusi logistik** dan **perpindahan masyarakat.**
- Indonesia merupakan salah satu **pasar** otomotif **terbesar** di dunia.
- Industri otomotif memiliki dampak ekonomi yang **sangat besar** karena banyaknya industri **supplier terlibat** dengan syarat, seluruh siklus hidup produk **dikelola** di dalam negeri.





Industri Otomotif di Indonesia: Siklus Hidup Produk



Revolusi Kendaraan Listrik: dari Kendaraan Listrik menuju Kesejahteraan

- Peraturan emisi gas buang yang semakin ketat
- Kendaraan listrik ‘tidak menghasilkan emisi gas buang’
- Ongkos produksi dan perawatan kendaraan Listrik telah turun secara signifikan

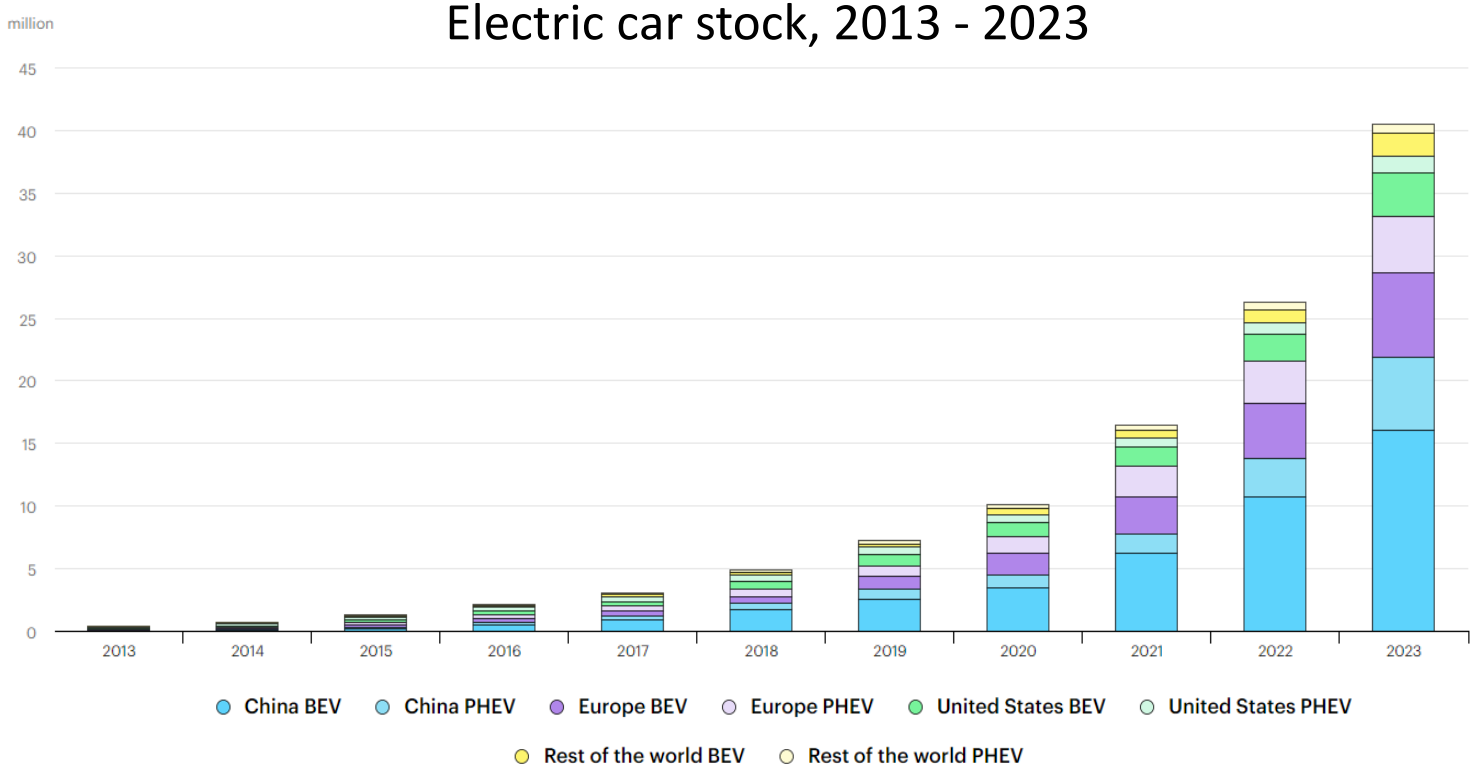
Revolusi kendaraan Listrik adalah **kesempatan** dan **momentum** untuk industri nasional mengambil pasar domestik yang telah dikuasai oleh industri otomotif luar negeri lebih dari **40 tahun**.

Kendaraan listrik berbasis baterai memiliki **jumlah komponen** bergerak dan komponen yang harus diganti selama pemakaian **lebih sedikit** dibanding kendaraan motor bakar.

Liu, Z., et al. (2021). Comparing total cost of ownership of battery electric vehicles and internal combustion engine vehicles. *Energy Policy*, *158*, 112564.

Populasi Kendaraan Listrik

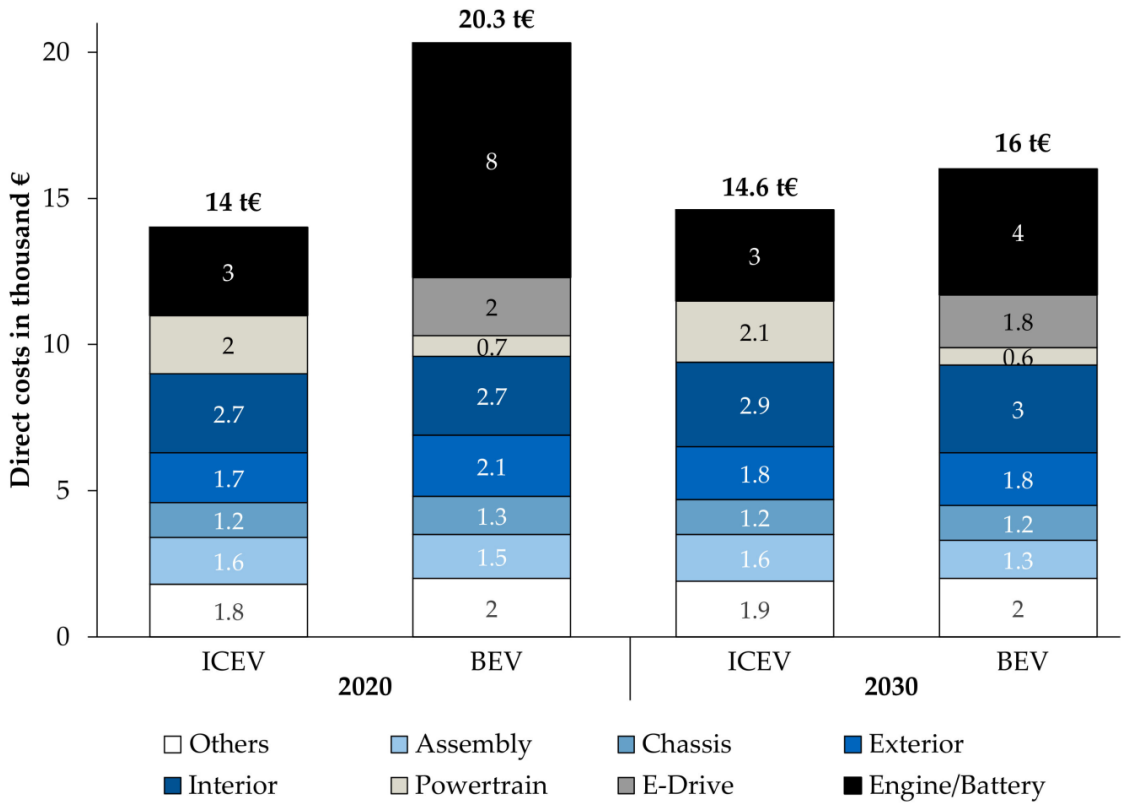
Populasi kendaraan Listrik di Indonesia dan di Dunia terus meningkat

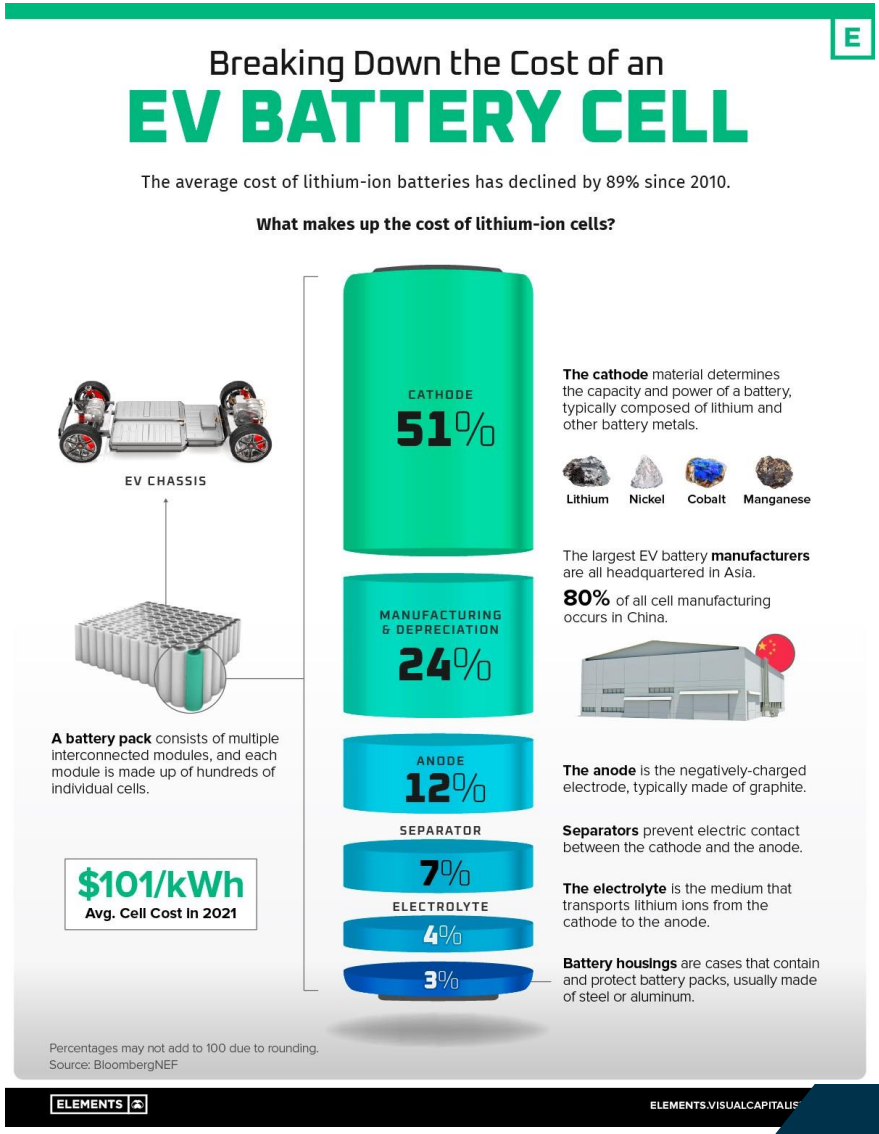


https://www.iea.org/reports/global-ev-outlook-2024/trends-in-electric-cars
https://goodstats.id/article/penjualan-mobil-listrik-terus-melonjak-setiap-tahunnya-61goQ
https://databoks.katadata.co.id/datapublish/2023/09/15/riset-deloitte-dan-foundry-penggunaan-motor-listrik-di-indonesianaik-13-kali-lipat-dalam-dua-tahun

