― Toward Carbon Neutrality ―

Toyota's Battery Development and Supply

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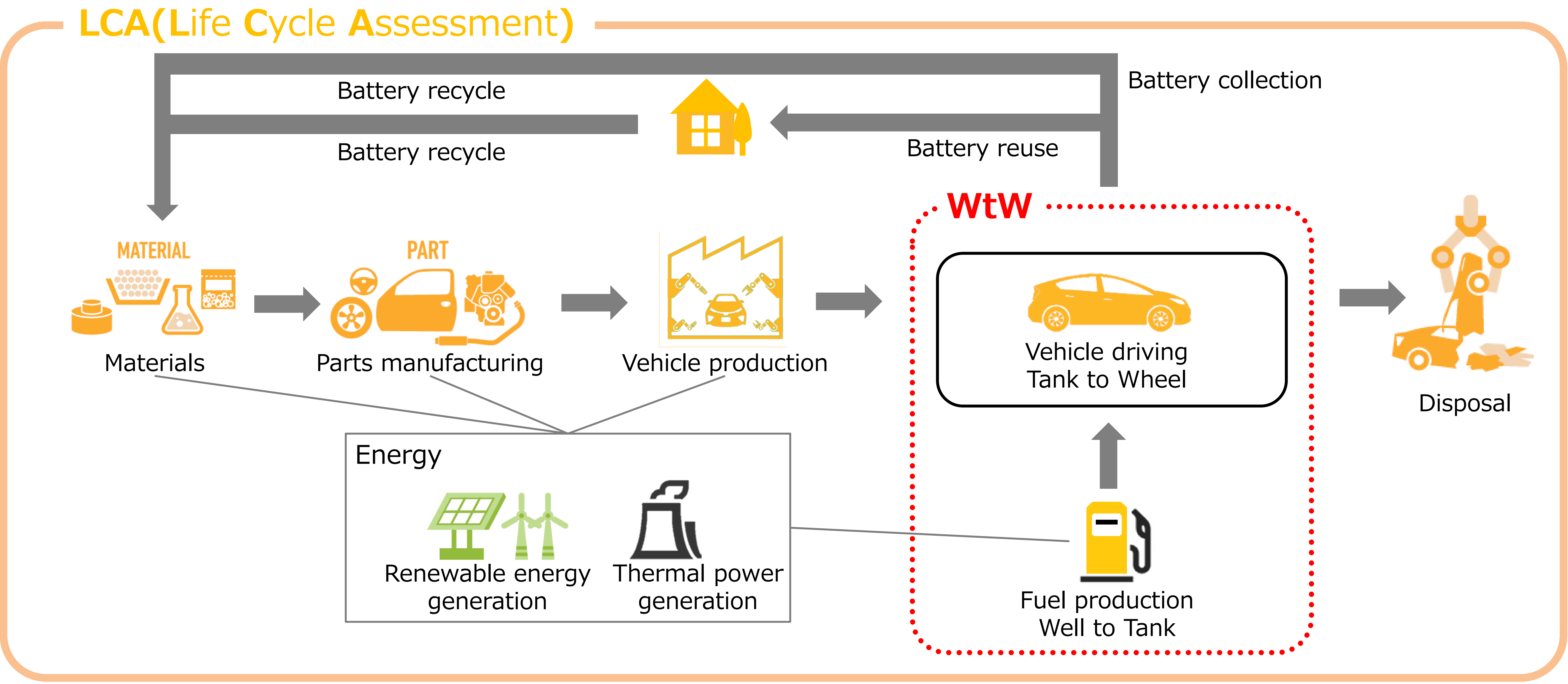
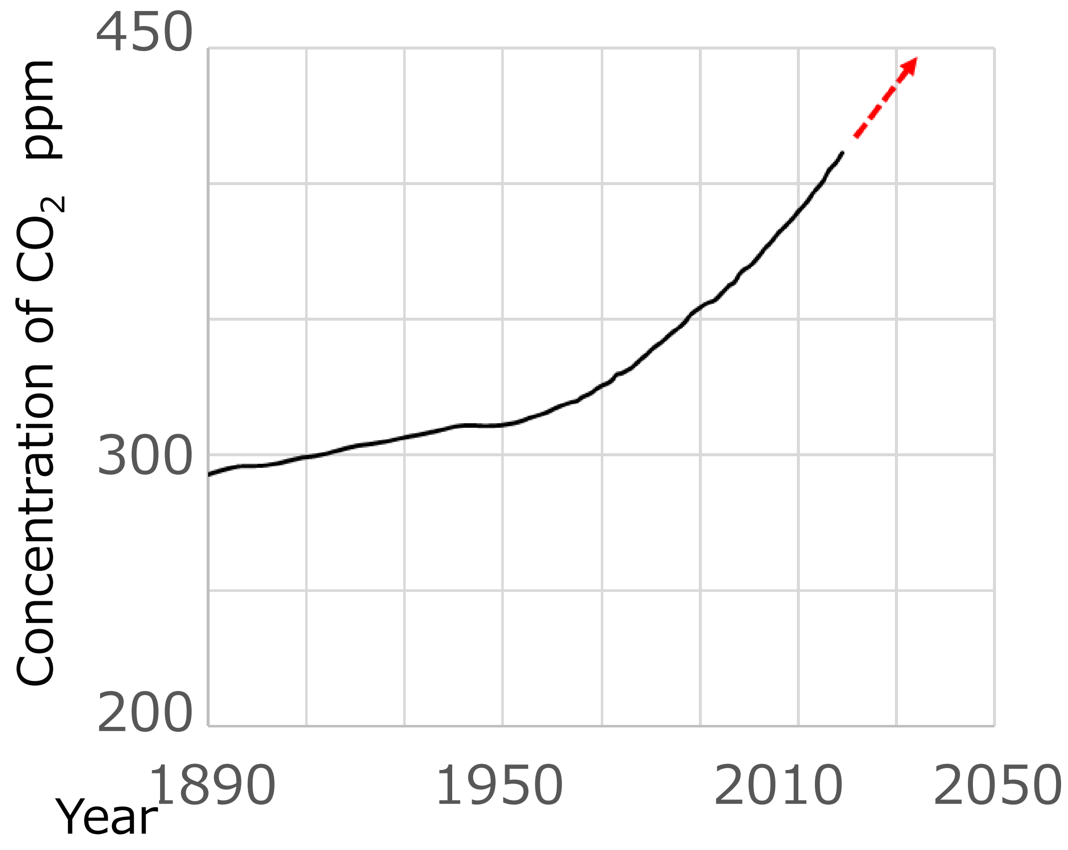
The meaning of carbon neutrality



Carbon neutrality means zero life cycle CO_2 emissions

Toward carbon neutrality

Change in world's concentration of CO_2*



To immediately reduce CO_2 emissions:

- **Areas in which renewable energy will be widely used going forward**

Rapid electrification

1 BEV has the reduction effect of 3 HEVs

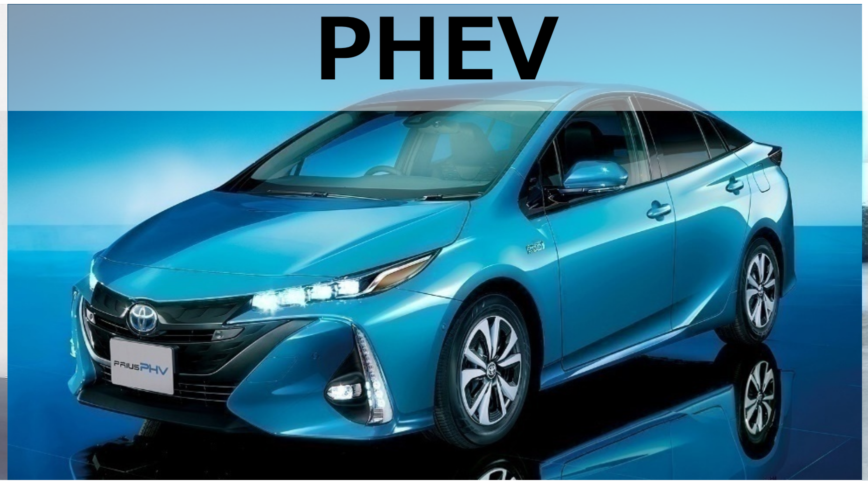
- **Areas in which renewable energy is already widely used**

Acceleration of the widespread use of ZEVs

＊TMC summarized based on the data from Japan Meteorological Agency and World Meteorological Organization, etc.

