
Toyota's Hybrid Technology



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1. Birth of the world's first mass produced hybrid: the Prius

The Challenge of car-making for the 21st century: Prius development³

Toyota started development of Prius in 1993, autumn

The theme that was given to the project team at that time:

- **Create the 21st century car**
- **Change the vehicle development method**

Project name: “G21”

The Challenge of car-making for the 21st century: Prius development

The mission of Prius was to create an entirely new concept vehicle to meet 21st century needs = outstanding fuel economy

Maintain or enhance good usability or comfort of conventional vehicles, but also simultaneously respond to the Challenges of motorized society in the 21st century



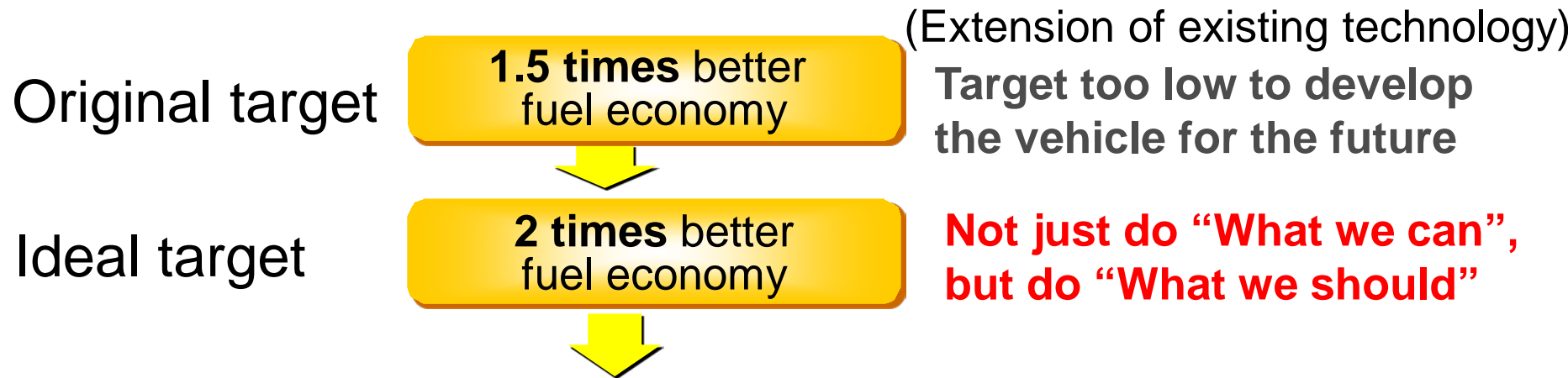
Overcome energy resources / environmental issues



Realize outstanding fuel economy

The Challenge of car-making for the 21st century: Prius development

Prius achieved far better fuel economy than original target



Mass production of the hybrid vehicle

Prius	28.0km/L
Conventional vehicle 1.5L (Gasoline)	14.0km/L

(Japanese 10-15 test mode)

The Challenge of car-making for the 21st century: Prius development

Dec. 1997 Sales of Prius had Begun

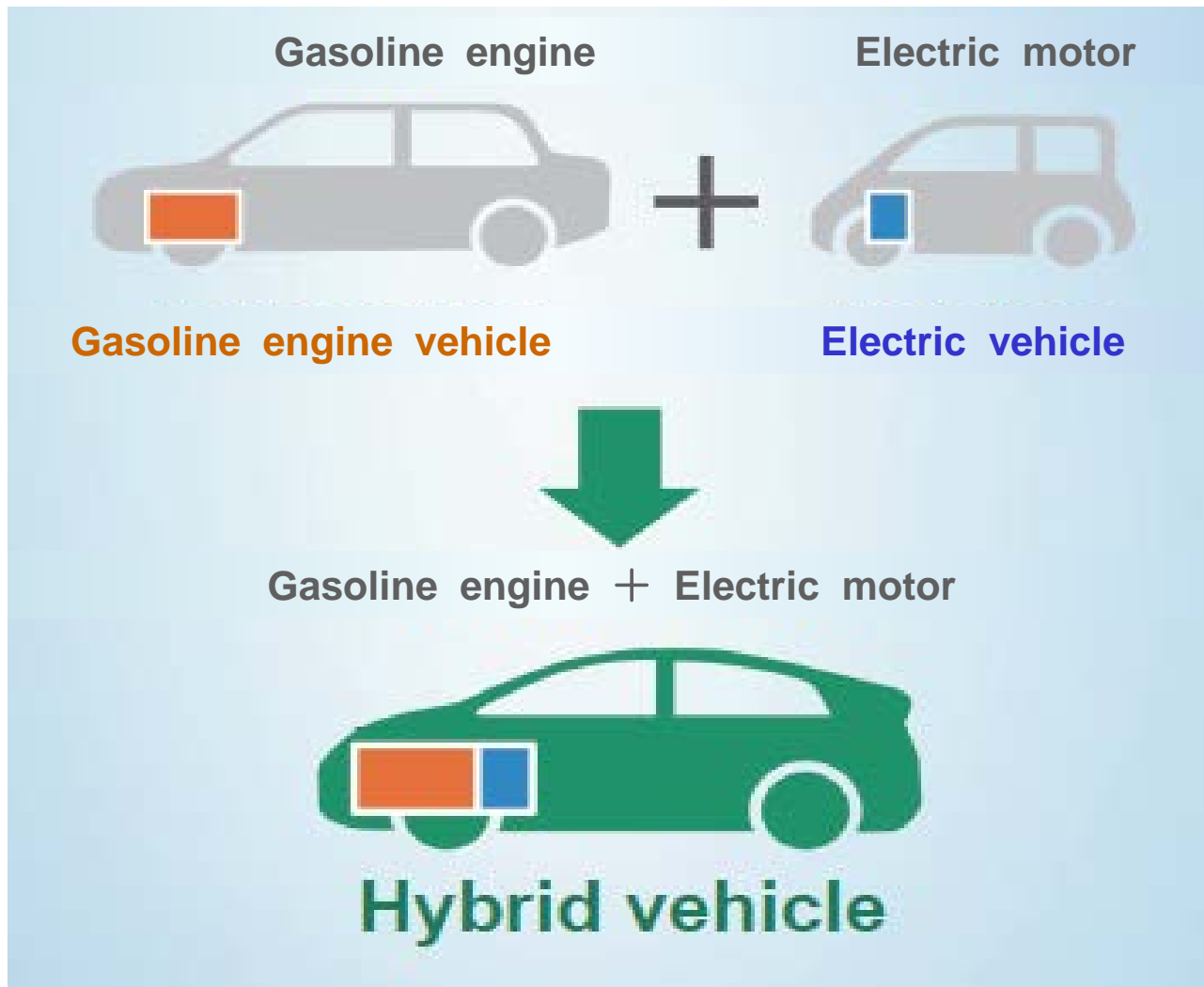


World's first mass produced hybrid vehicle

2. What are Hybrids?

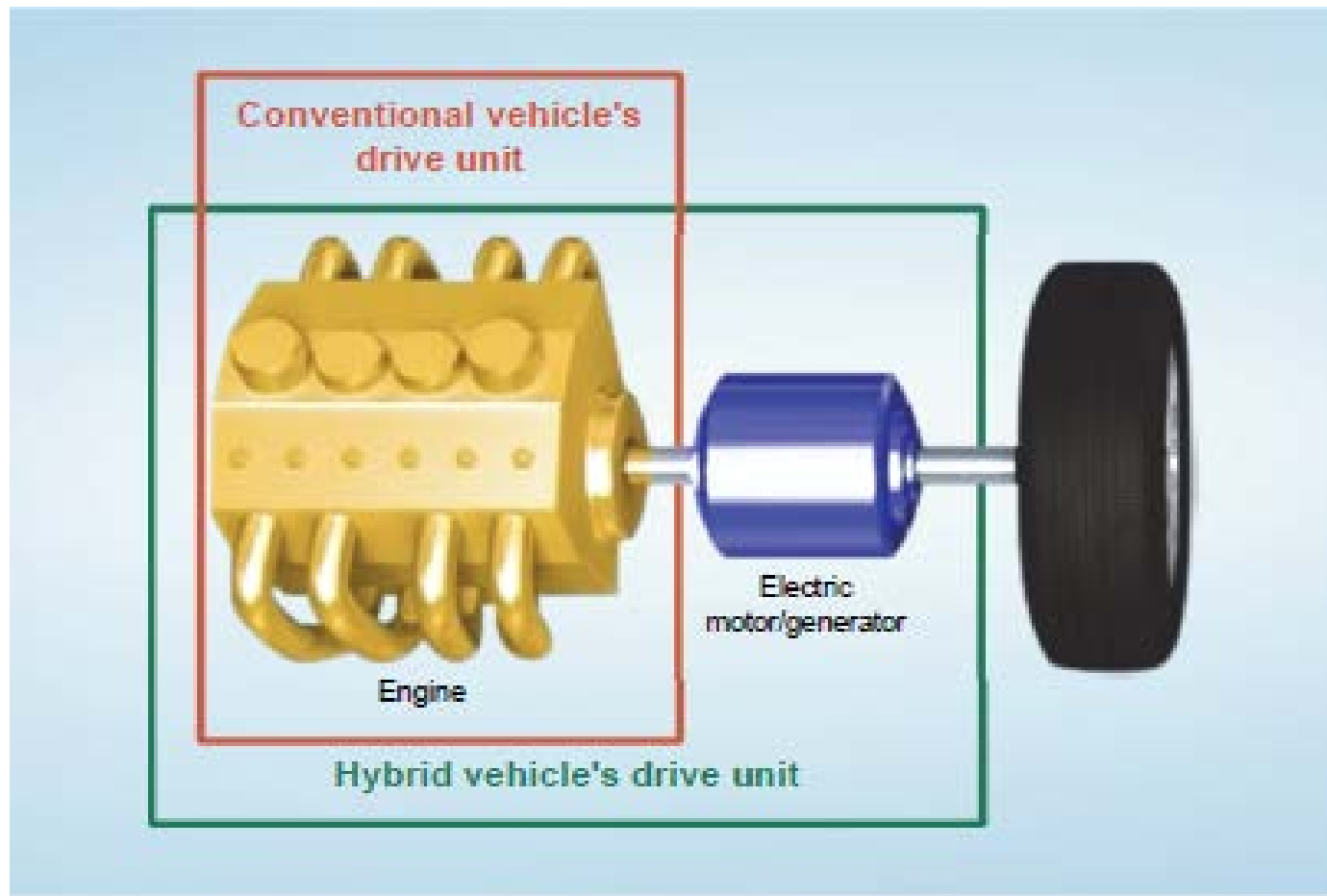
Feature of Toyota's Hybrid Vehicles

Hybrid vehicles have two power sources; Gasoline engine and electric motor which bring about greater efficiency