Harga Baterai pada Kendaraan Listrik

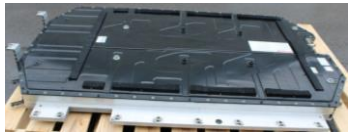
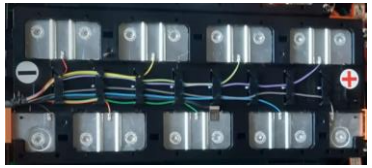
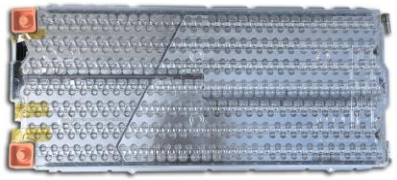
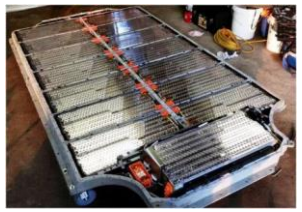
- **Baterai** masih menjadi komponen **termahal** pada kendaraan listrik
- **Ongkos produksi** kendaraan Listrik akan **kompetitif** pada tahun 2030
- Lebih dari **50%** ongkos produksi sel baterai berasal dari **katoda**





König, A., Nicoletti, L., Schröder, D., Wolff, S., Waclaw, A., & Lienkamp, M. (2021). An overview of parameter and cost for battery electric vehicles. *World Electric Vehicle Journal*, *12*(1), 21.
https://www.arenaev.com/heres_a_breakdown_of_the_cost_of_an_ev_battery-news-55.php

Konfigurasi Baterai pada Kendaraan Listrik

Cathode Powder	Battery cell	Battery Module	Battery pack ($200~$250/kWh)	Electric Vehicle
NCM 	 Pouch 			 Nissan Leaf
				 Hyundai Ioniq 5
LFP 	Prismatic 			 Wuling Air EV
NCA 	Cylindrical 			 Tesla Model S

Masalah Tersisa pada Kendaraan Listrik

Produksi Masal

- Material penyusun katoda masih relatif ‘langka’
- Desain *battery cell* dan *battery pack* terlalu beragam dan bergantung pada produsen
- Penyeragaman dan standardisasi khususnya pada baterai dan *charger* mungkin sulit dilakukan

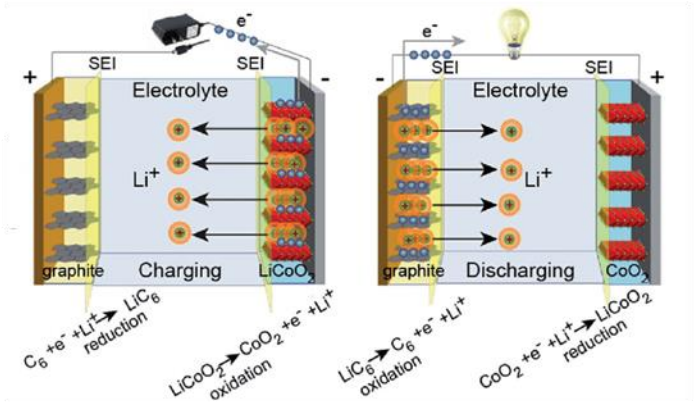
Safety Issue

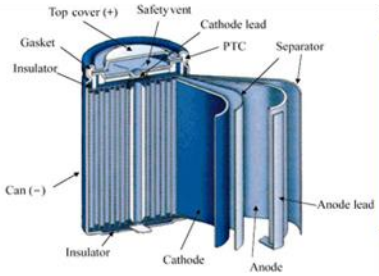
- Semakin meningkatnya populasi kendaraan Listrik, modus kecelakaan ‘baru’ akan muncul
- Angka kecelakaan dapat ditekan dengan pengalaman yang tercatat (*database*) dan pembaruan standard keselamatan

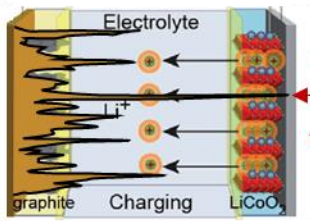
Penelitian Baterai Kendaraan Listrik

Our research focus

Internal Cell Level

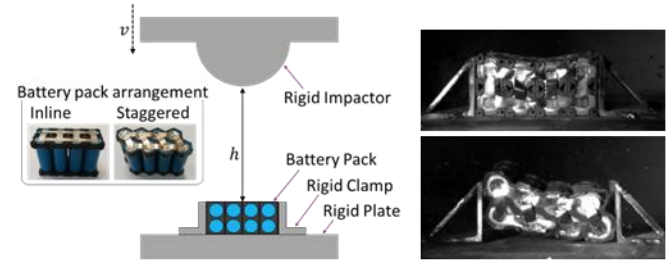


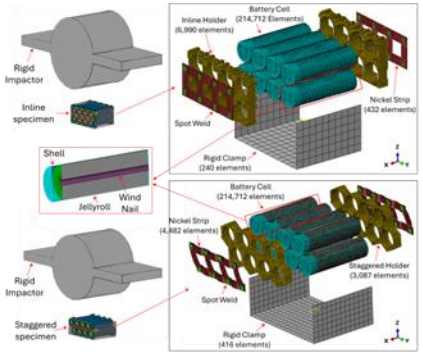


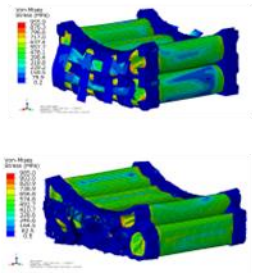


Dendrite growth causing short circuit and thermal runaway

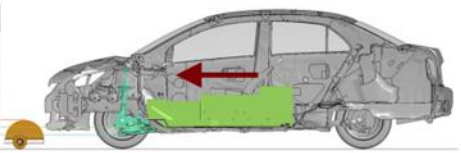
Cell, Module, and Pack Level



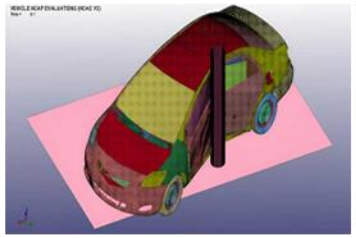




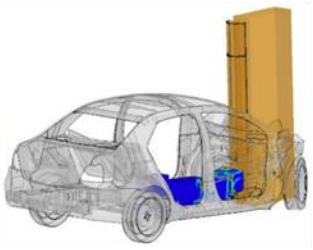
Vehicle Level



Debris impact



Side impact



Front impact

[4] Widyantara, R. D., Zulaikah, S., Juangsa, F. B., Budiman, B. A., & Aziz, M. (2022). Review on Battery Packing Design Strategies for Superior Thermal Management in Electric Vehicles. *Batteries*, *8*(12), 287

Masalah dan Proteksi Baterai Kendaraan Listrik

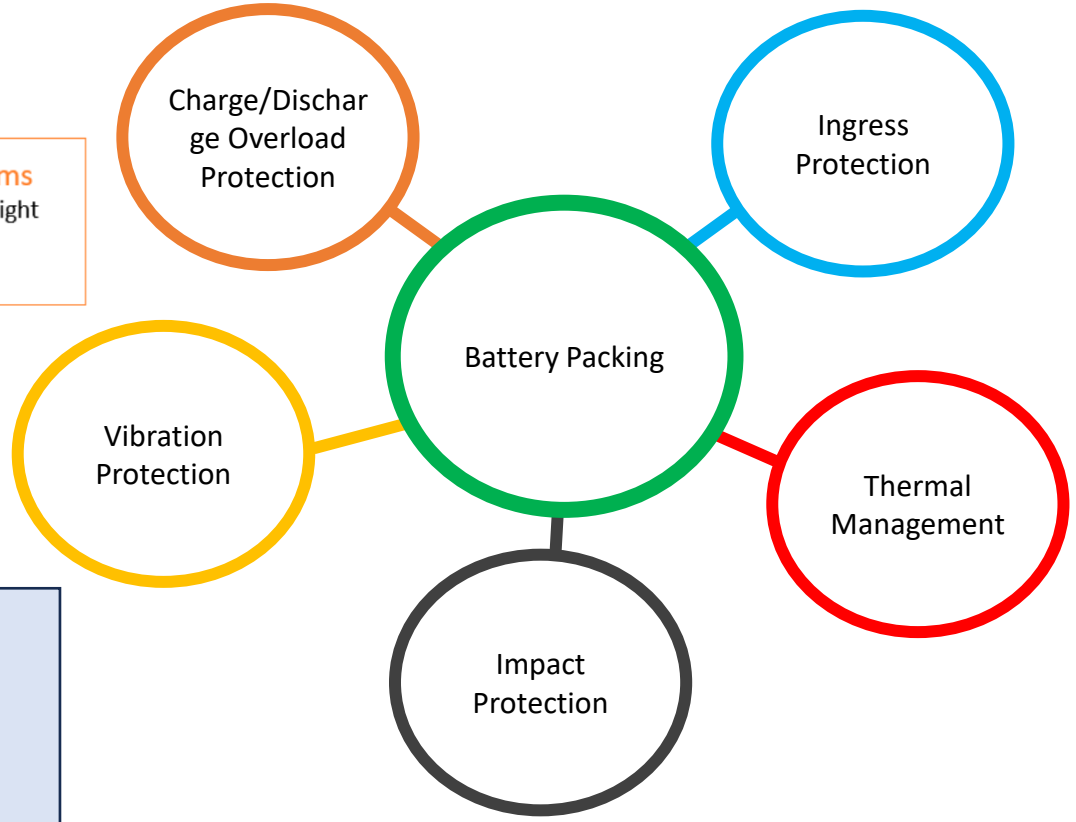
Battery Cell Characteristic Problems
- Narrow range operational temperature
- Energy density proportional to thermal event
- Damage susceptibility of structural material