Expanding options for achieving carbon neutrality

Electrified vehicle lineup toward carbon neutrality



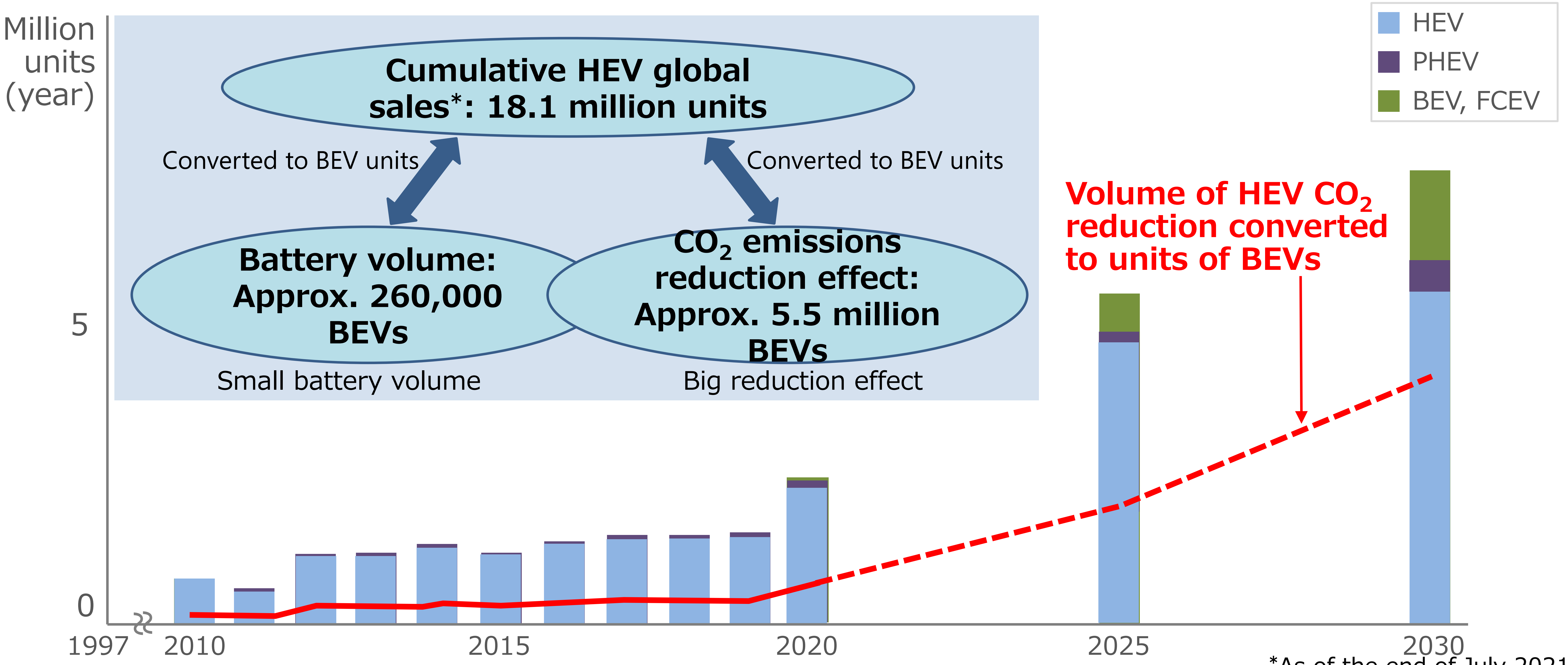
Electrified vehicle sales volume forecast for 2030

Electrified vehicles **8** million units

including BEVs＋FCEVs **2** million units

Providing our customers around the world with sustainable and practical products

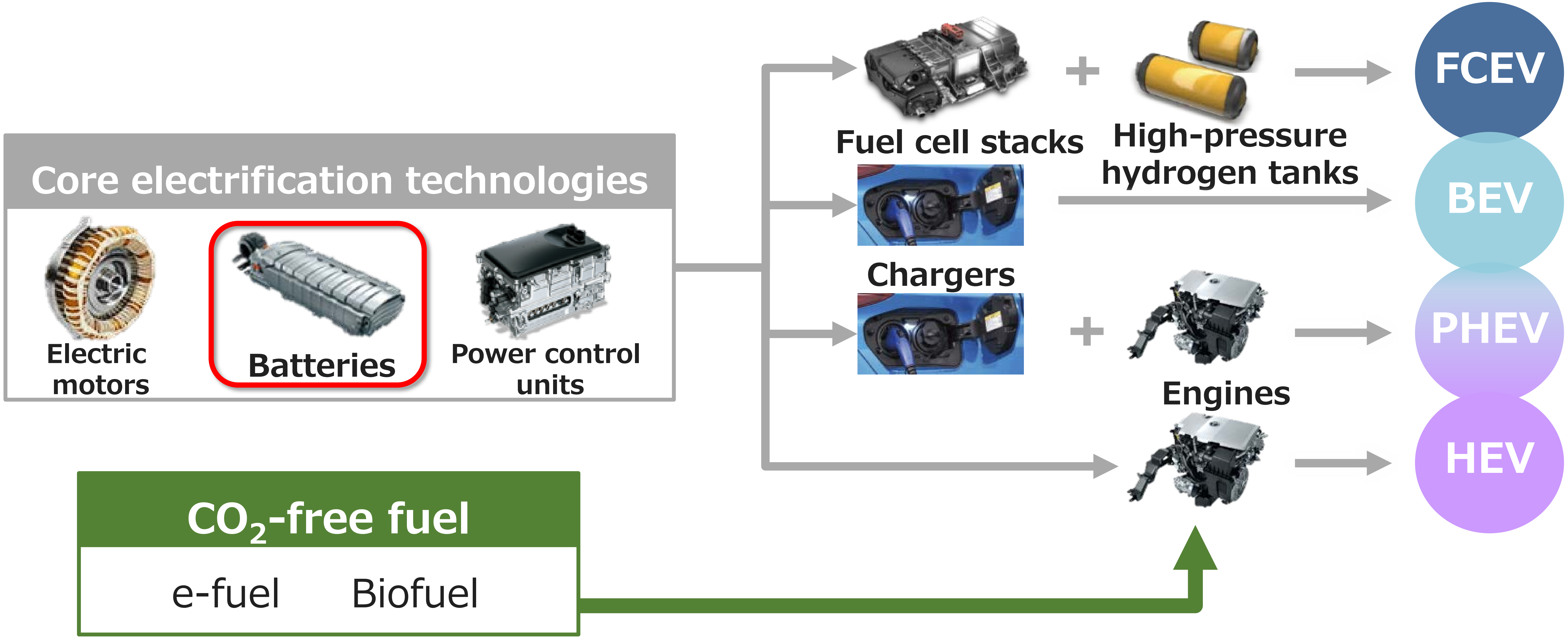
Path toward carbon neutrality: Electrified vehicle global sales



*As of the end of July 2021

- **Dissemination of HEVs has efficiently reduced CO_2 emissions with a small volume of batteries.**
- **Advancing BEV & PHEV technologies for further dissemination**