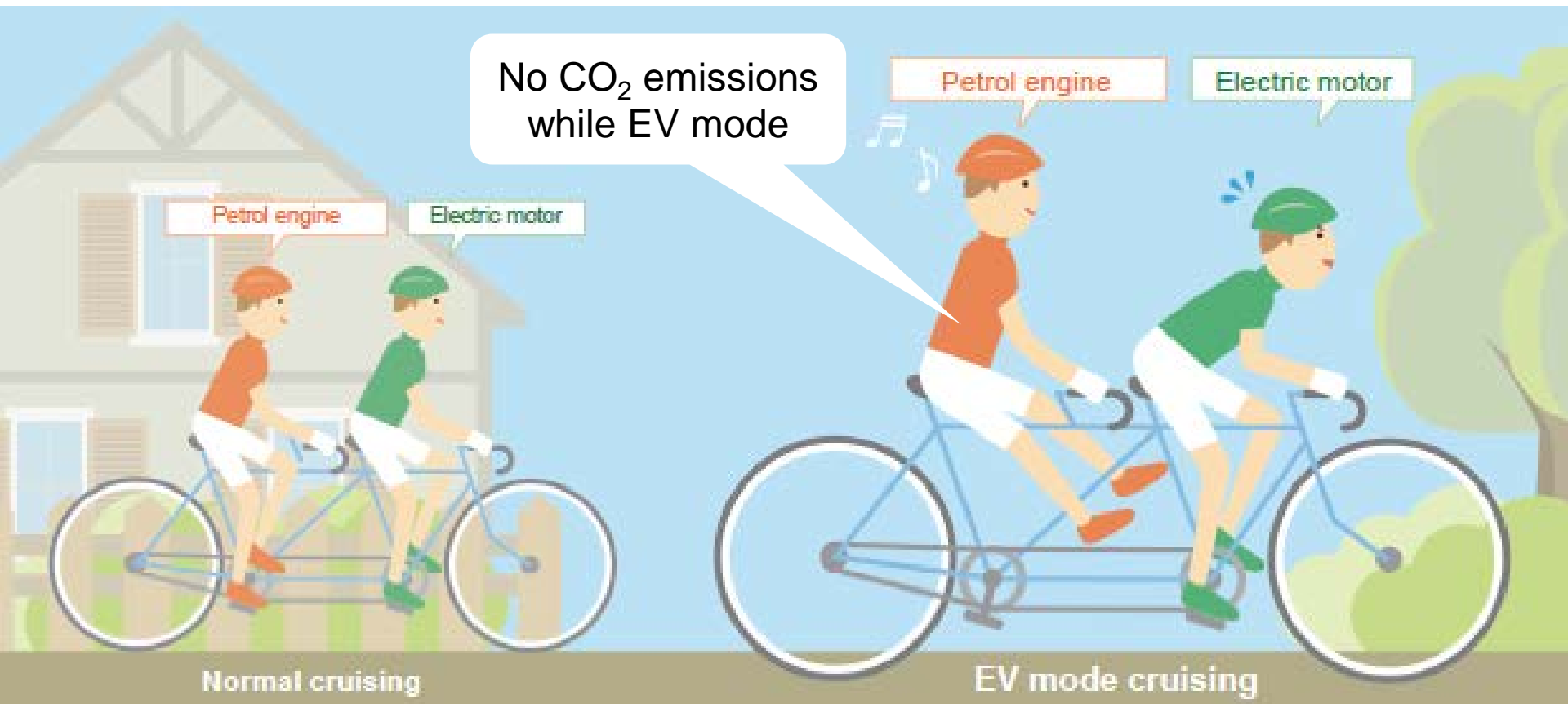
Feature of Toyota's Hybrid Vehicles

By combining the benefits of gasoline engines and electric motors, hybrid vehicles offer excellent driving performance and eco-friendliness



Feature of Toyota's Hybrid Vehicles

When Hybrid vehicles are in EV mode, only the electric motor works and therefore, no CO₂ emissions.



Feature of Toyota's Hybrid Vehicles

Also, hybrid vehicles save energy recovered from braking

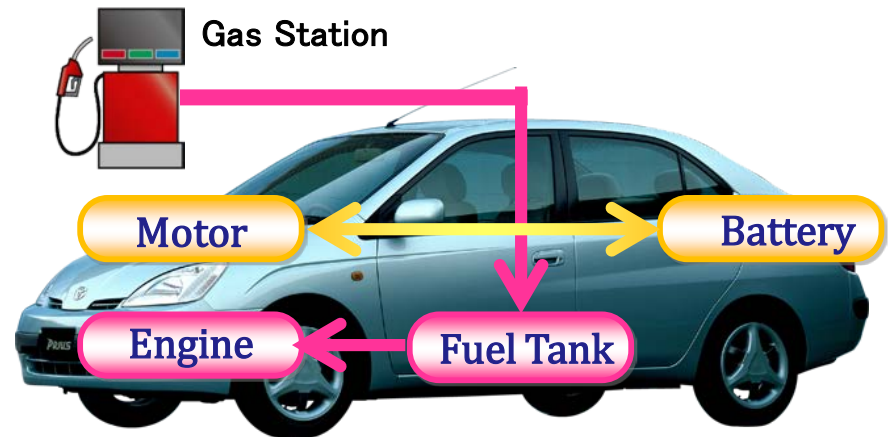


Feature of Toyota's Hybrid Vehicles

HVs use two or more distinctive types of power to enhance fuel efficiency and environmental performance through recovery and re-using of energy

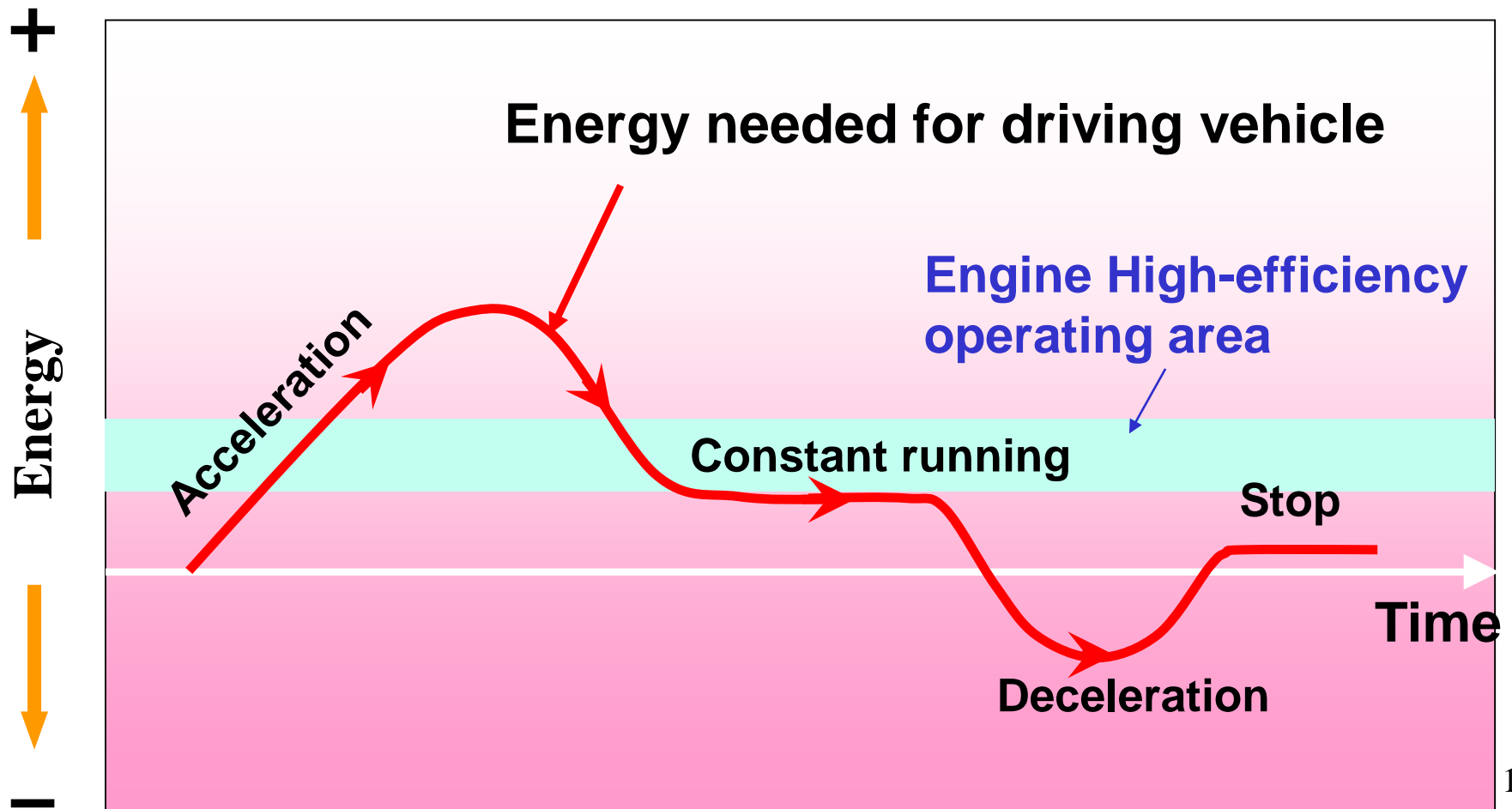
First Prius (1997) :