Environmental Problems
- Wide temperature range in subtropic climate
- Weather condition (humidity, etc.)
- Reckless driving behavior

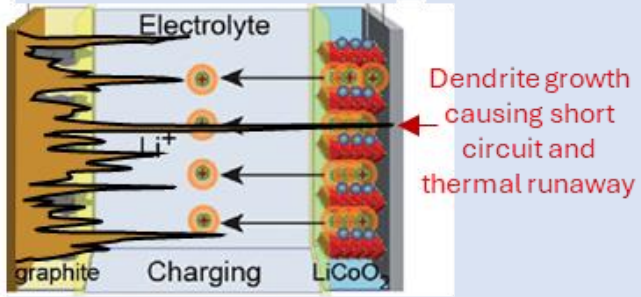
Battery Thermal Management and Packing Design

Module Cooling Design Problems
- Limited space and available vehicle weight
- Complex design requirement
- Limited coolant capacity

Battery Thermal Response

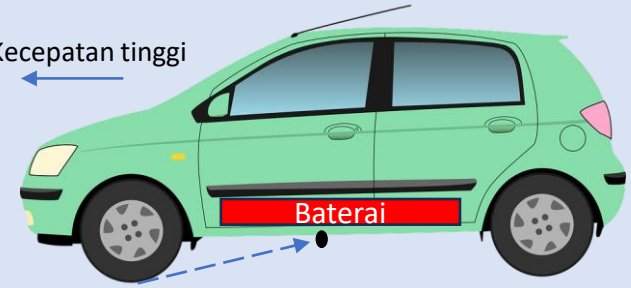


Pertumbuhan dentrite pada elektroda



Dendrite growth causing short circuit and thermal runaway

Stone chip impact pada mobil listrik



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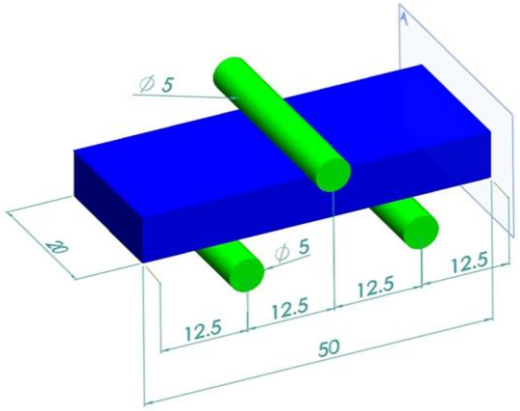
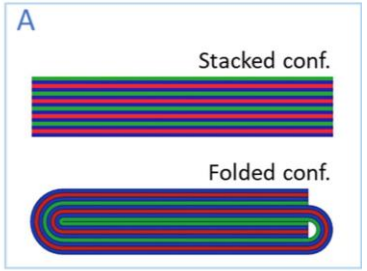
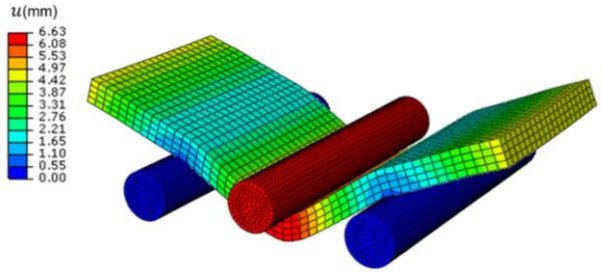
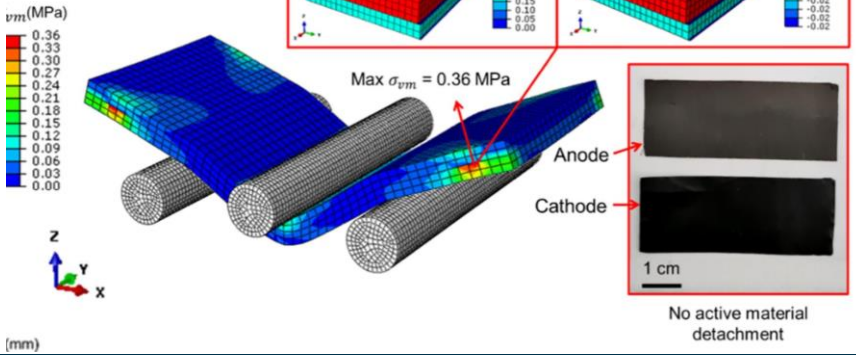
Configuration vs Rigidity of Pouch Battery Cell

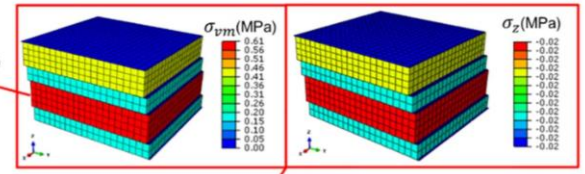
- Pengaruh konfigurasi **bertumpuk** dan **berlipat** pada pouch battery cell diungkap
- Teknik pemodelan **homogenisasi** diperkenalkan
- Daerah yang berpotensi **short circuit** dapat **diprediksi**



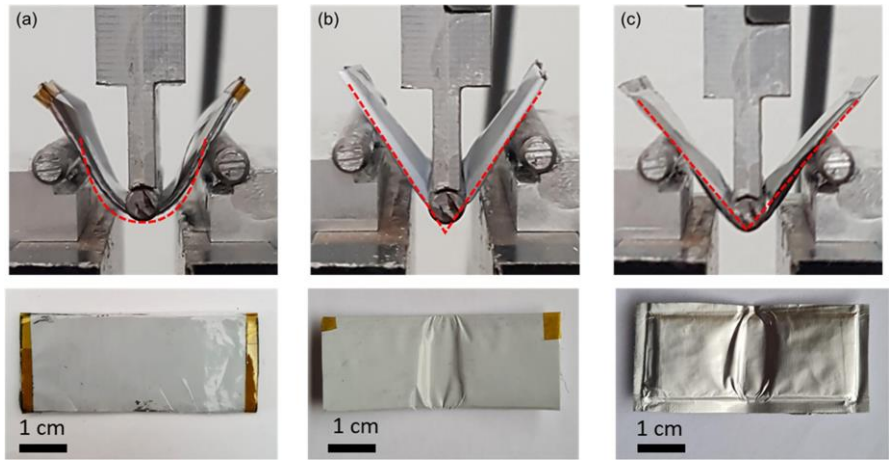


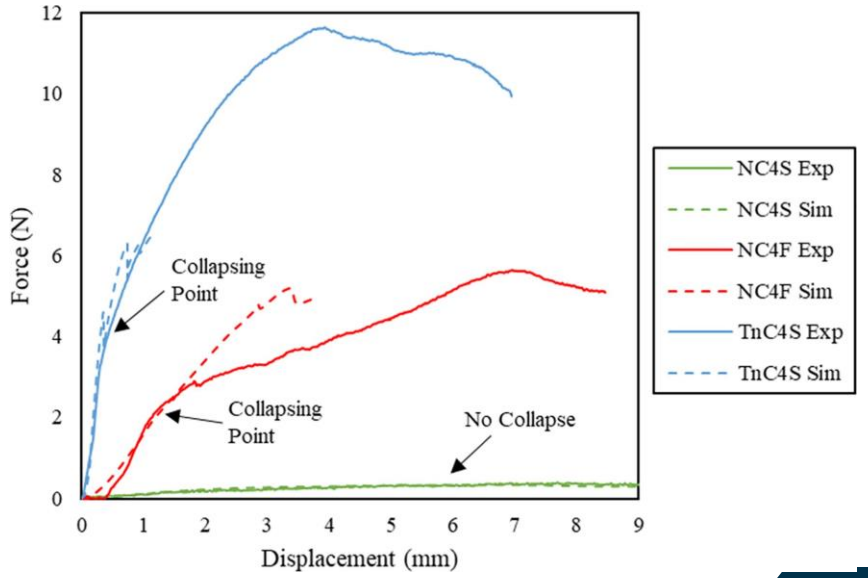






No active material detachment

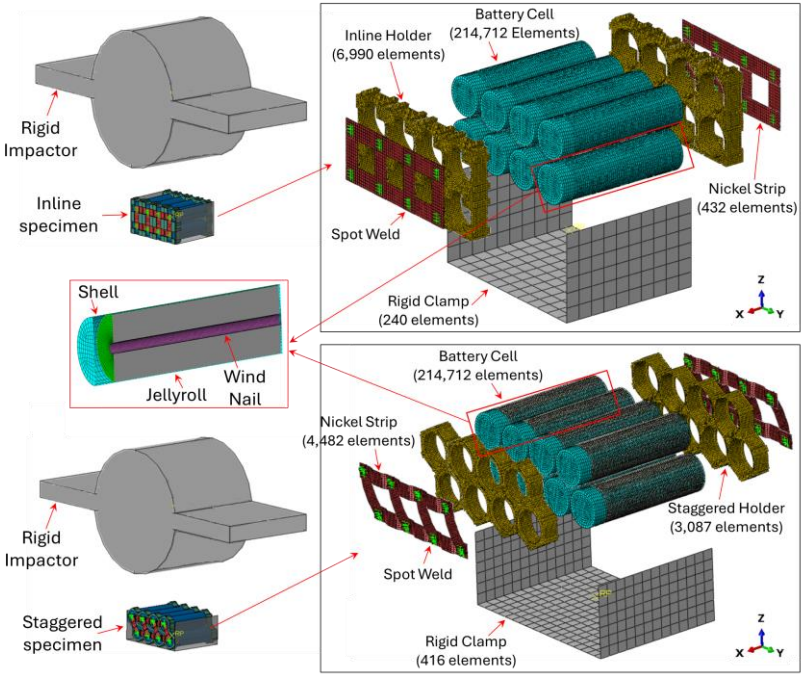


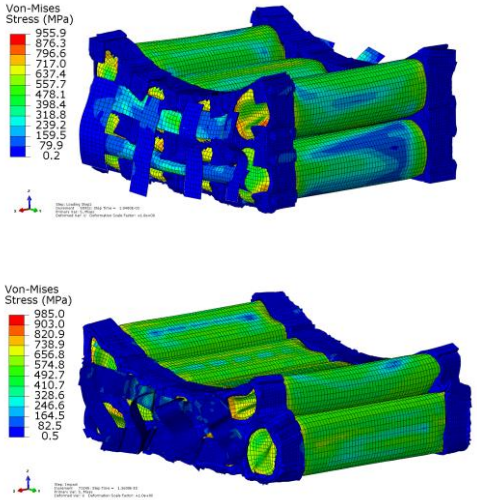


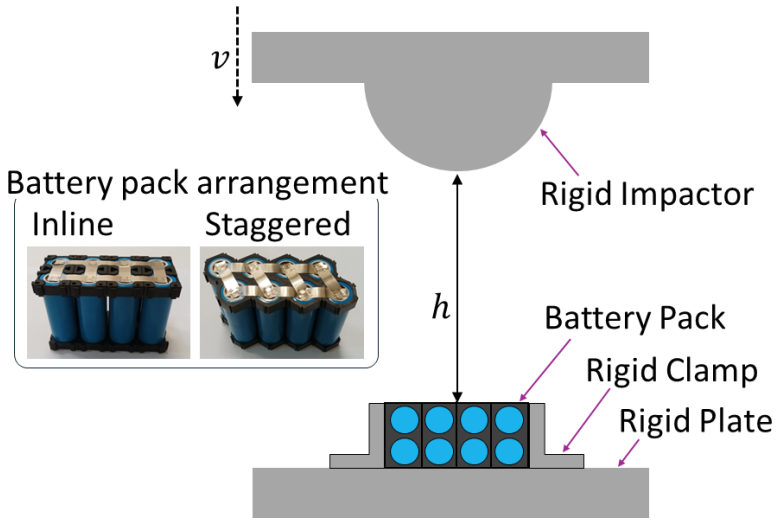
Budiman, B. A., Rahardian, S., Saputro, A., Hidayat, A., Nurprasetio, I. P., & Sambegoro, P. (2022). Structural integrity of lithium-ion pouch battery subjected to three-point bending. Engineering Failure Analysis, 138, 106307.