Technologies supporting full lineup of electrified vehicles



Full lineup of batteries

1997 | 2011 | 2021 | 2025 | 2030

HEVs

Focused on instantaneous power

Toyota Group and partners

1st-gen. Prius

Evolution of nickel-metal hydride batteries

Prius α

Yaris

Evolution of lithium-ion batteries

Toyota Group

Aqua

Expanded use of bipolar nickel-metal hydride batteries featuring new structure

Increased instantaneous power

PHEVs・BEVs

Focused on endurance

Toyota Group and partners

1st.-gen. Prius PHV

C-HR/IZOA

bZ4X

Evolution of lithium-ion batteries

Practical BEV development based on BEV-dedicated platform

Toyota Group

New lithium-ion batteries

- Evolution of current lithium-ion batteries
- Innovation in battery structure
- Solid-state batteries

Increased endurance

Affordable, high-quality products

Battery development concept

Common to all batteries for HEVs, PHEVs, BEVs, and FCEVs

Security

Safety

Long service life

High level of quality

Aiming to create safe batteries that can be used with peace of mind always and for their entire lifetime, have high resale value, and contribute to the building of a resource-recycling society

Affordable, high-quality products

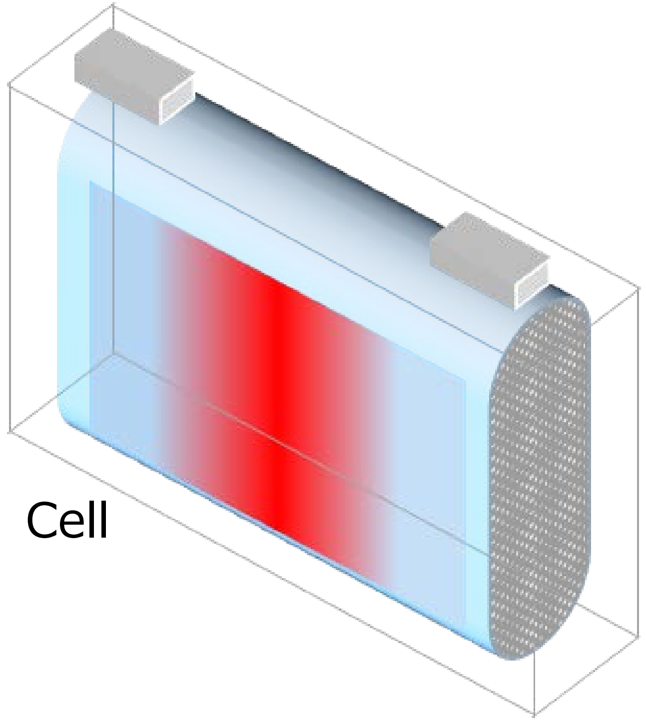
High-level performance

Giving electrified vehicles meaning through dissemination
Increasing customer choice

Highly balancing 5 elements to provide reliable batteries

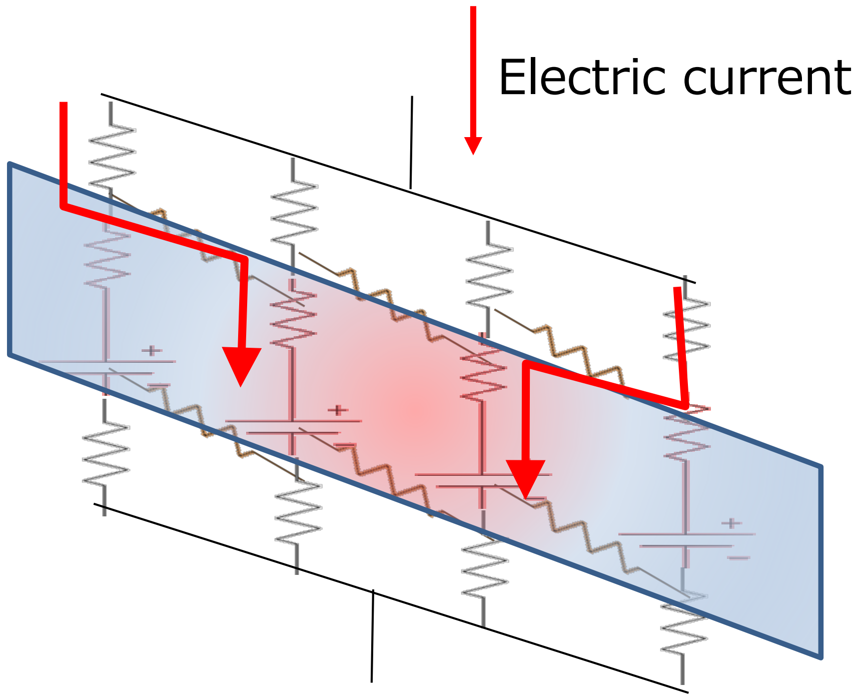
Safety: Battery control systems

Verification of effect of high loads on battery internals



Simulated experiments to measure polarization of electrolyte components (which generates heat) during charging and discharging

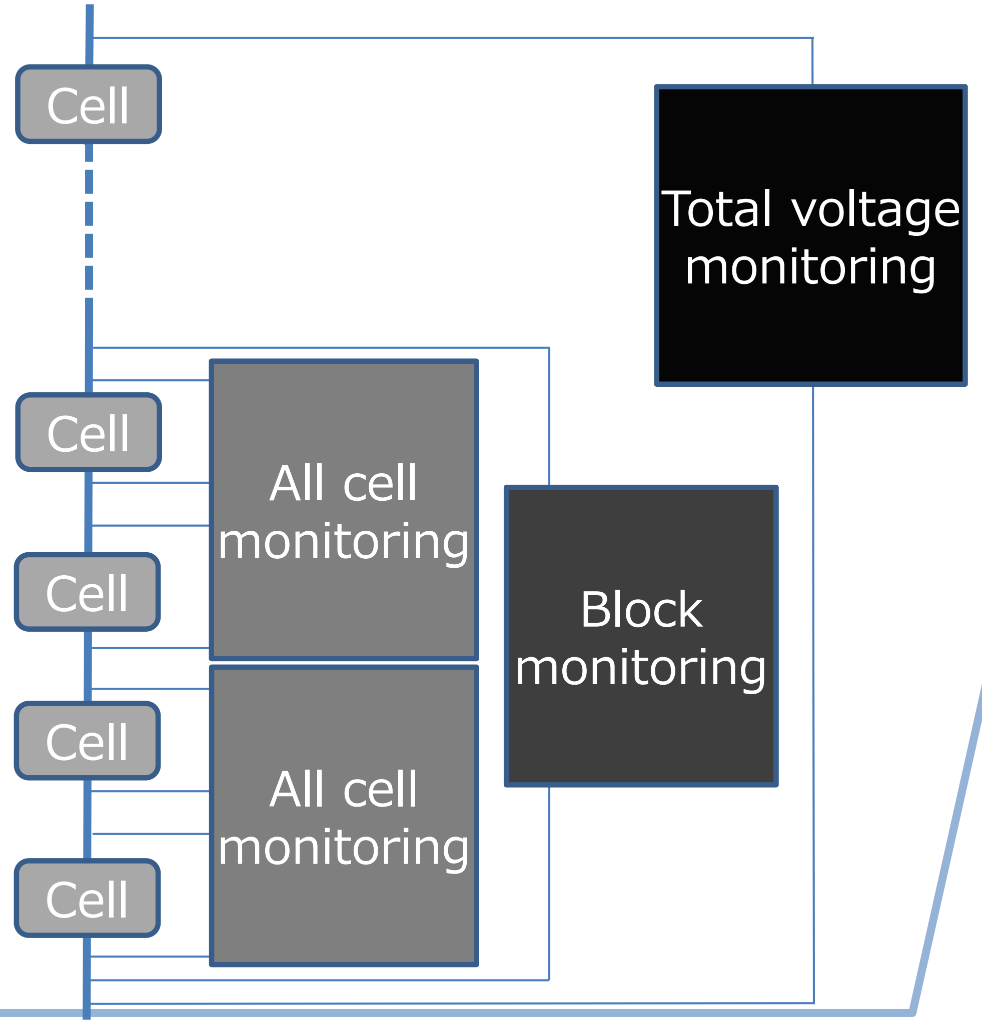
Construction of principle-based theoretical model