- (1) The world's first mass produced HV
- (2) Power sources – the internal combustion engine and electric motor
- (3) Battery is the power buffer which allows regenerated power during braking to be re-used
- (4) Achieve high level of fuel efficiency and low-emissions with 2 power sources and battery



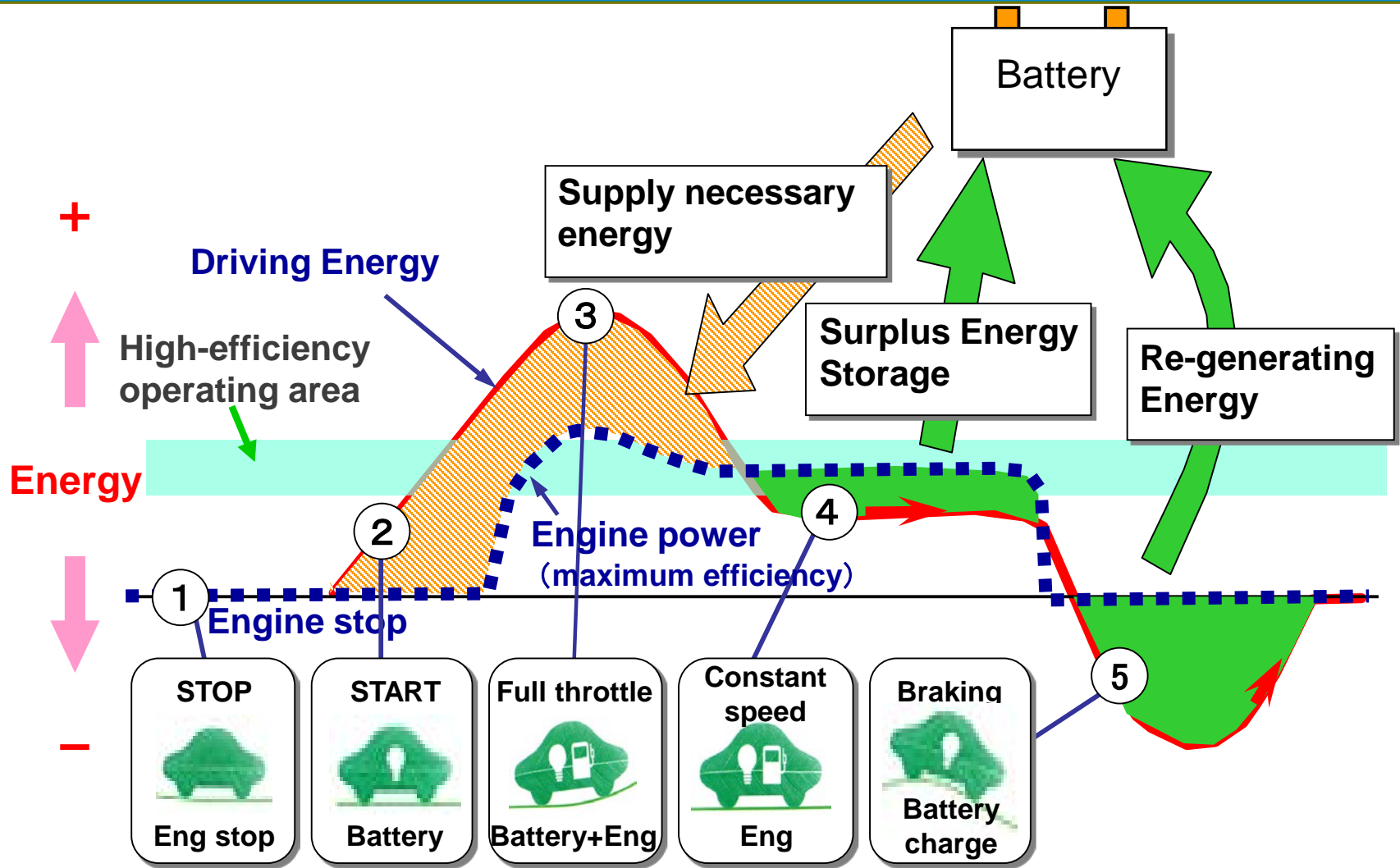
Driving energy in conventional vehicles

Energy needed for driving is often not in the high-efficiency area



Energy management of Toyota's Hybrid System

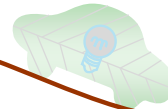
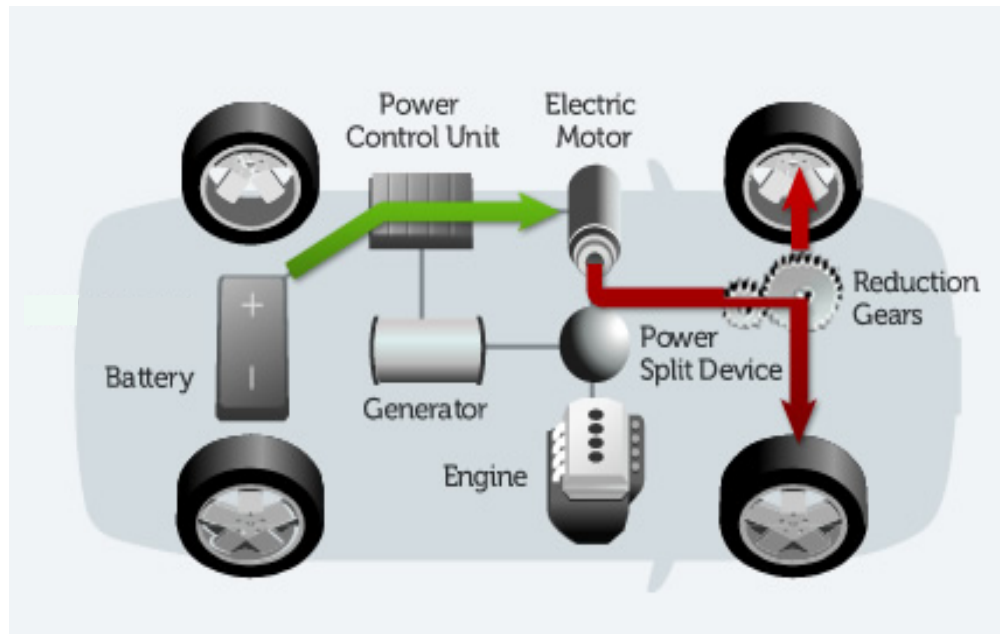
In hybrid vehicles, battery supports engine for the less-efficiency operation area, and also store energy for less energy consuming drive



How Toyota's Hybrid System works

When starting and light-load driving, electric motor drives the wheels by using electricity from the battery

Starting and light-load driving



How Toyota's Hybrid System works

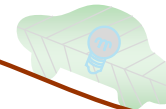
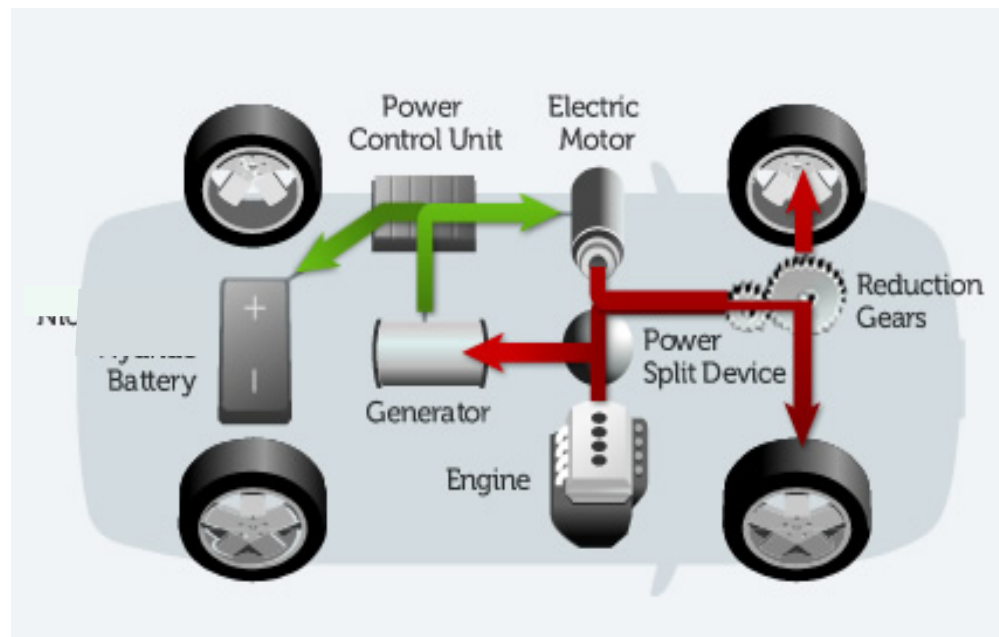
When normal driving, the engine power is split into 2 portions,