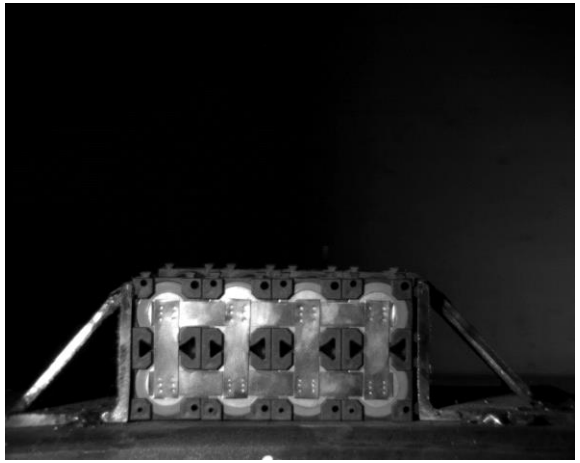
Arrangement vs Impact Response of Cylindrical Battery Cell

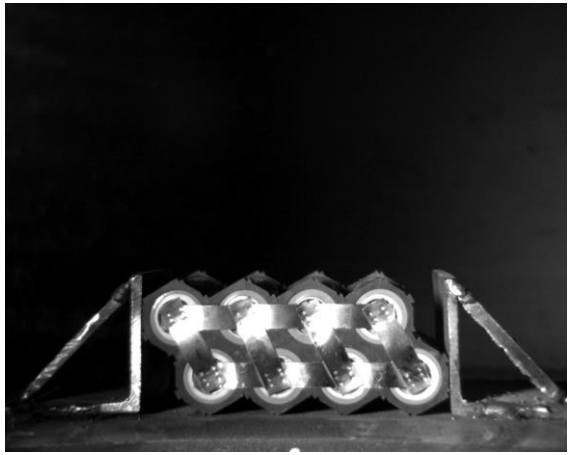
- Pengaruh susunan **inline** dan **staggered** pada cylindrical battery cell diungkap
- **Drop test impact** dilakukan
- Model simulasi **nonlinear** elemen hingga dikembangkan
- Daerah yang berpotensi **short circuit** dapat **diprediksi**

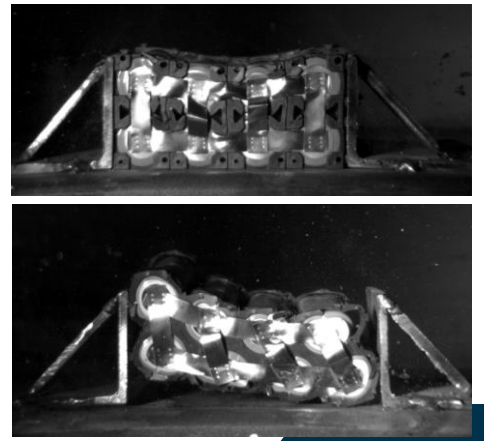




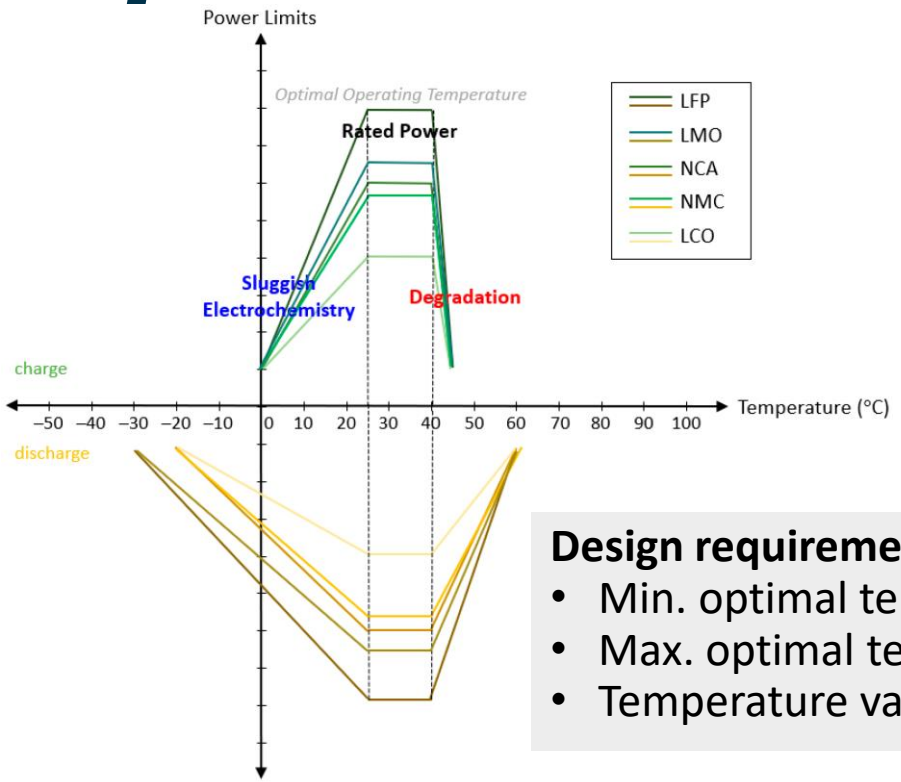




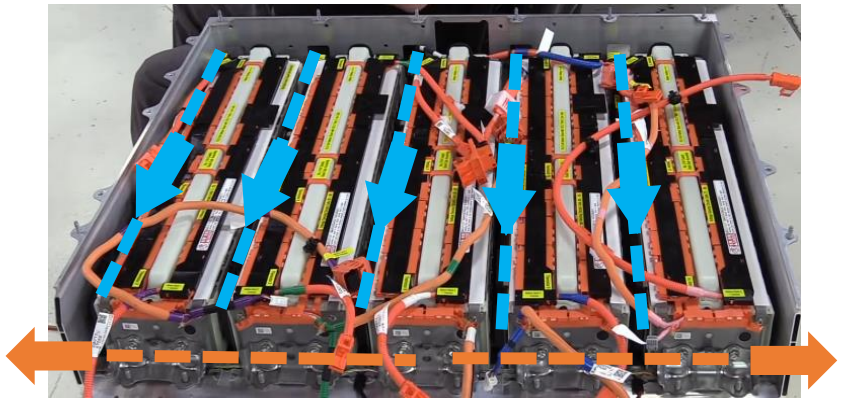




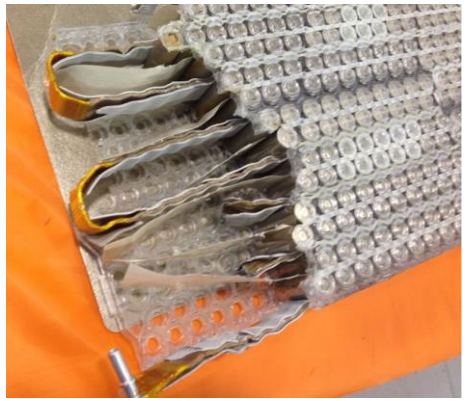
Liquid vs Air Cooling system Design



Toyota Prius Prime battery Pack



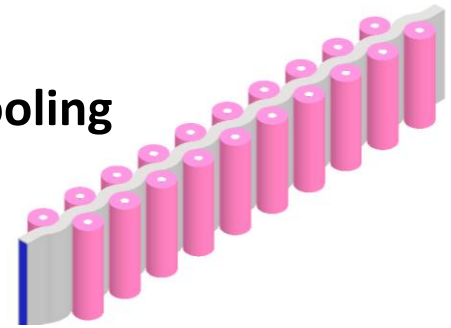
Tesla Model X

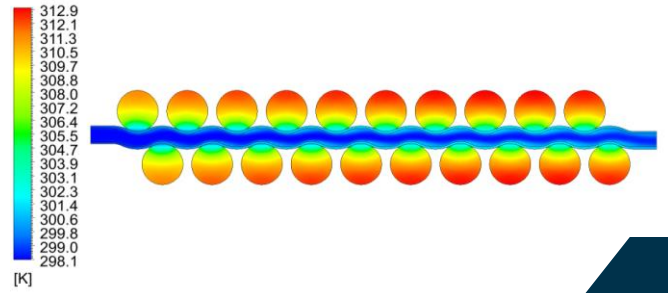


Design requirements

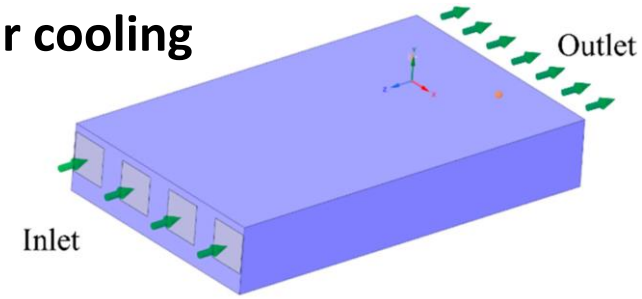
- Min. optimal temperature: **25 °C**
- Max. optimal temperature: **40 °C**
- Temperature variance: **5 °C**

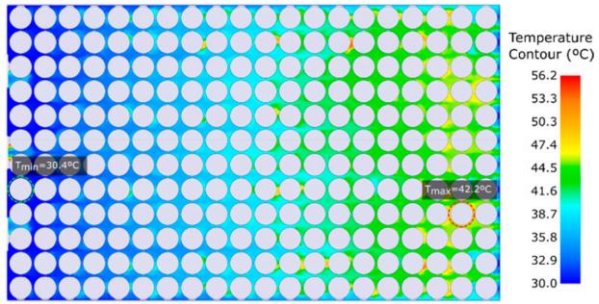
Liquid cooling





Air cooling





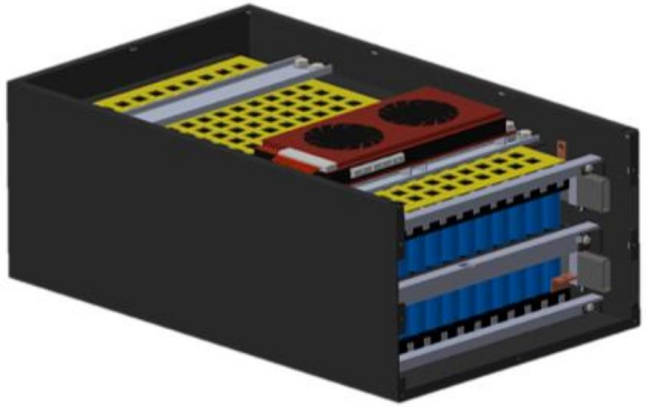
Widyantara, R. D., Naufal, M. A., Sambegoro, P. L., Nurprasetio, I. P., Triawan, F., Djamari, D. W., Nandiyanto, A. B., Budiman, B. A., & Aziz, M. (2021). Low-cost air-cooling system optimization on battery pack of Electric Vehicle. *Energies*, *14*(23), 7954.