Confirmation of certainty and reliability based on vast amounts of experimental data

Control by multiple monitoring of voltage, current, and temperature

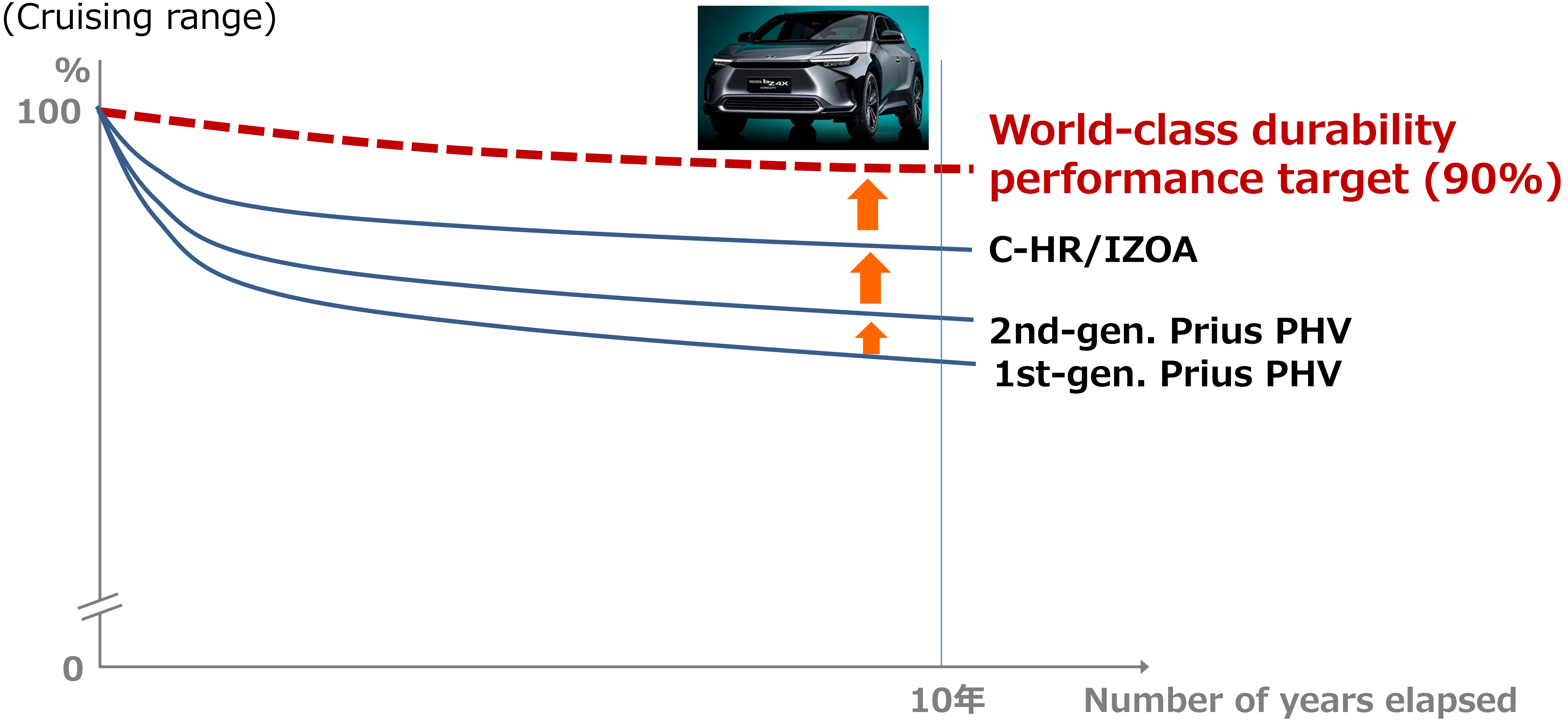
Example: Voltage monitoring of C-HR/IZOA BEVs



Multiple monitoring of voltage, current, and temperature to detect signs of and prevent abnormal heat