1) for driving the wheels,

2) for feeding generator/motor to supplement engine power

Excess electricity during light-load driving is charged to battery

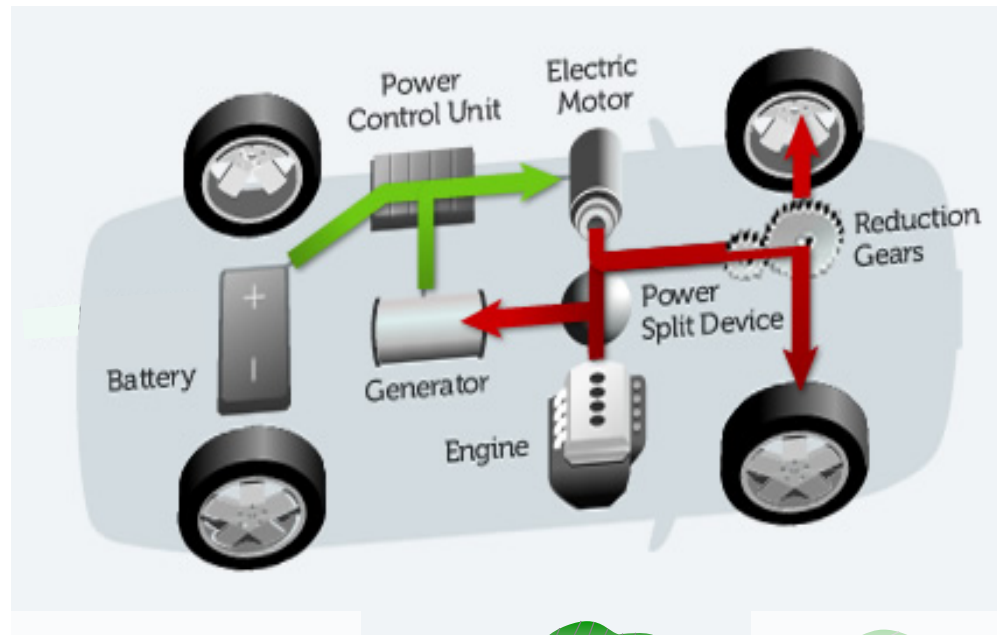
■ Normal driving



How Toyota's Hybrid System works

When in full acceleration mode, battery supplies more power to drive the electric motor.

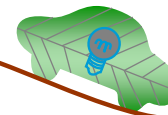
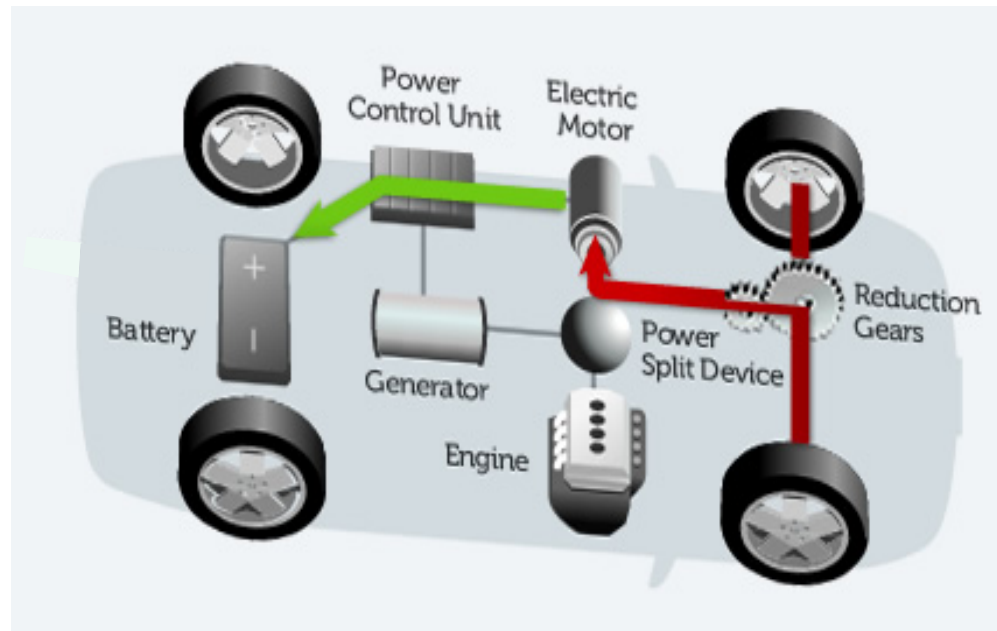
■ Full acceleration



How Toyota's Hybrid System works

When decelerating and braking, regenerative braking recharges the electricity from motor to battery

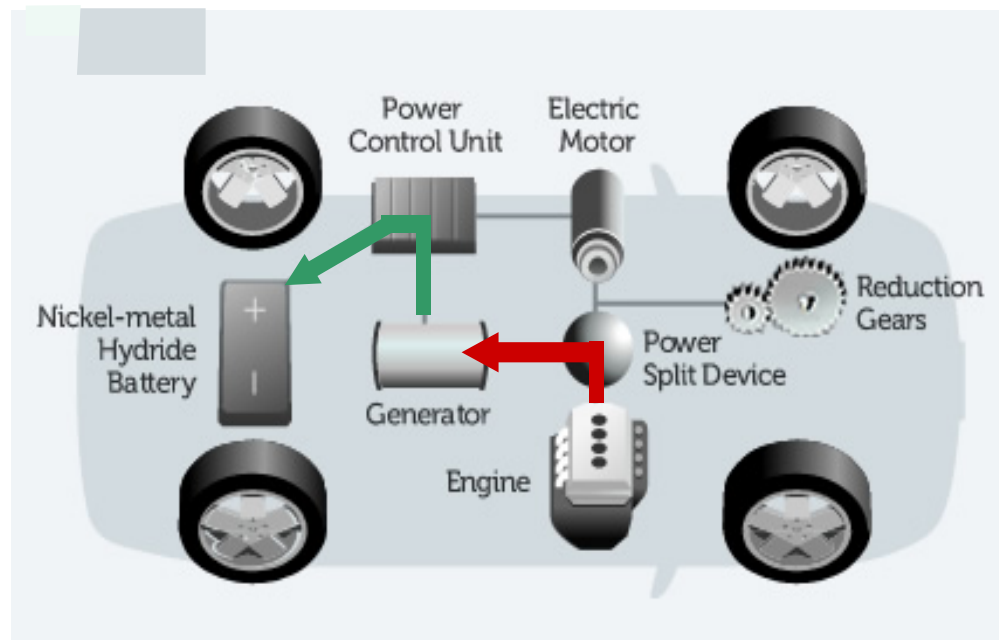
■ Decelerating and braking



How Toyota's Hybrid System works

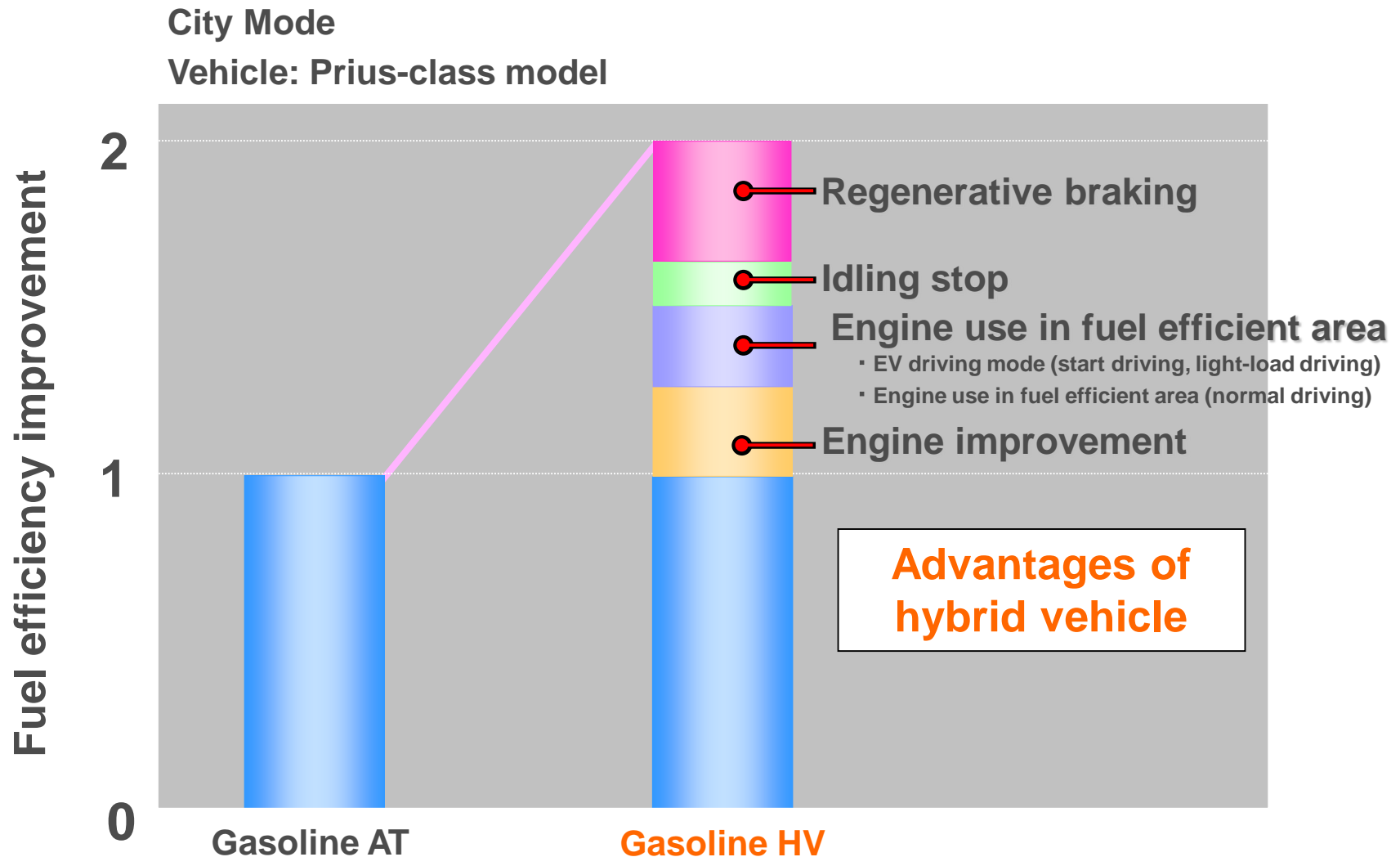
The amount of charged electricity has reduced, the engine drives the generator to recharge the battery