Battery Pack Prototyping for Electric Motorcycle and Electric Trike

Prototipe battery pack dirancang dengan mempertimbangkan:

- 5 pilar proteksi untuk menjamin keamanan operasional tinggi
- Ongkos produksi yang rendah
- Performa dan kehandalan operasi yang maksimal
- Tingkat kandungan dalam negeri (TKDN) yang tinggi

Battery pack e-trike

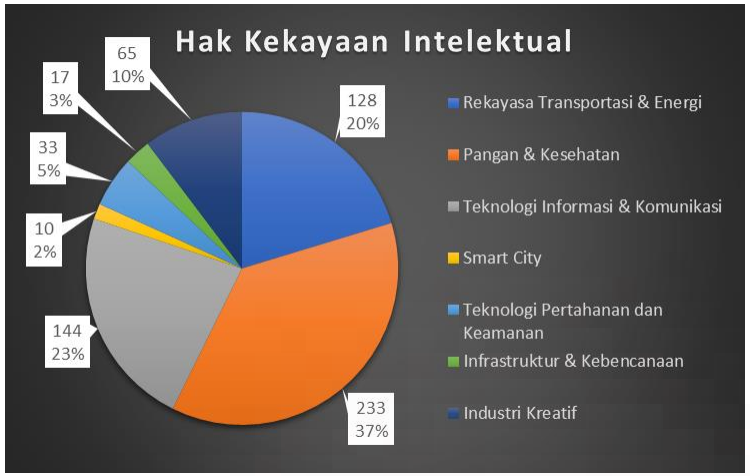


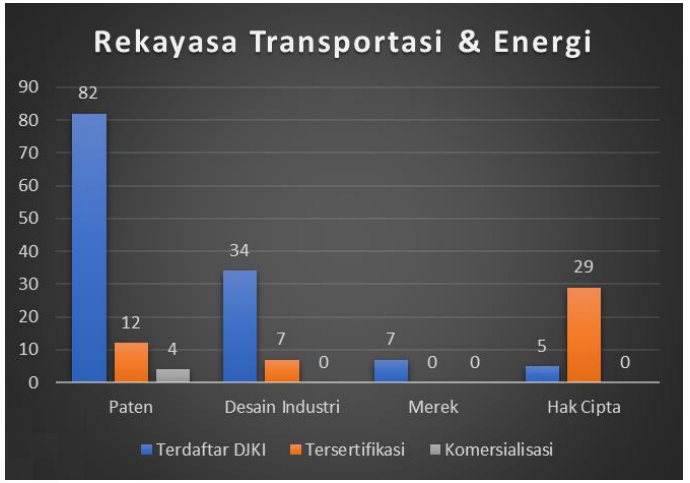
Battery pack motor listrik

Widyantara, R. D., Naufal, M. A., Sambegoro, P. L., Nurprasetio, I. P., Triawan, F., Djamari, D. W., ... & Aziz, M. (2021). Low-cost air-cooling system optimization on battery pack of electric vehicle. Energies, 14(23), 7954.

Teknologi Integrasi Kendaraan Listrik

- **Tim peneliti kendaraan Listrik ITB** melalui NCSTT telah melakukan banyak pengembangan teknologi kendaraan Listrik beserta teknologi komponennya dengan **prototipe**, **jumlah HKI**, dan **publikasi ilmiah** yang masif.
- **Apakah industri nasional kita siap untuk menyerap hasil penelitian kita?**





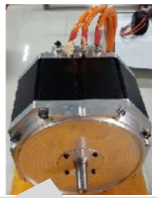
KOMPONEN KUNCI HASIL RISET ITB

Range Extender

Battery Management System

120 kW Inverter

EV-ECU



5, 75, and 120 kW BLDC Motors

DC-DC Converter

E-Bus Smart Dashboard

On-Board Charger

Battery Pack

PROTOTIPE KENDARAAN LISTRIK ITB

E-Trike

City Car EV

Angkutan Kota EV

Platform Bus Listrik Konversi

Calya Konversi

Rancang Bangun *Electric Trike*

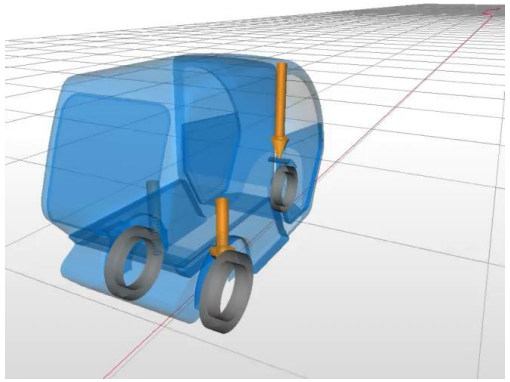
Pengembangan sistem suspensi dan kemudi untuk meningkatkan kenyamanan berkendaraan dan stabilitas kendaraan

Pengembangan teknologi baterai dan battery pack berbasis LFP dan NCM termasuk integrasi charging tipe 2 kerjasama tim kenlis ITB Bersama mitra Gotion Indonesia

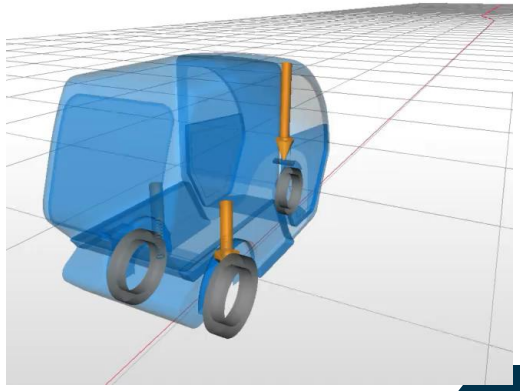
Motor Listrik BLDC 5 kw dengan efisiensi daya tinggi hasil penelitian tim kenlis ITB Bersama mitra Pindad

Pengembngan chassis dan body e-trike yang dirancang dan dibuat ‘from the scratch’ termasuk integrasi wiring harness, interior, dashboard, controller untuk menciptakan TKDN 90%

Double Lane Change (ISO 3888-1:2020)
v = 21 km/h



Single Lane Change (Wong, 2008)
v = 21 km/h



Rancang Bangun *Platform Electric Bus*

Wiring harness dirancang memenuhi standard otomotif (*automotive grade*) dengan proteksi maksimal

Battery Pack ***liquid cooling system*** dirancang untuk memproteksi *thermal runnaway*

Pemanfaatan **ladder chassis lokal** dipadu dengan komponen kendaraan Listrik terbaik untuk meningkatkan *local content*

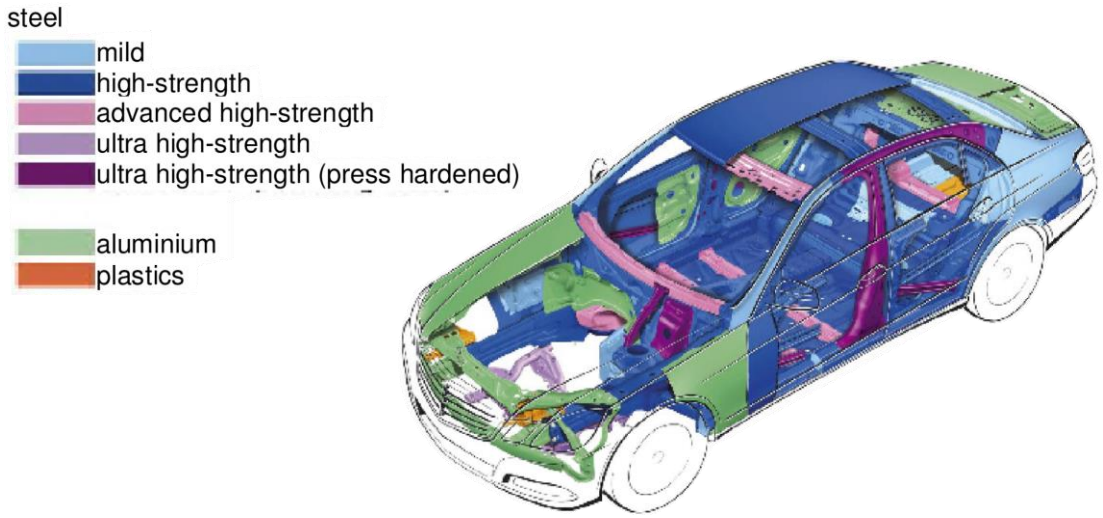
Spesifikasi ***platform*** untuk kebutuhan bus medium ukuran sedang yang merupakan 90% populasi bus di Indonesia

Pengembangan dan penerapan teknologi yang unik dan spesifik, belum ada yang menyerupai

Crashworthiness Design for Electric Vehicles

Kriteria desain struktur mobil:

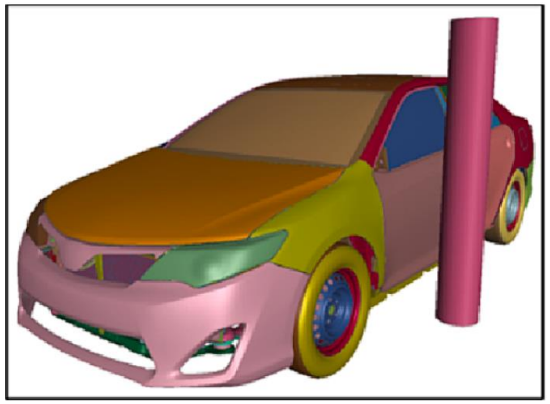
- Struktur mobil harus dapat menyerap energi impak saat terjadi tabrak depan dan tabrak belakang
- Struktur mobil harus mampu menahan beban impak dan tidak terguling saat terjadi tabrak samping