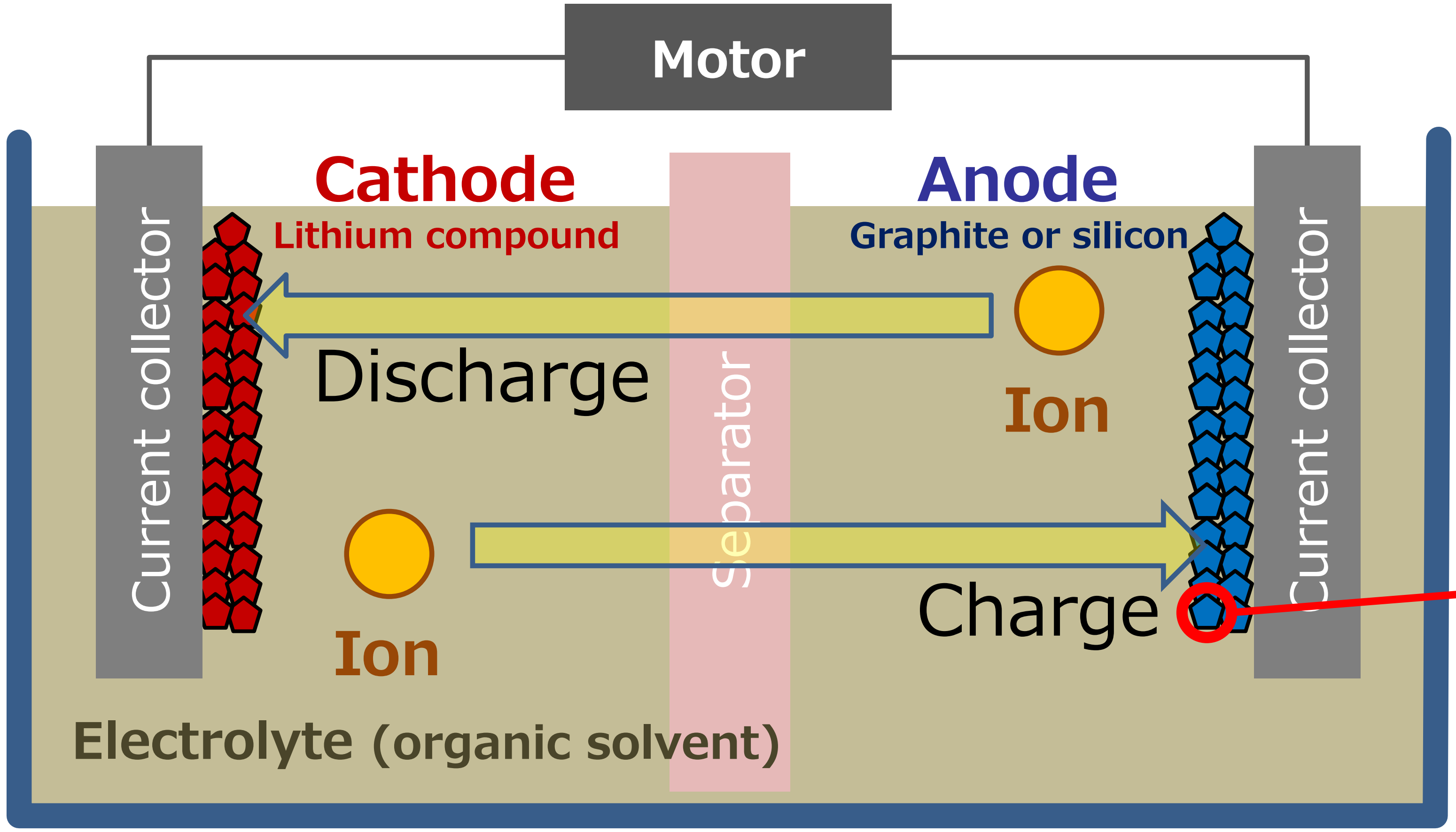
Long service life

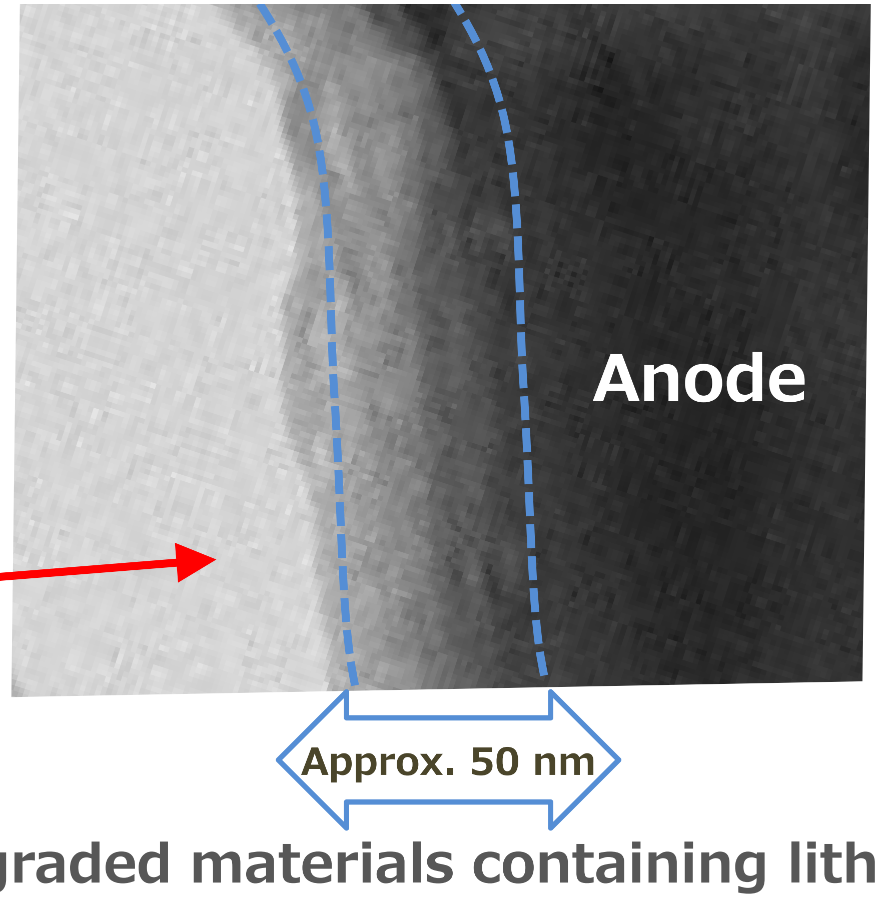
Battery capacity maintenance rate
(Cruising range)



Aiming for world-class endurance with the TOYOTA bZ4X

Long service life: Applying HEV-honed technologies to BEVs





Inhibiting formation of degraded materials on anode surfaces

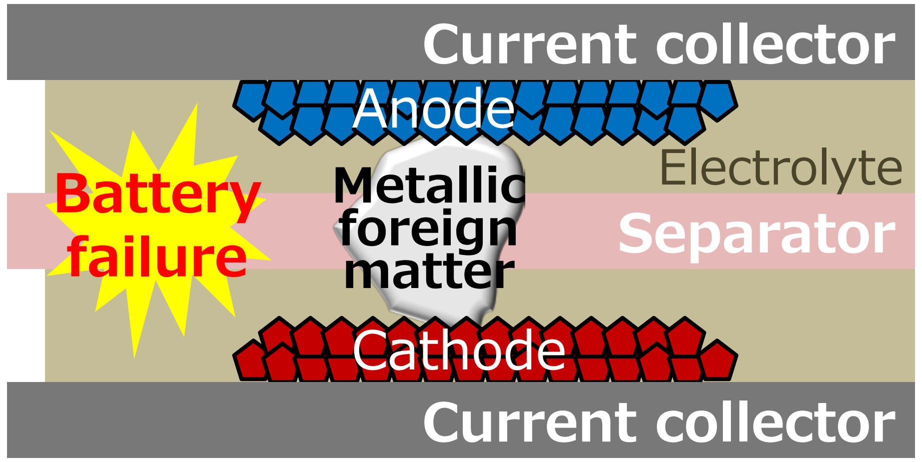
- Appropriate anode surface treatment to prevent degradation
- Design and production technology that prevents moisture contained in battery materials from being introduced into the battery
- Adoption of structure that ensures uniform cooling of battery
- Construction of control system that prevents load from being applied to the entire battery

One key to extending battery life

Suppress degradation in battery materials, pack structure, control systems, etc.

High-level quality: Control of metallic foreign matter

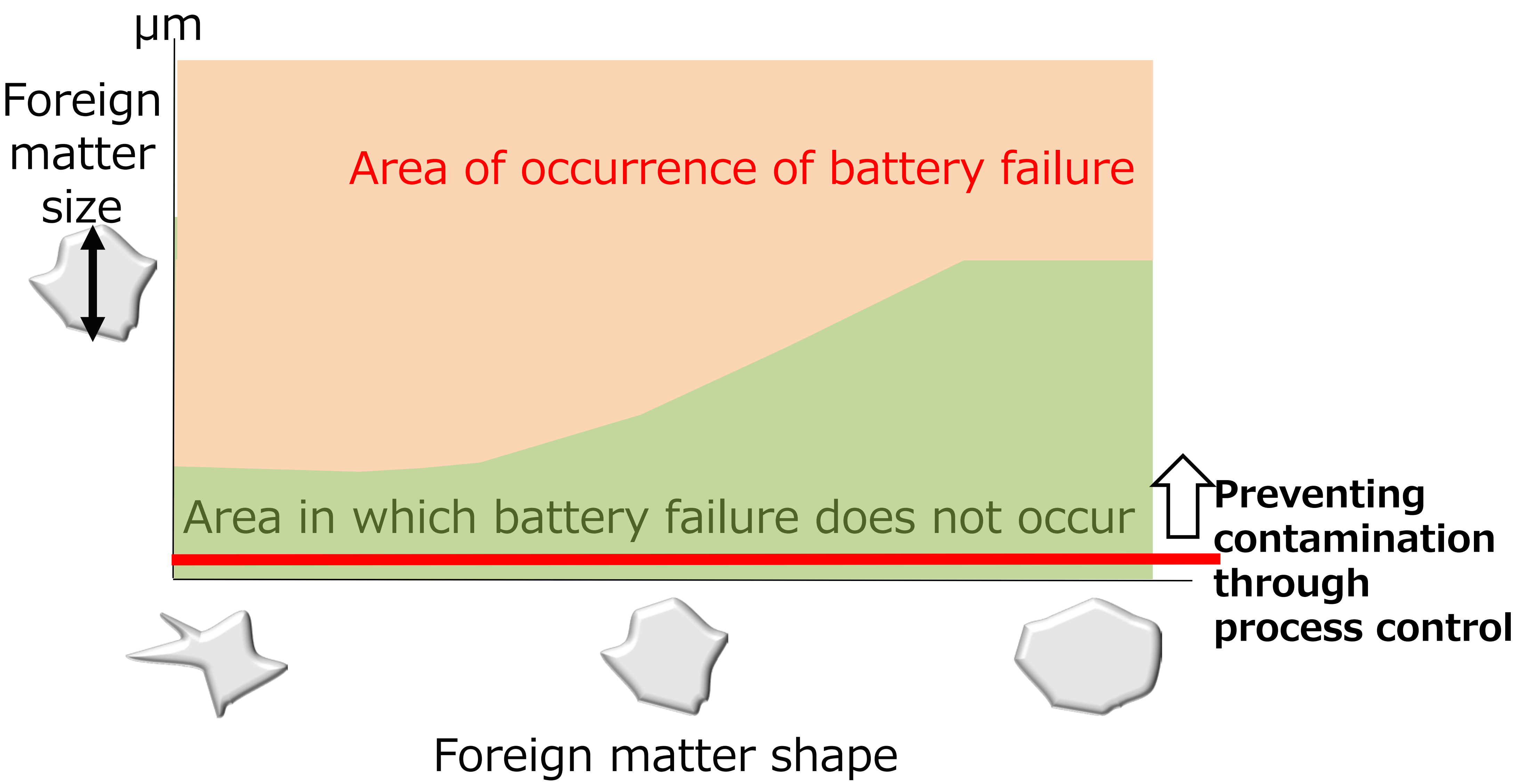
Effect on batteries of metallic foreign matter