Battery-charging



Why Toyota's Hybrid System is fuel efficient

Toyota's Hybrid technology realizes high fuel efficiency compared to gasoline engine cars



Why Toyota's Hybrid System is fuel efficient

Toyota's hybrid vehicles are “strong hybrid” vehicles that combine the use of a high efficient gasoline engine and a high output electric motor/generator.



Toyota Hybrid System (THS)

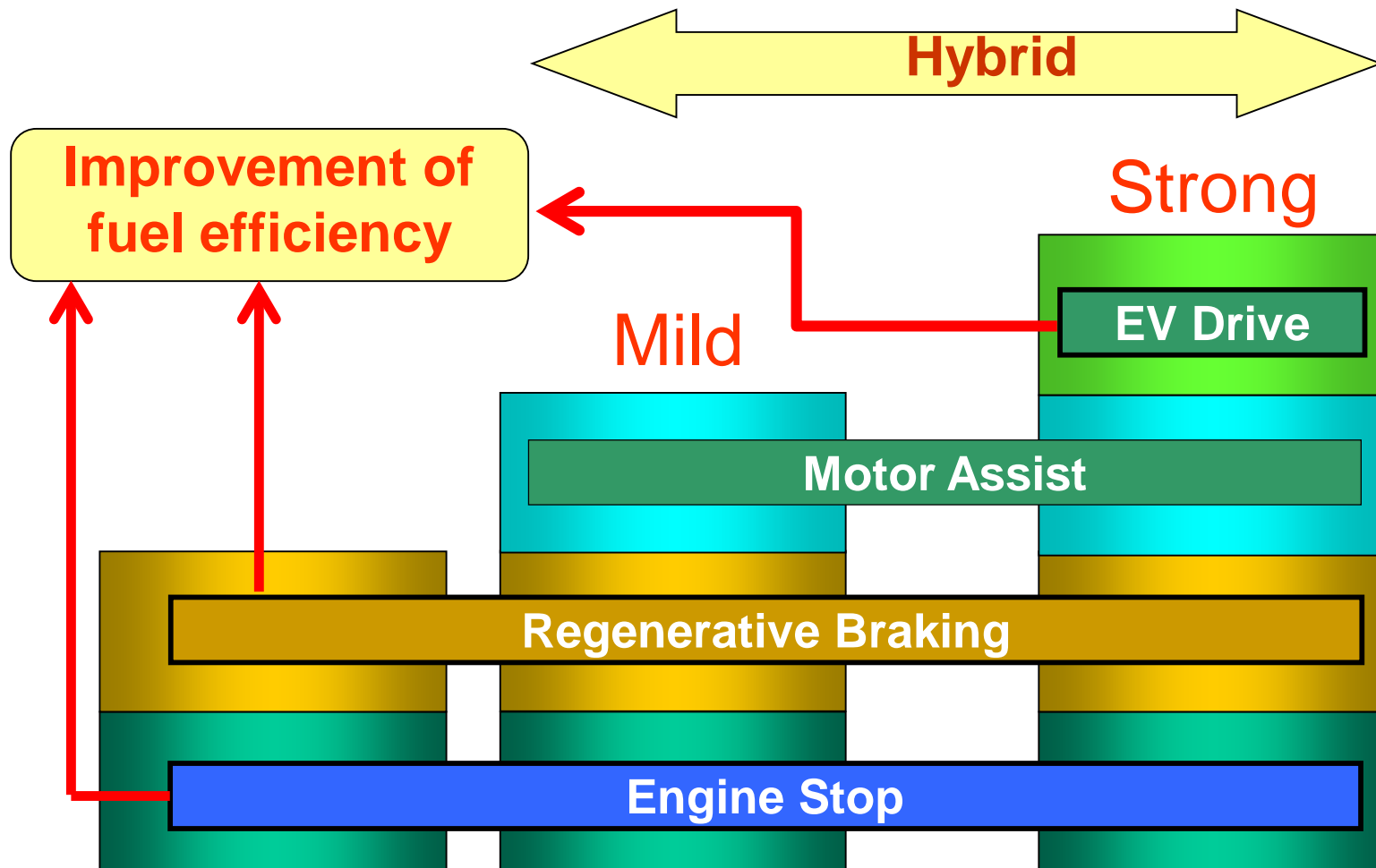


Other hybrid systems
(Mild hybrid vehicle)

Why Toyota's Hybrid System is fuel efficient

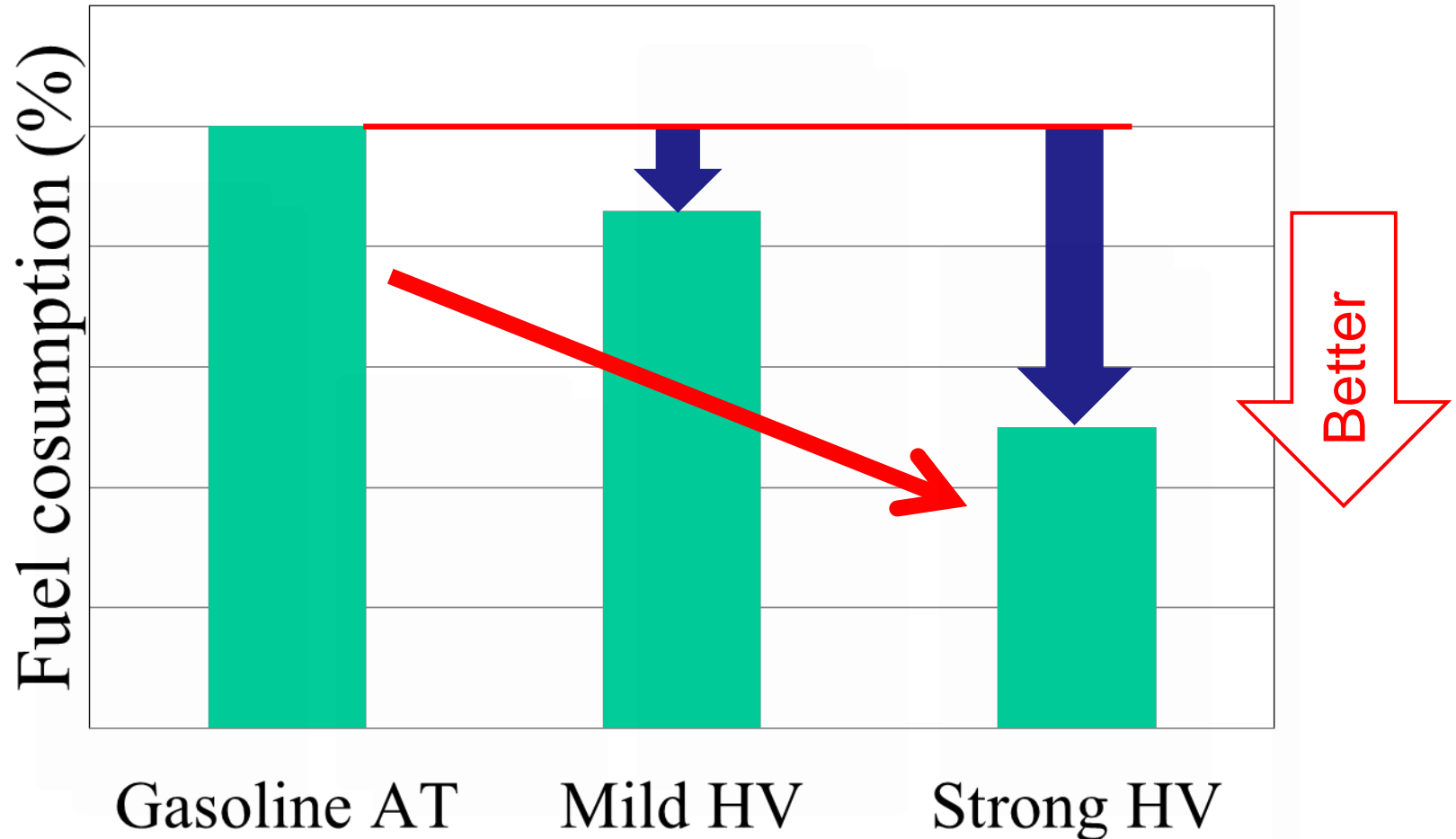
The difference between Strong HV and Mild HV is that Strong HV has the EV drive function