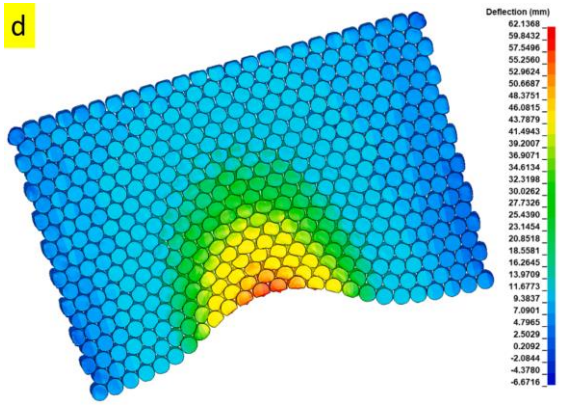


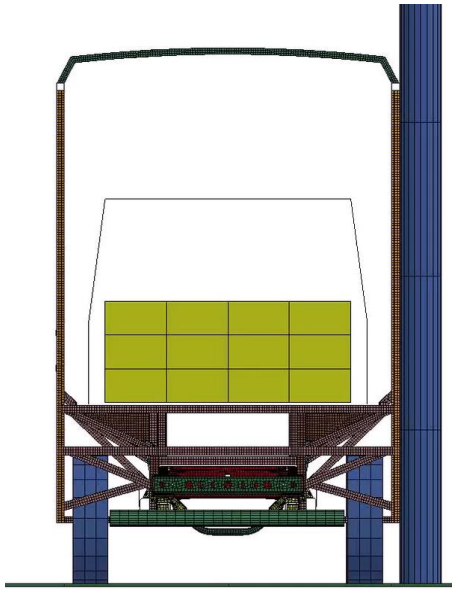
Pada perancangan mobil Listrik, baterai harus diproteksi seperti pengendara/penumpang

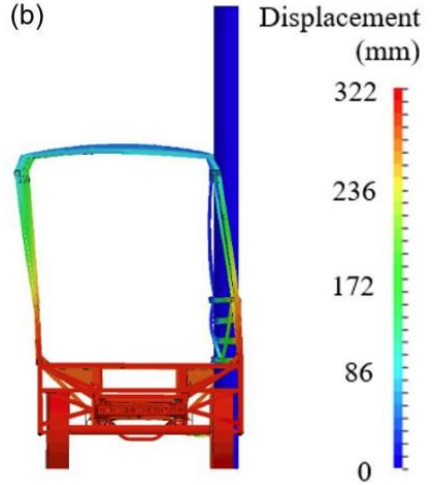
Erdmann, Christian & Flaxa, Volker & Guettler, Jürgen & Rieth, Marcus & Schoettler, Joachim. (2011). Reliably processable steel for chassis components with high structural durability.
Gu, L., Yang, R. J., Tho, C. H., Makowskit, M., Faruquet, O., & Li, Y. (2001). Optimisation and robustness for crashworthiness of side impact. *International Journal of Vehicle Design*, *26*(4), 348.

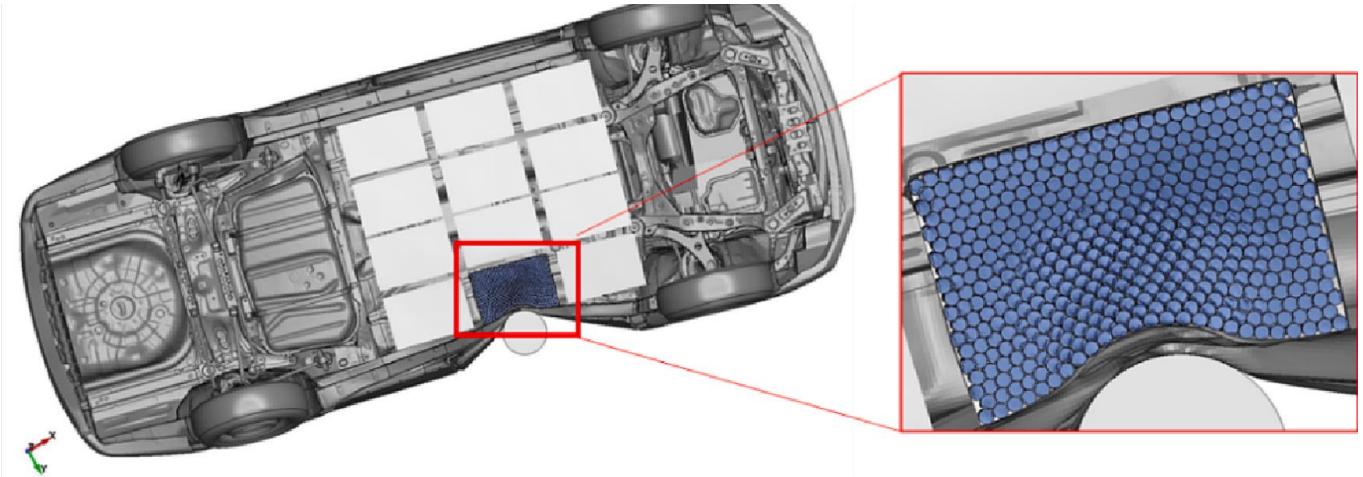
Simulasi Tabrak Samping *Electric Vehicles*

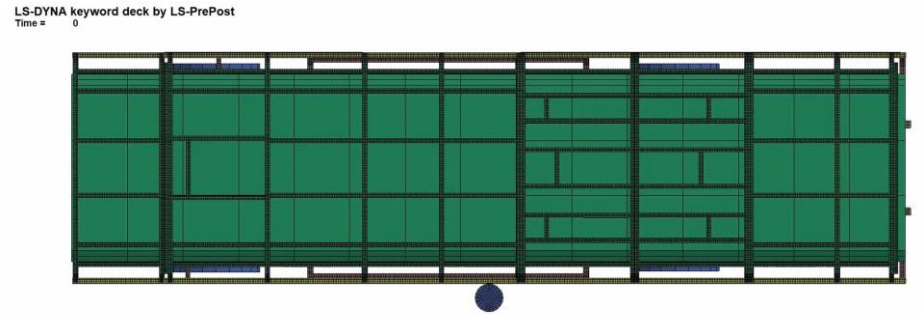






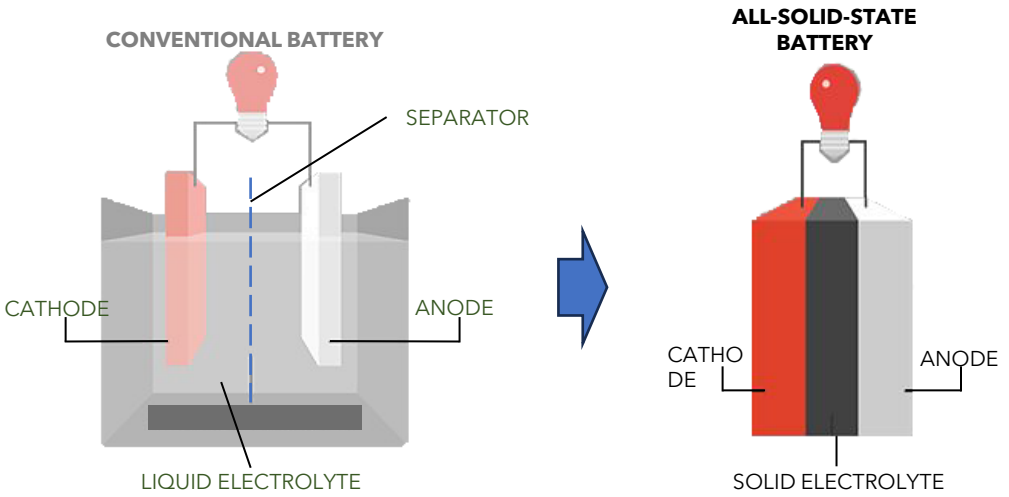




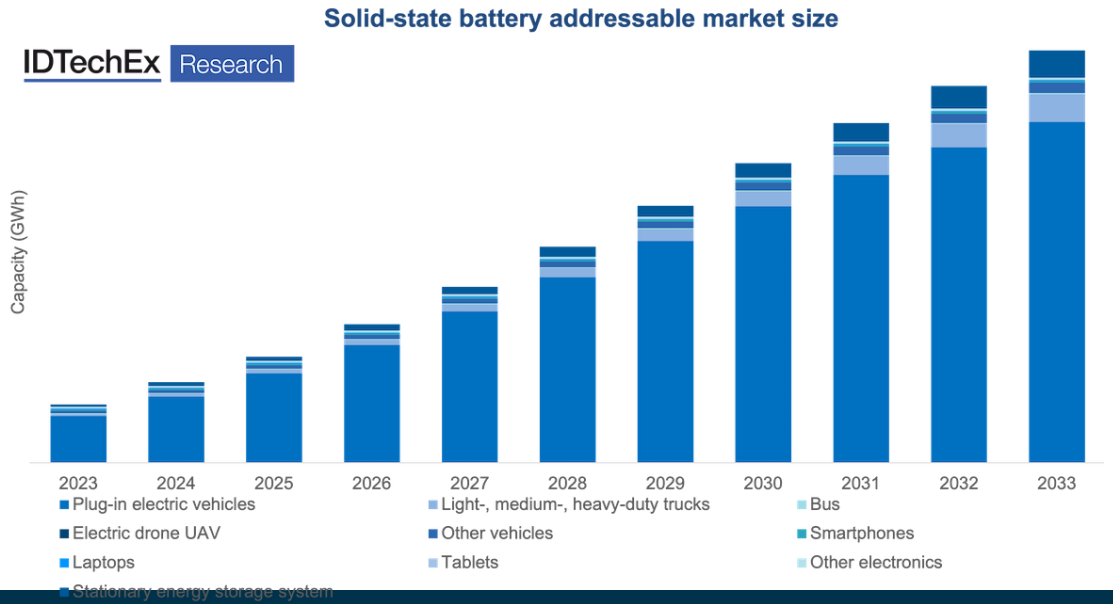


Mustaffa, Z., Al-Qadami, E. H. H., Topa, A., Budiman, B. A., Hamka, N. A. M., Dharmowijoyo, D. B. E., & Razi, M. A. M. (2024). Numerical assessment of the side impacts on lithium-ion battery module integrated with honeycomb reinforcement. Engineering Failure Analysis, 161, 108290.