Battery failure due to contact between the anode and cathode

The need to control foreign matter

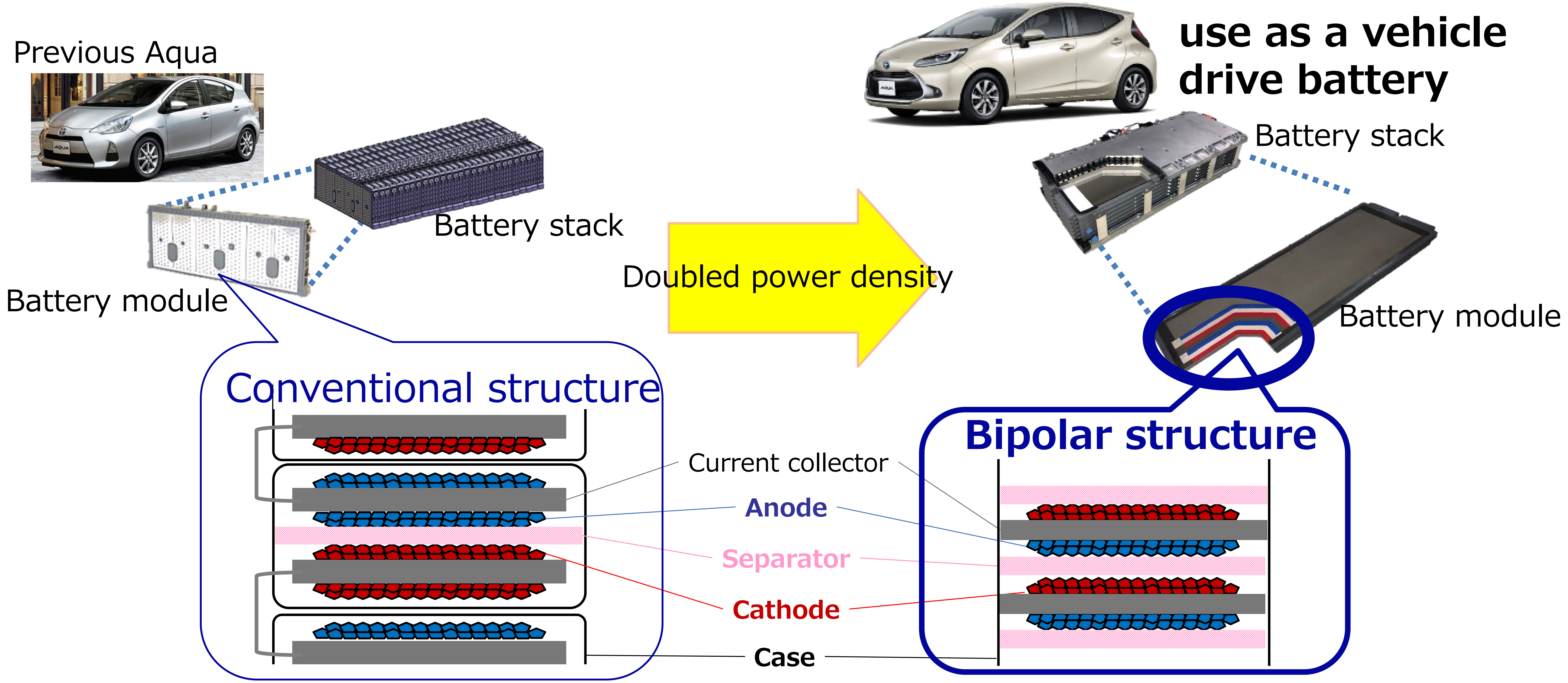
Effect of size and shape of metallic foreign matter on occurrence of abnormalities



Determining the size and shape of foreign matter that can cause battery abnormalities and controlling the effect of foreign matter

Bipolar nickel-metal hydride battery

In the new Aqua - world’s first use as a vehicle drive battery



Taking up the challenge of innovating battery structure for more powerful acceleration

Next-generation BEVs

RAV4 L EV

RAV4 EV

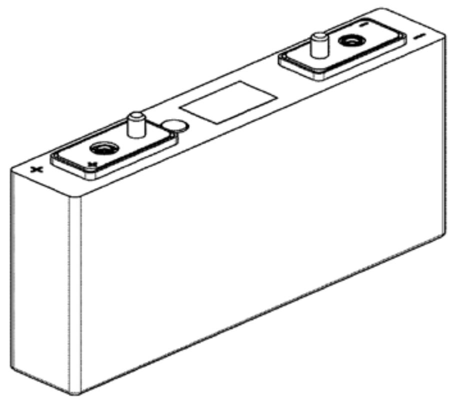
C-HR / IZOA

TOYOTA bZ series
First model: Toyota bZ4X

A unique Toyota BEV that utilizes technology cultivated through years of HEV development

Battery cost targets: Integrated vehicle-battery development

Battery development



Greater than 30% reduction in cost of single battery

- Development of low-cost materials: cobalt-free, nickel-free, and new electrode materials
- Manufacturing process innovation: New development of battery manufacturing processes and battery material processes
- New structure: Integrated structure of battery cells and packs to match the vehicle
- Evolution of battery control model: Fuller use of battery capacity with focus on safety, security, and long service life

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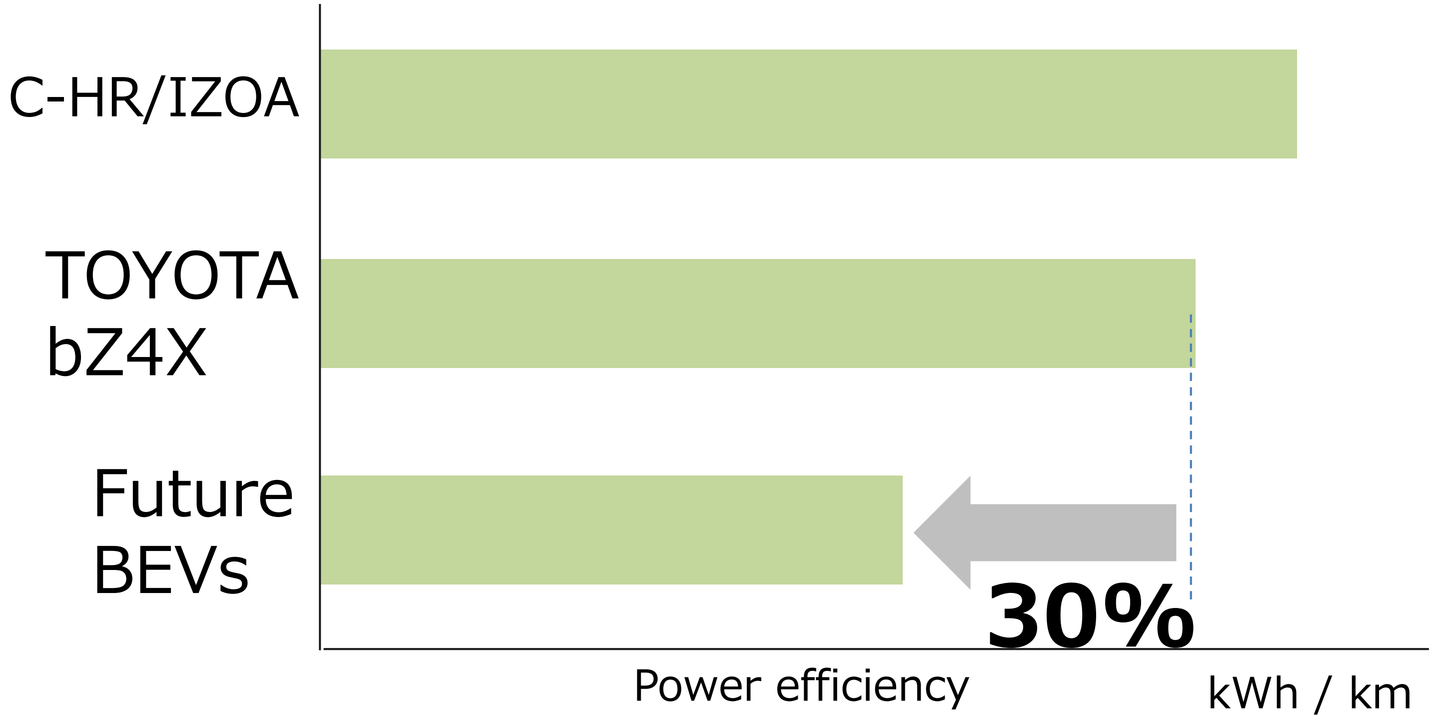
Vehicle development