Classification by function of hybrid systems



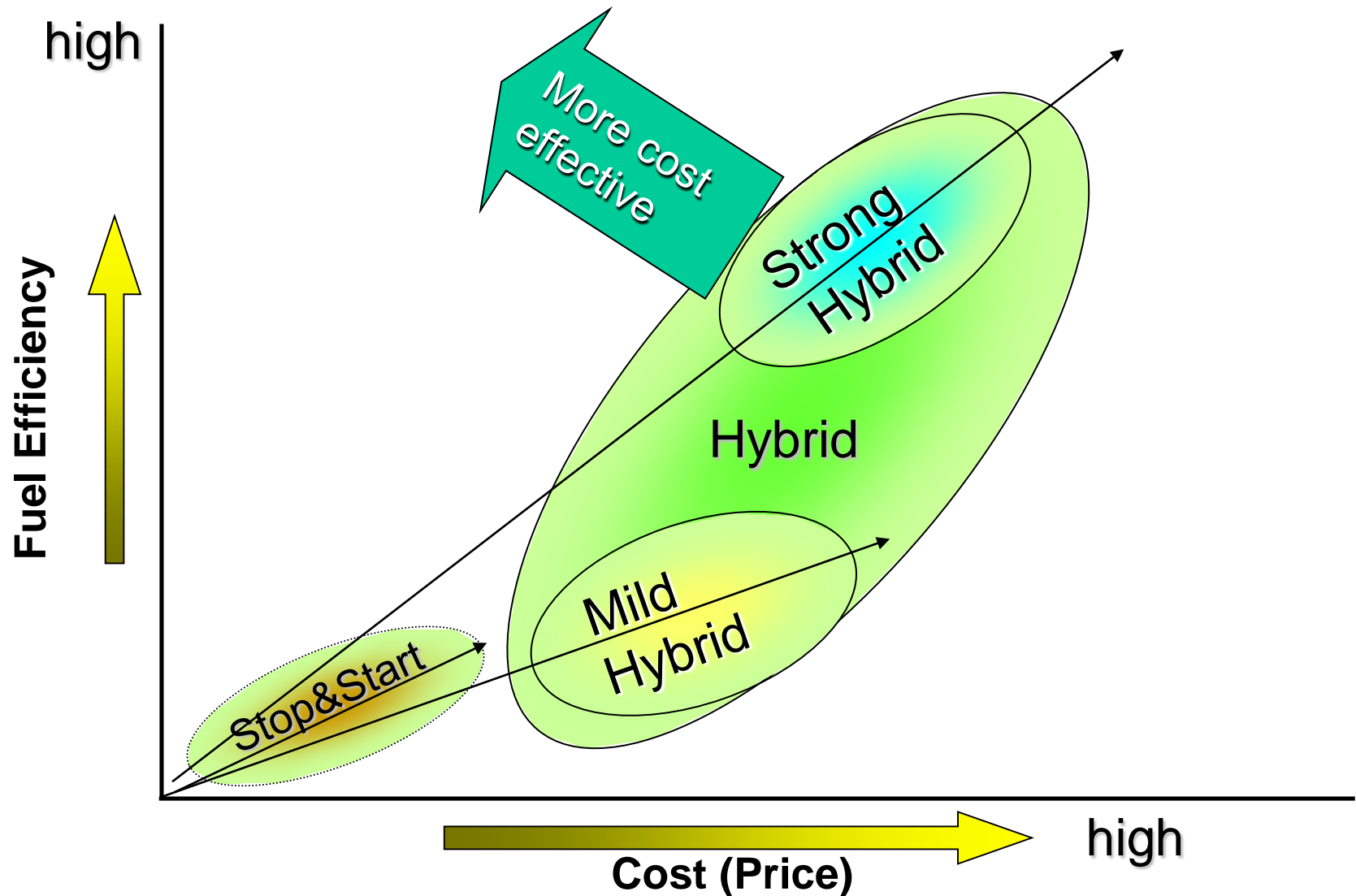
High fuel efficiency

Strong HV fuel efficiency is much better than that of Mild HV



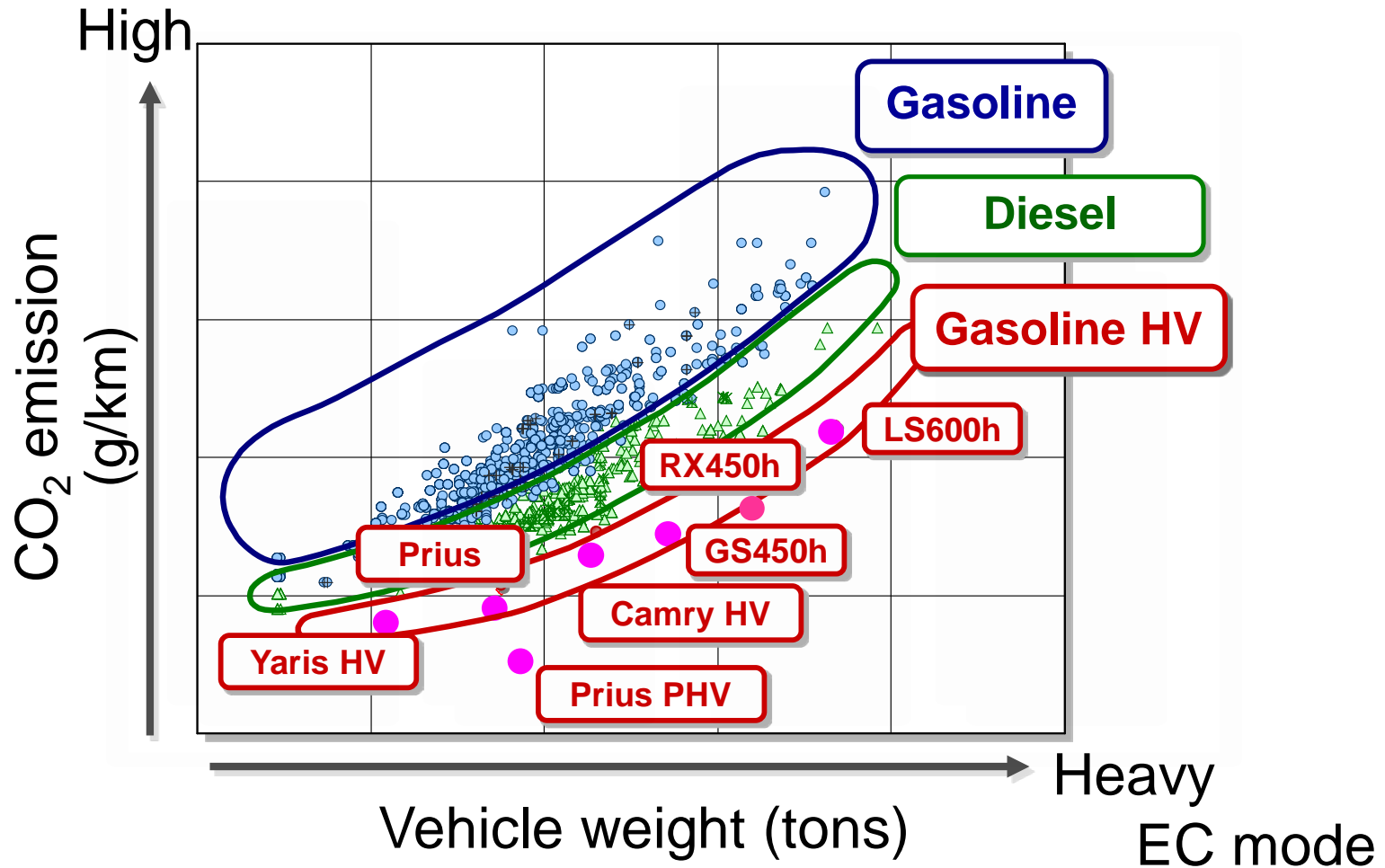
High fuel efficiency and better cost performance

Strong Hybrids are relatively more costly, but have high fuel efficiency and are more cost effective