Baterai Masa Depan



- Enhanced safety (no leakage and minimal short circuit event)
- Higher energy density (up to 4 times)
- Potentially long cycle life
- Wide operating temperature range (no need cooling system!?)
- Simplified and flexible design



Toyota Touts Solid State EVs With 932-Mile Range, 10-Minute Charging by 2027

The Japanese automaker says it has found a new material that will help commercialize the elusive, long-awaited solid state battery, but it's light on details.

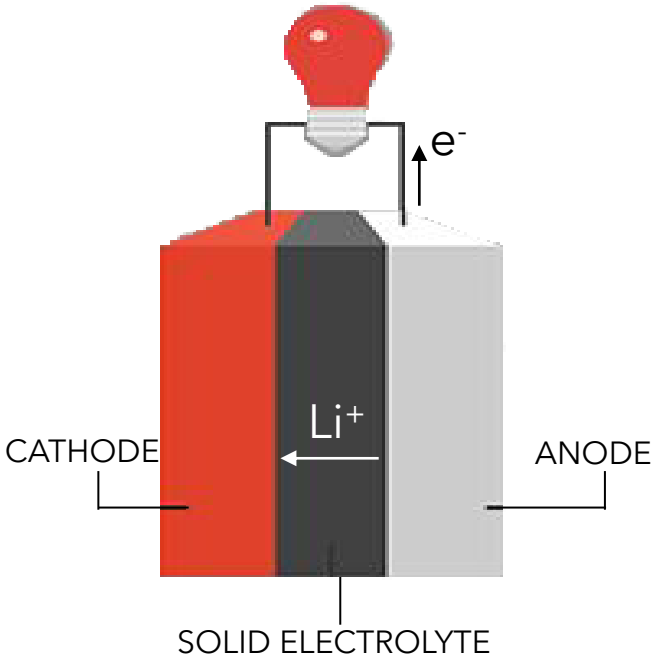
by Emily Dreibelbis

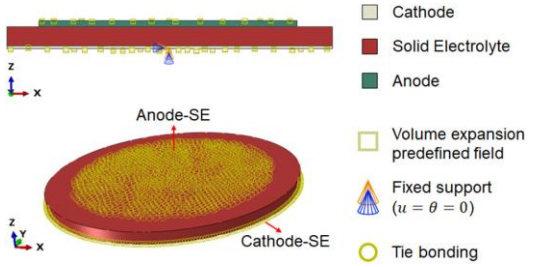
Jun 13, 2023

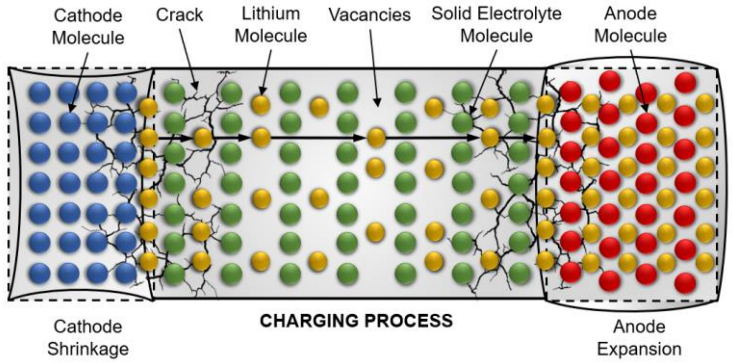
https://www.pcmag.com/news/toyota-touts-solid-state-evs-with-932-mile-range-10-minute-charging-by

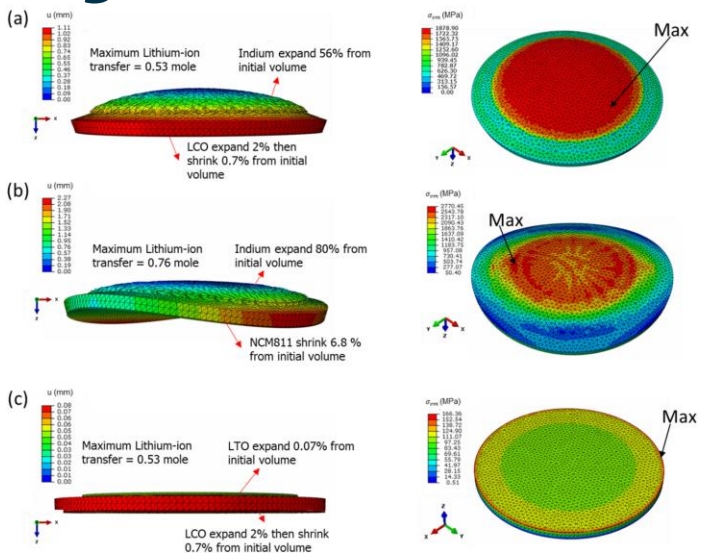
Masalah *Solid State Battery*

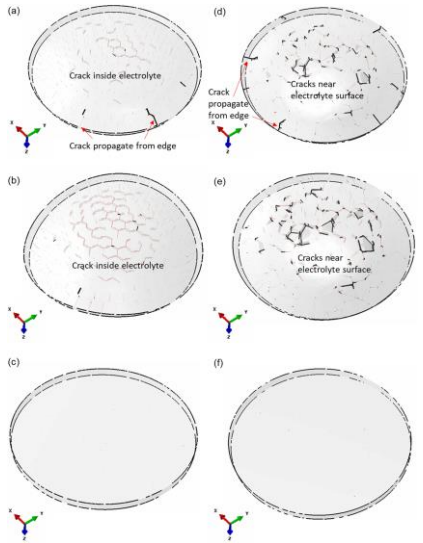
SOLID-STATE BATTERY (Discharging Process)

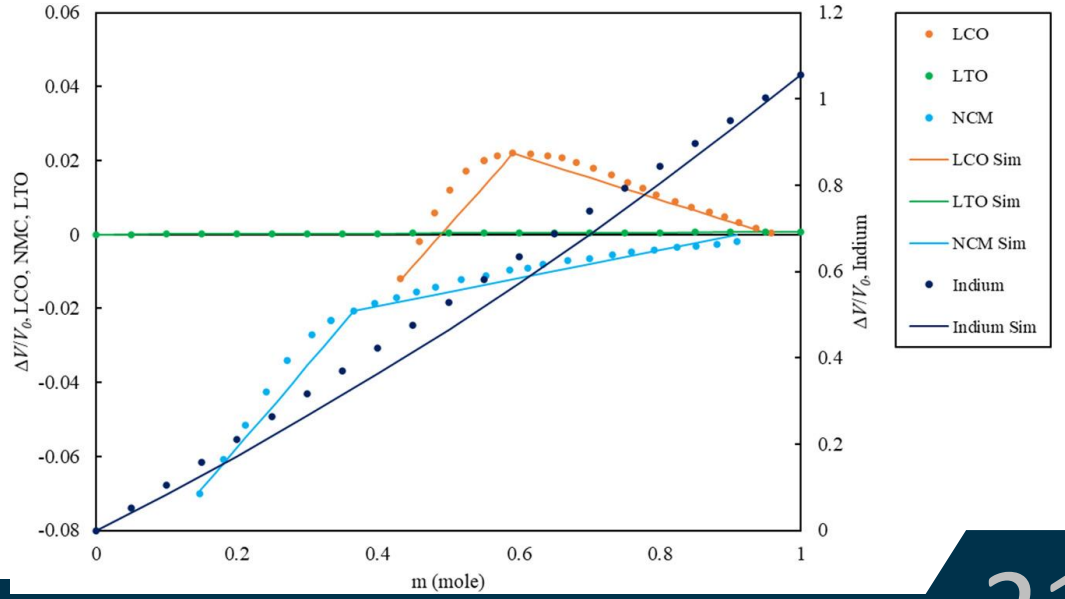










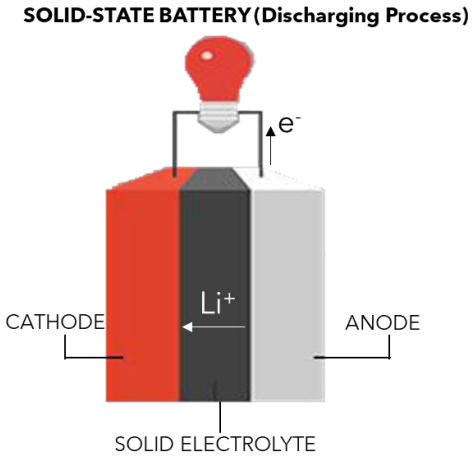


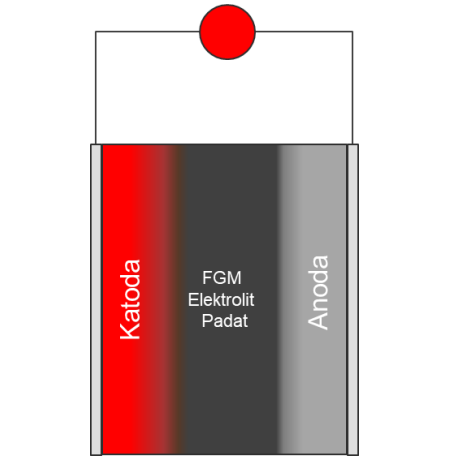
Solid Electrolyte problems

(1) Mechanic: Cracks occurrence during charging-discharging cycle

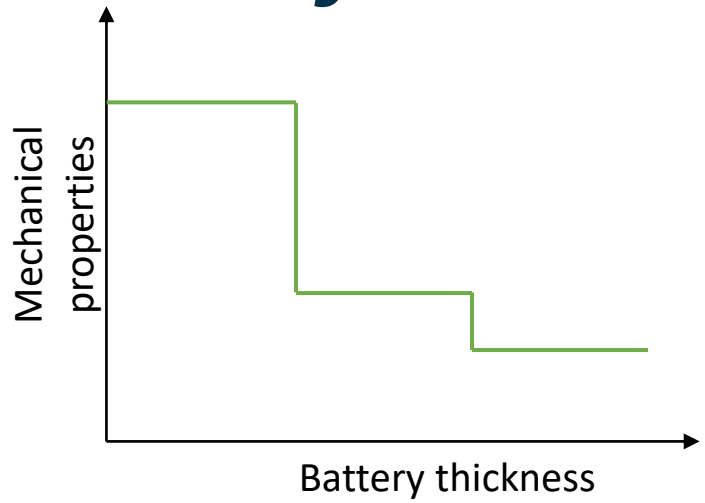
(2) Electric: Ionic conductivity degradation due to cracks