30% improvement in power efficiency = 30% reduction in battery capacity

(30% cost reduction)

Achieve the following by utilizing and developing technologies cultivated through 18.1 million electrified vehicles:

Reduction of vehicle driving resistance to suit electrified vehicles
Further expansion of energy regeneration
Optimal energy/thermal management of entire vehicle and components
Optimal efficiency design and control of entire powertrain system

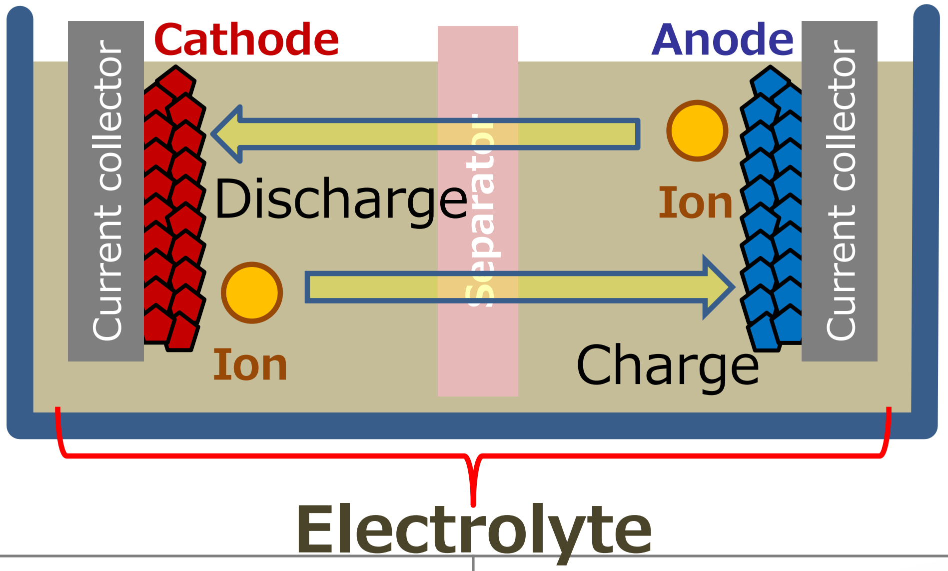
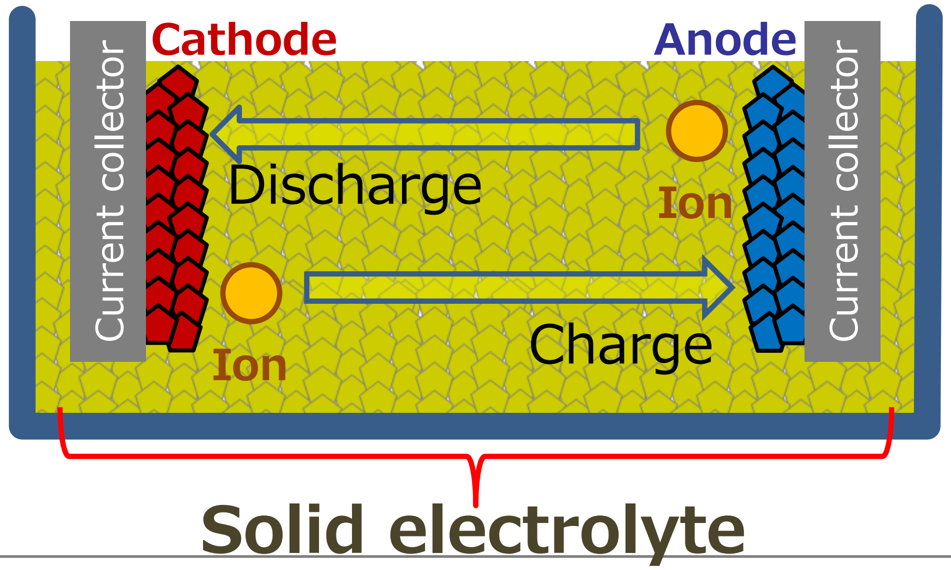
Reducing cost by 30% by improving power efficiency and reducing cost of battery development by 30% ⇒ 50% reduction in battery costs (per vehicle)

-In the second half of 2020s

Next-generation lithium-ion battery

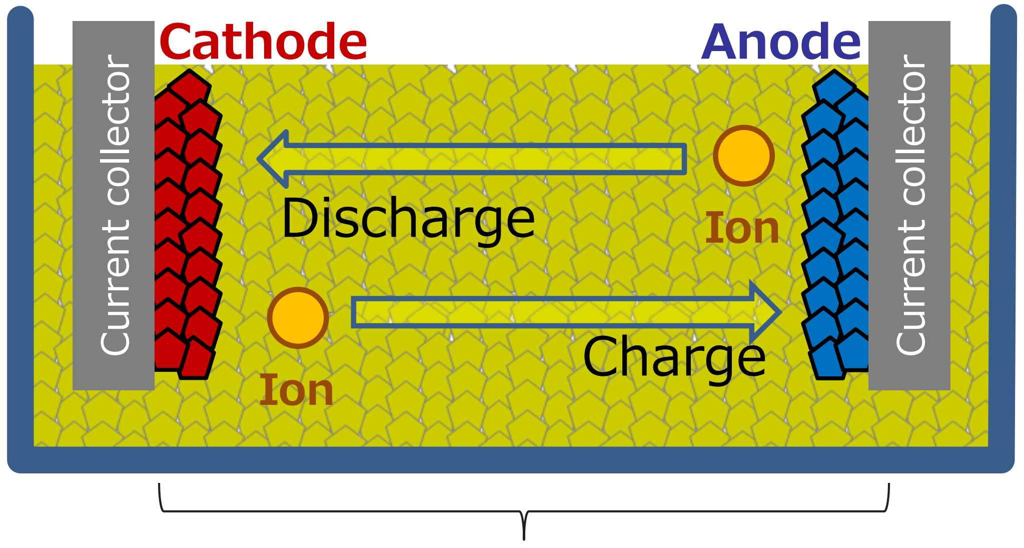
【Aims】

Longer service life	Greater energy density	More compact size	Lower cost

	Evolution in liquid-based battery materials	Innovation in liquid battery structure	All-solid-state batteries
Composition			
Structure	 Prismatic	**New structure**	 Laminated

Taking on the challenge of developing a wide range of batteries for the second half of the 2020s
Providing BEVs equipped with batteries with improved characteristics that enable driving with peace of mind

Characteristics of all-solid-state batteries



Solid electrolyte

Simple ion movement (fast)