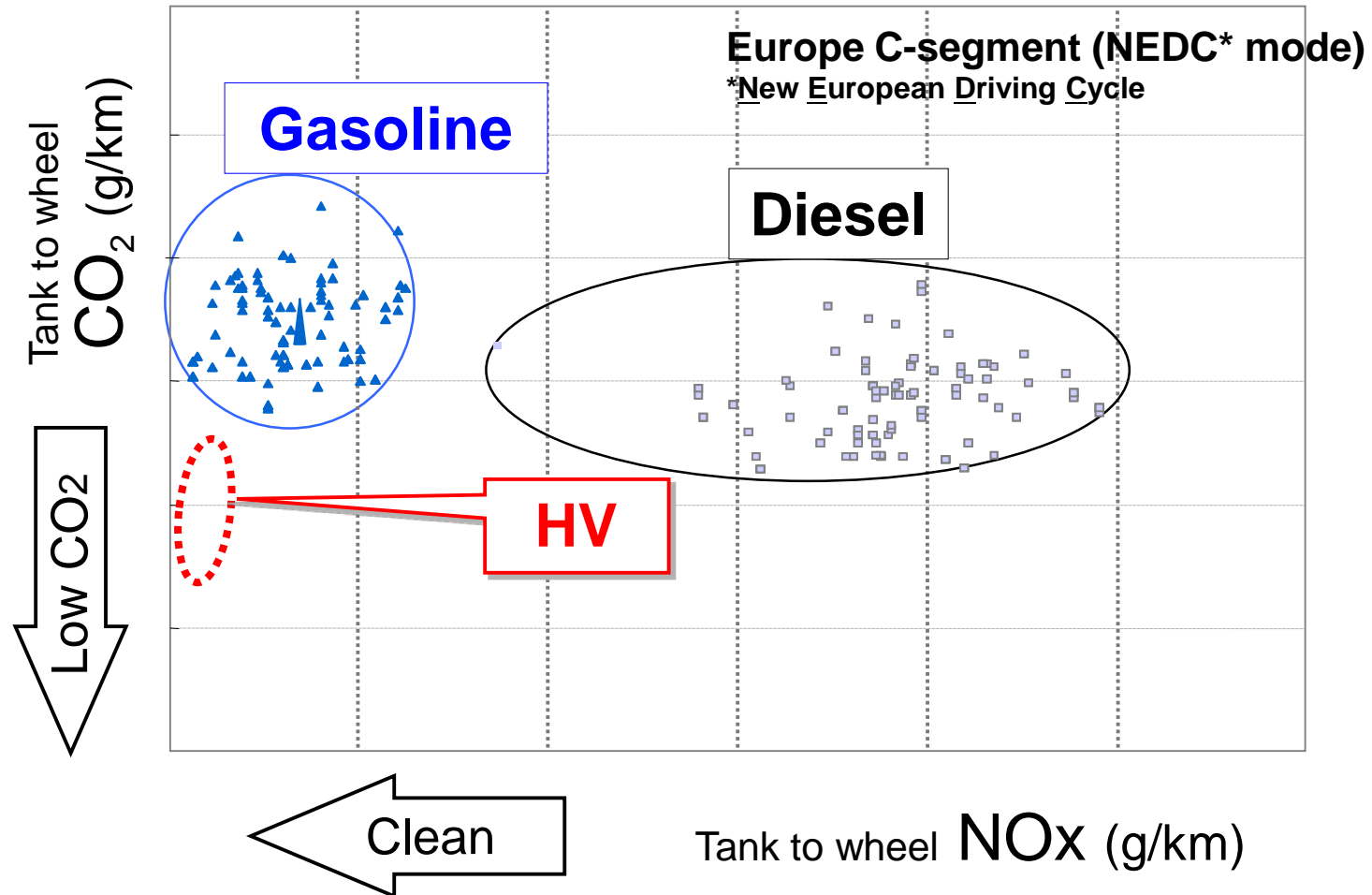
Low emissions: Carbon dioxide (CO₂)

Hybrid vehicles can contribute to the reduction of CO₂ emission



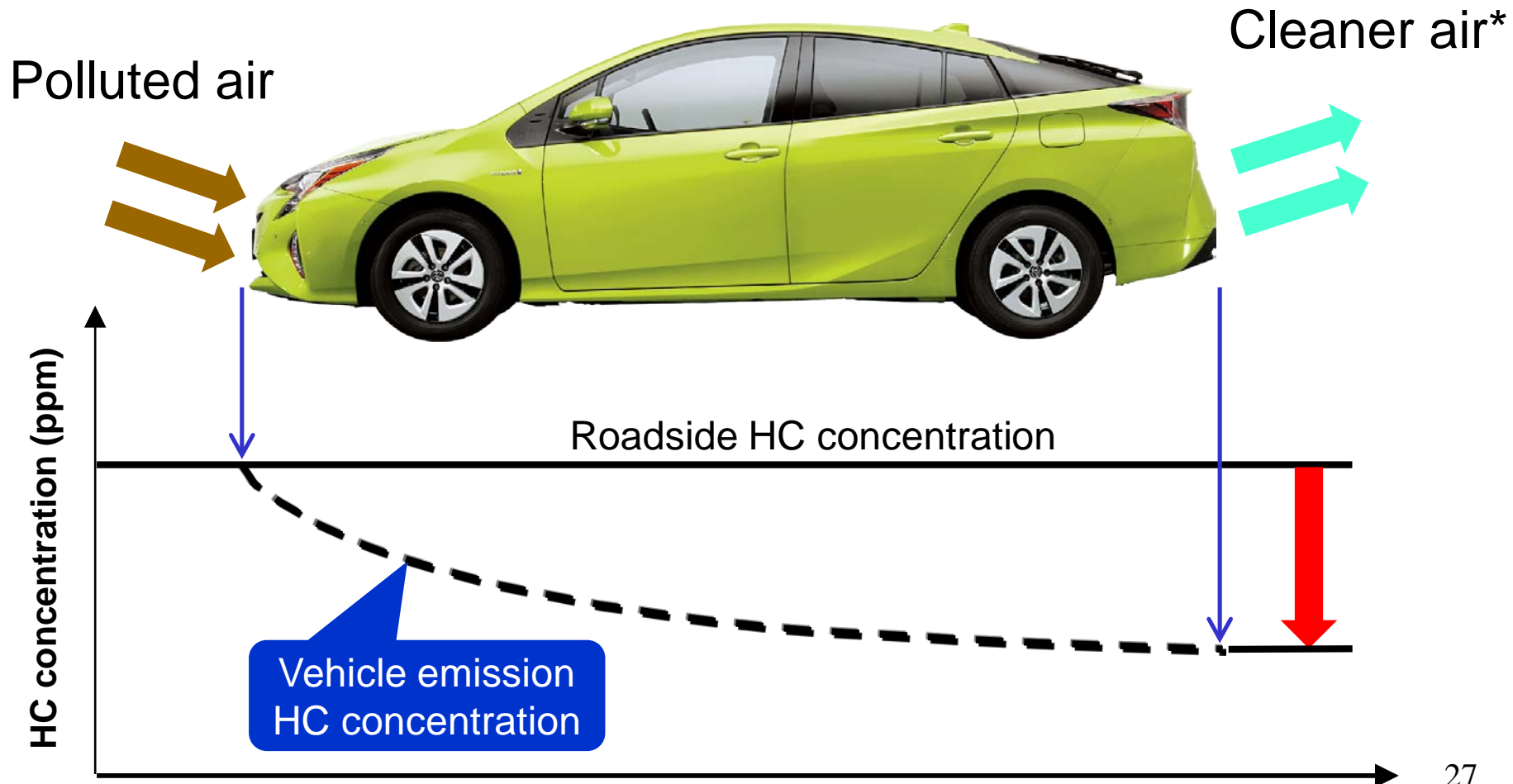
Low emissions: Nitrogen oxide (NO_x), Carbon dioxide (CO₂)

HVs manage both lower emissions(NO_x) and lower CO₂



Low emissions: Hydrocarbon (HC)

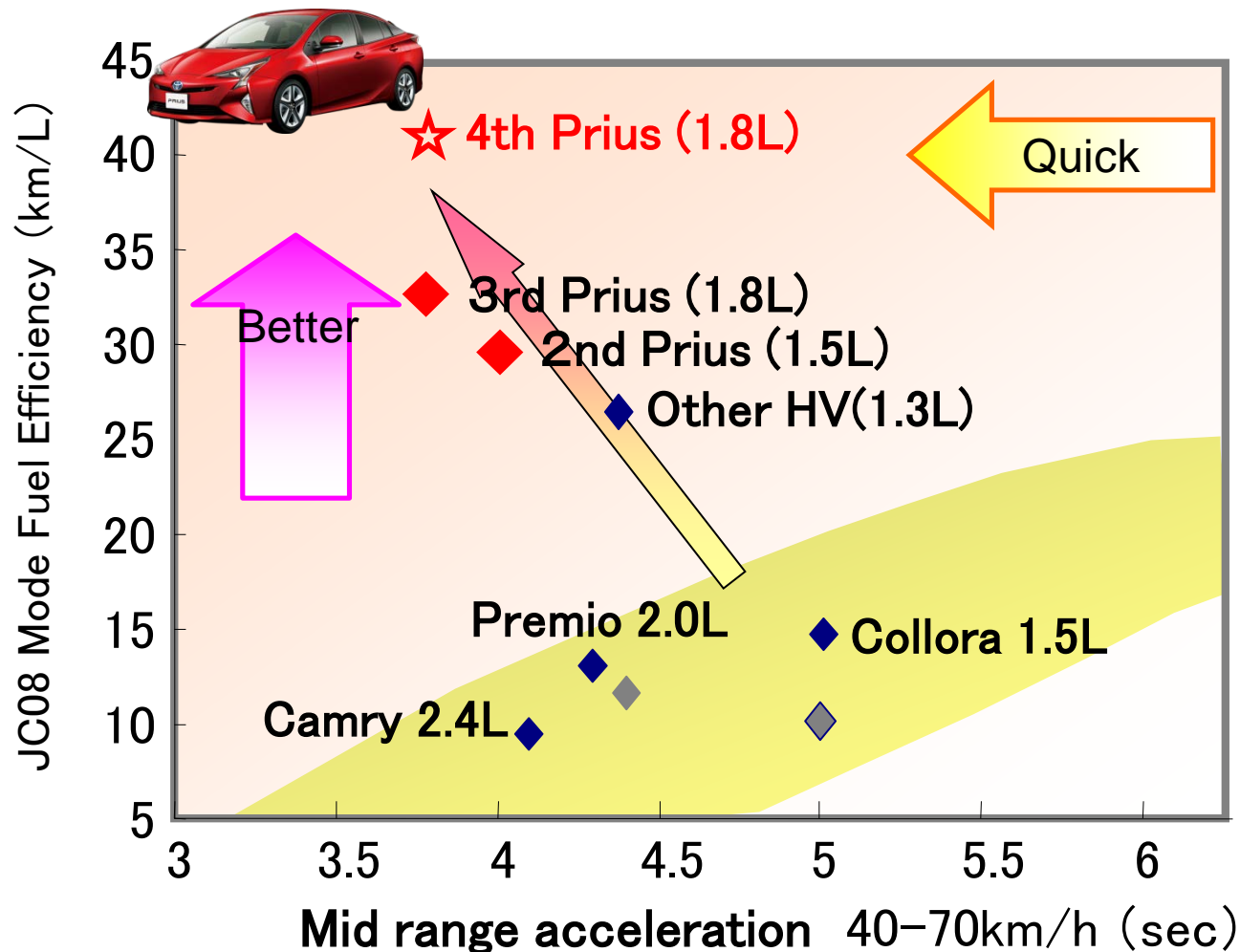
The more HVs there are on the road, the atmosphere becomes cleaner



*Concentration levels of HC in the air in urban areas is reduced.