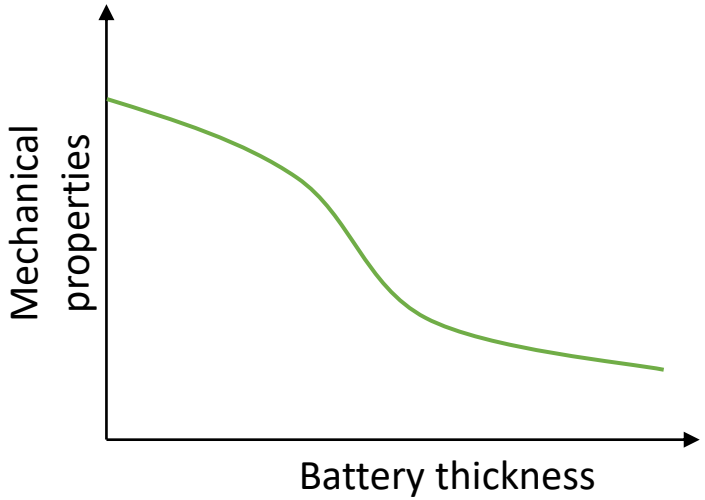
Functionally Graded Materials (FGM) pada *Solid State Battery*

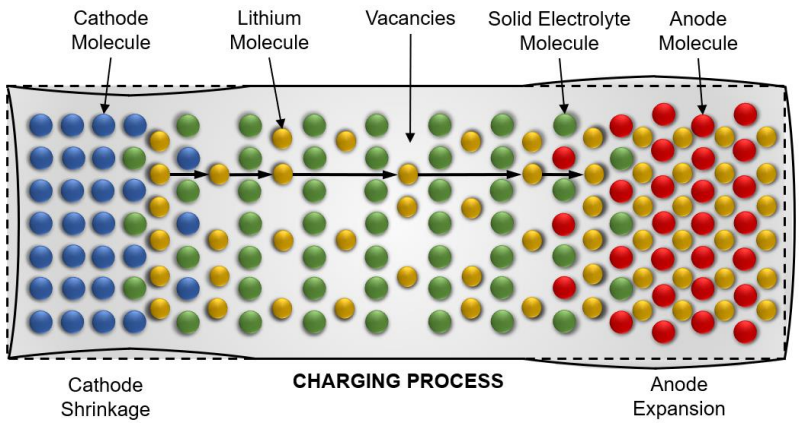




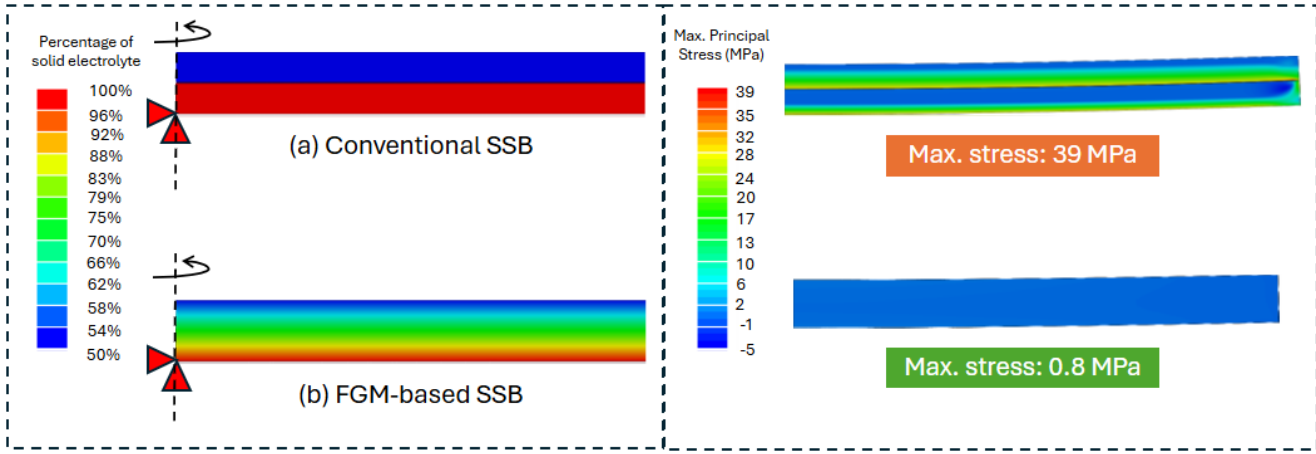
Solusi: *Functionally Graded Materials* (FGM)



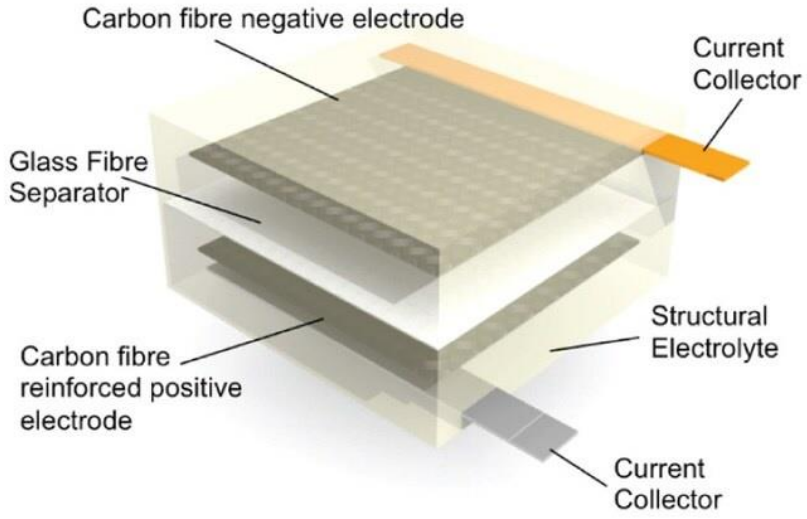


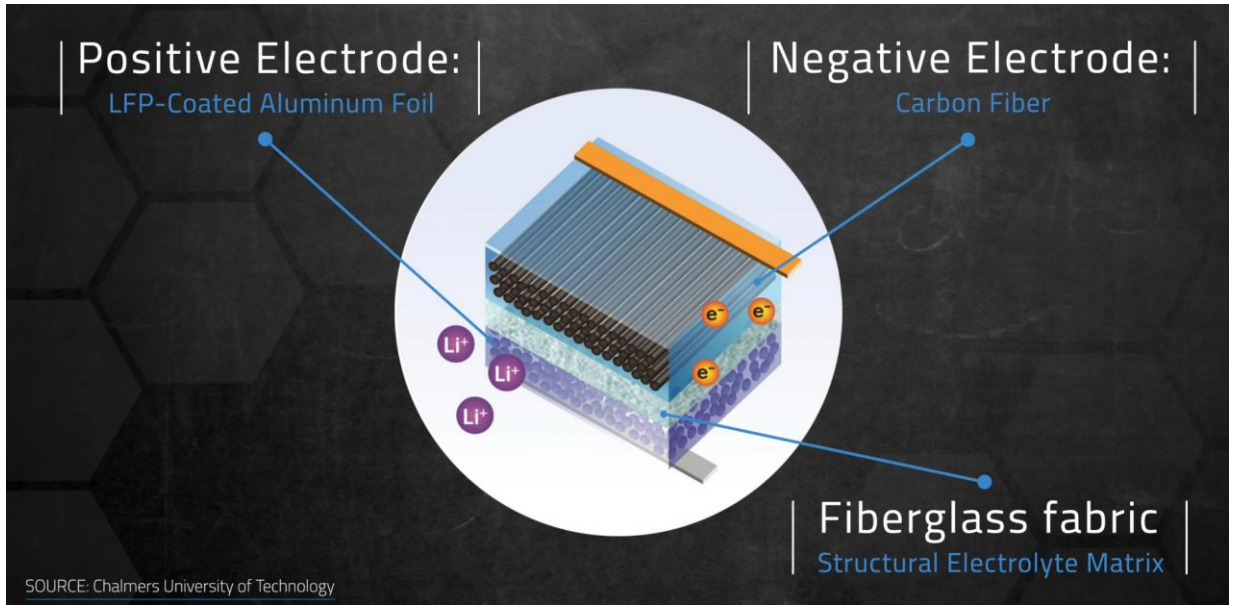


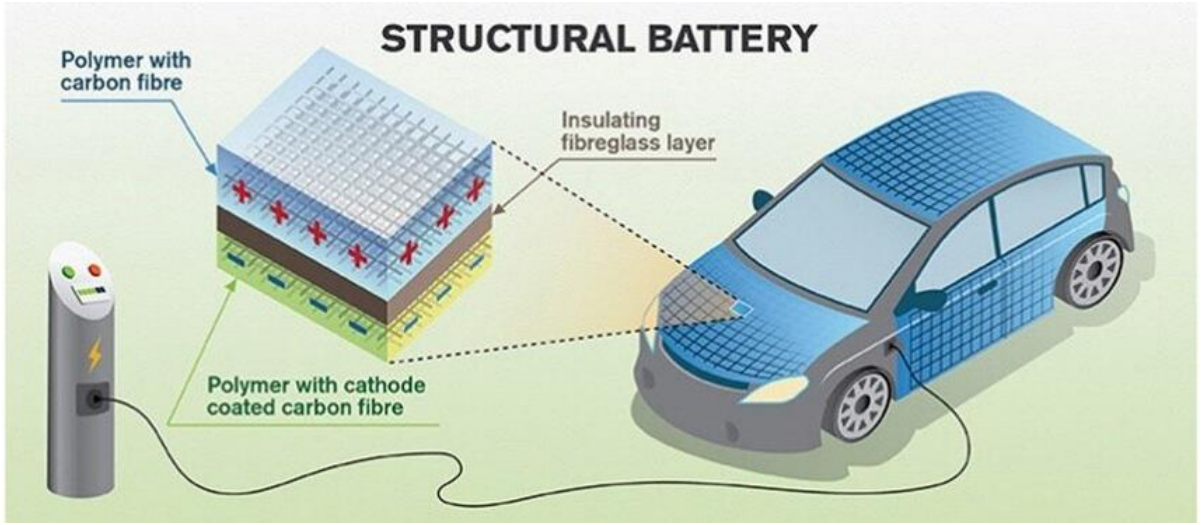
Preliminary simulation results



Structural Battery







Summary

- Revolusi kendaraan Listrik adalah kesempatan sekaligus tantangan bagi peneliti dan industri nasional untuk menguasai pasar otomotif domestik.
- Penelitian baterai pada *vehicle level* saat ini berfokus pada penurunan ongkos produksi dan peningkatan keselamatan.
- Penguasaan teknologi integrasi baterai pada kendaraan Listrik dengan penerapan teknologi proteksinya menjadi tantangan yang harus diselesaikan.
- *Solid state battery* adalah baterai generasi baru yang berpotensi memenangkan persaingan kendaraan Listrik secara mutlak sehingga perlu dikuasai oleh kita.

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