High voltage tolerance

High temperature tolerance

High output

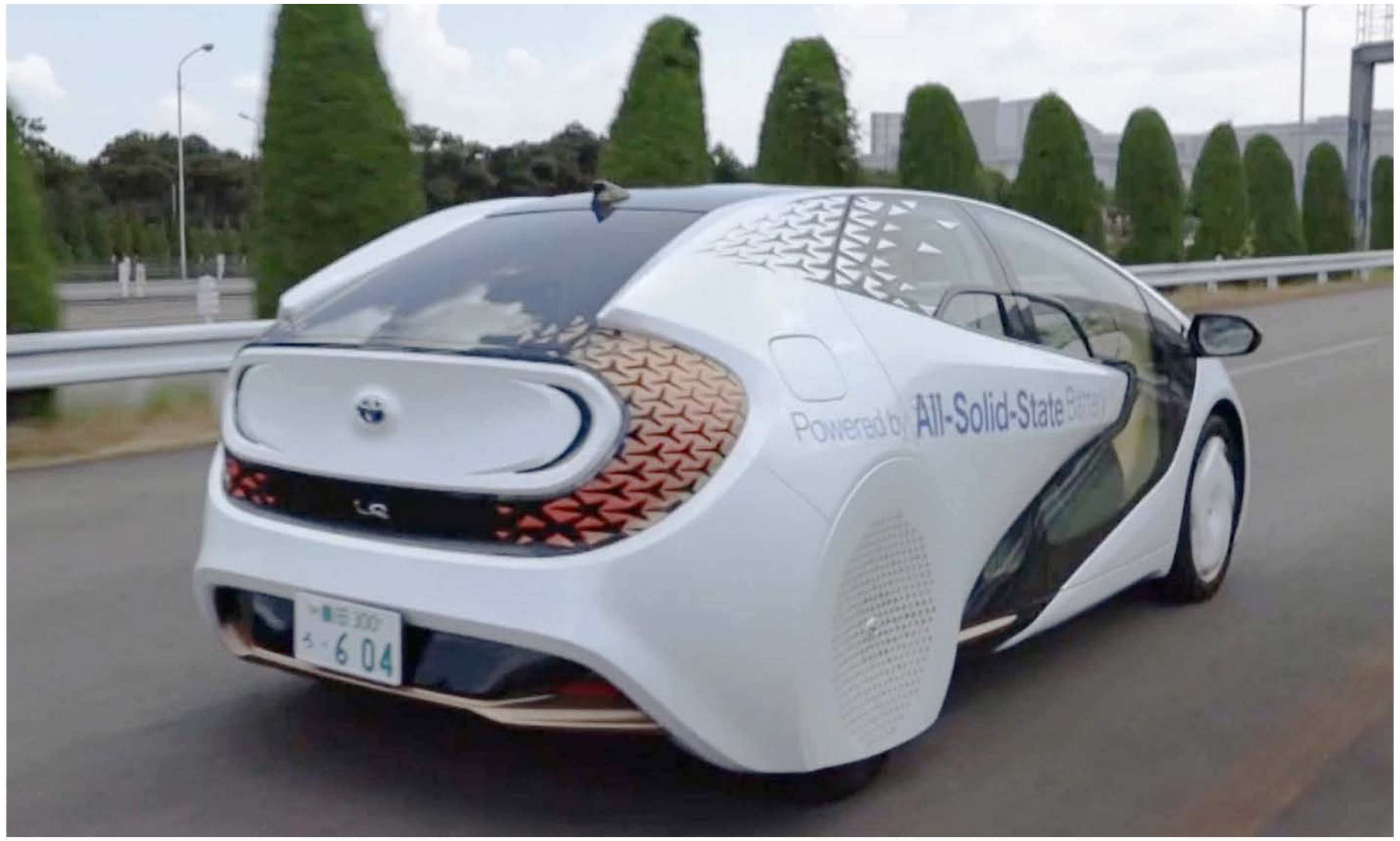
Long cruising range

Shorter charging time

Progress in development of all-solid-state batteries

June 2020

August 2020



Obtained license plate registration in August 2020 and conducted test drives

- ➢ **All-solid-state battery prototype vehicle built and driving data obtained**
- ➢ **Now identifying the merits and challenges of use in vehicles**

Future Development and Challenges of All-Solid-State Batteries

【Merits of all-solid-state batteries】

Simple ion movement (fast)

High voltage tolerance

High temperature tolerance

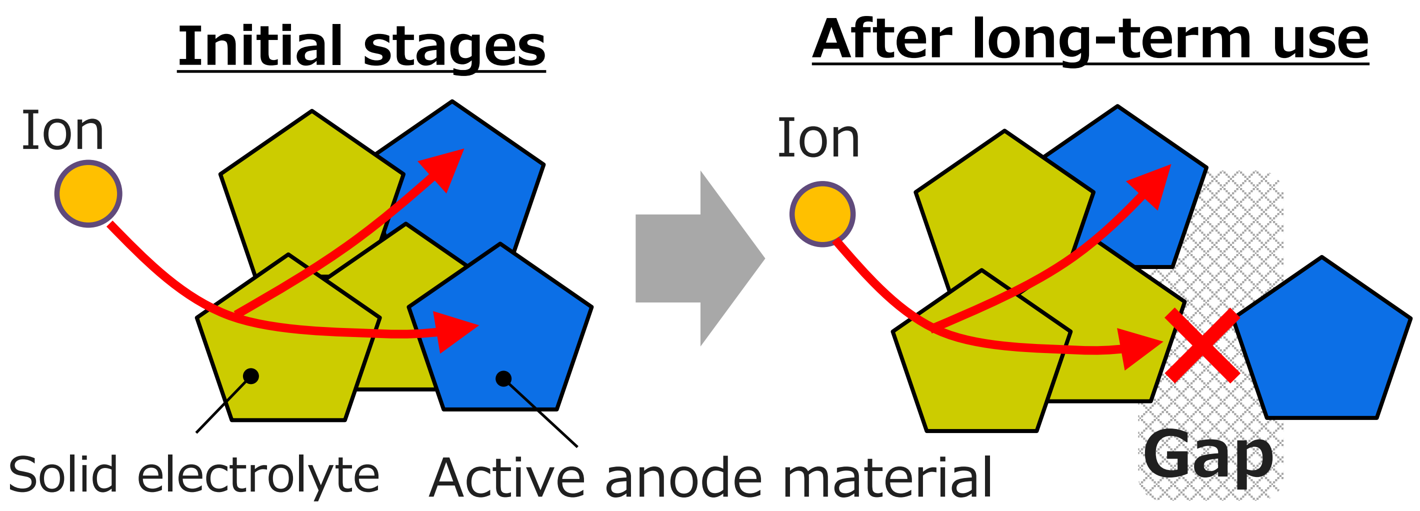
Early realization of use in HEVs

Utilizing ion speed for high-output batteries

Development of process for bonding solid materials

R&D for future use in BEVs

Key issue: Securing the service life of high-capacity batteries



Now developing materials to reduce the occurrence of gaps

- **First considering vehicles that utilize all-solid-state battery characteristics**
- **Overcoming challenges and envisioning rollout from HEVs to BEVs**

Battery procurement and collaboration structure

CATL

弗迪电池
FinDreams Battery

BYD subsidiary.
Transferred relevant project in 2021.

prime planet
energy & solutions

TOYOTA

TOYOTA

EV ENERGY
プライムアースEVエナジー(株)

GS YUASA

Panasonic

TOSHIBA

Future direction based on local conditions

- Strengthen collaboration with partners and consider new cooperative structures
- Rapid start-up of production within the Toyota Group

Toyota’s battery strategy by 2030

Development

Cost reduction through integrated development of vehicles and batteries to provide reasonably priced vehicles

Target costs for future batteries

Aim for **50% reduction**
(per vehicle)

Investment in batteries:
1.5 trillion yen

Supply

Build a flexible supply network and production system based on small basic units

Aiming to flexibly respond to increasing battery demand

More than
180GWh ➡ **200GWh**

Spread of electrified vehicles, including BEVs

Sustainable & Practical

TOYOTA

SUSTAINABLE
DEVELOPMENT
GOALS