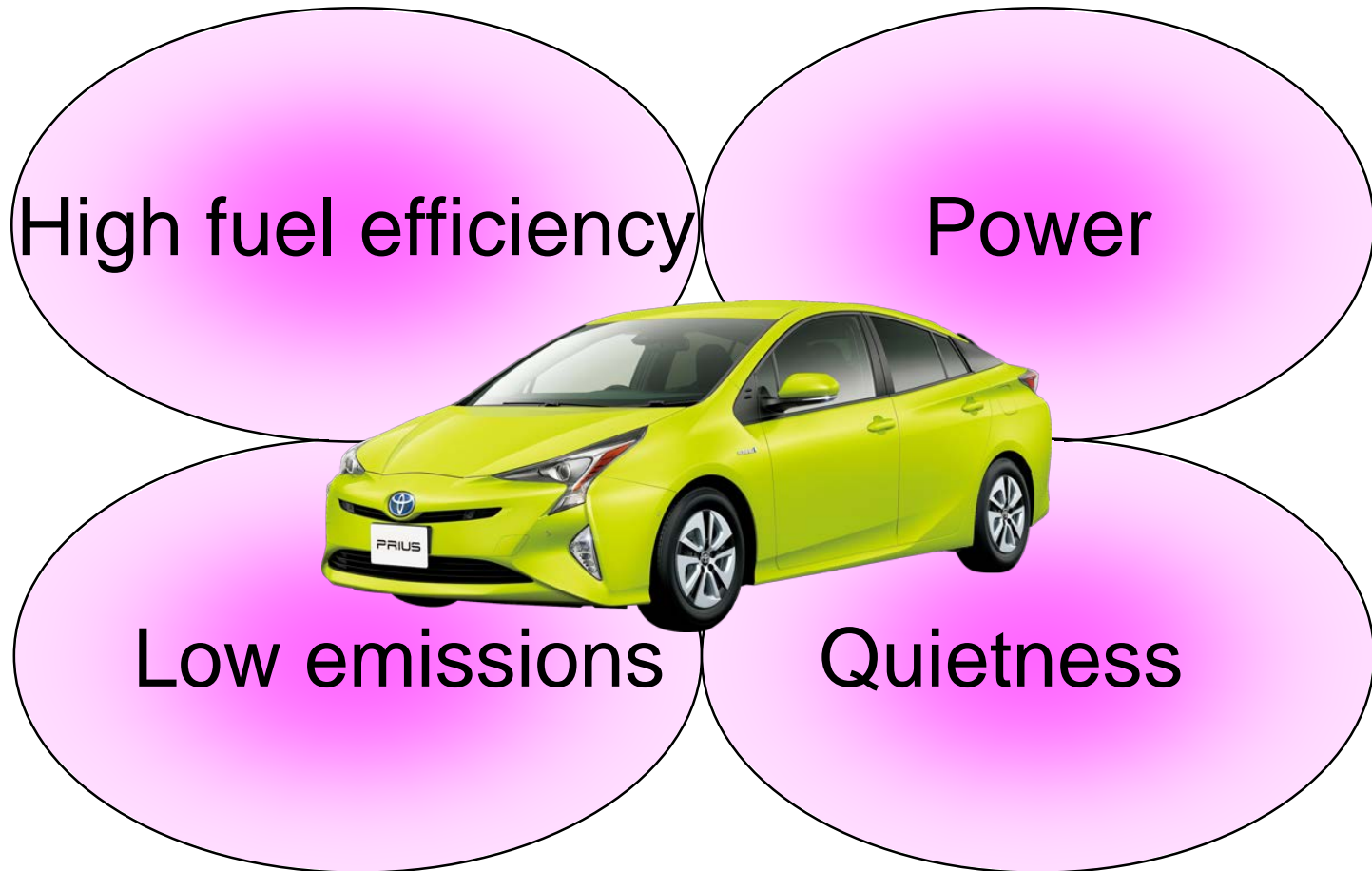
High driving performance

HVs realize the dual functions of high driving performance and fuel efficiency



Benefit of Toyota's HV

In addition to high fuel efficiency and low emissions, hybrid vehicles have strong power and quietness as characteristics



Benefit of Toyota's HV: Power



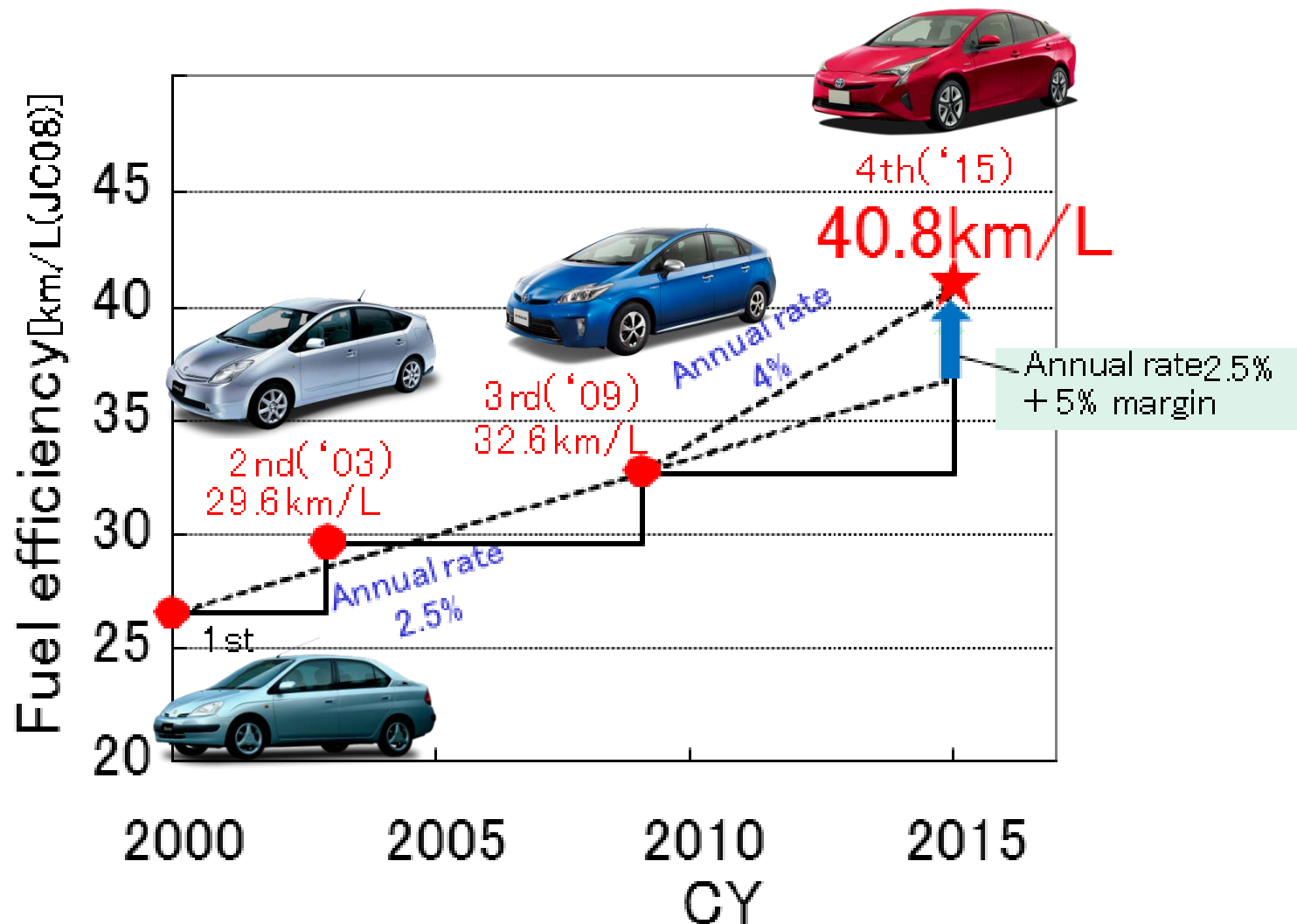
Benefit of Toyota's HV: Quietness



3 . Evolution in the Fourth-generation Prius

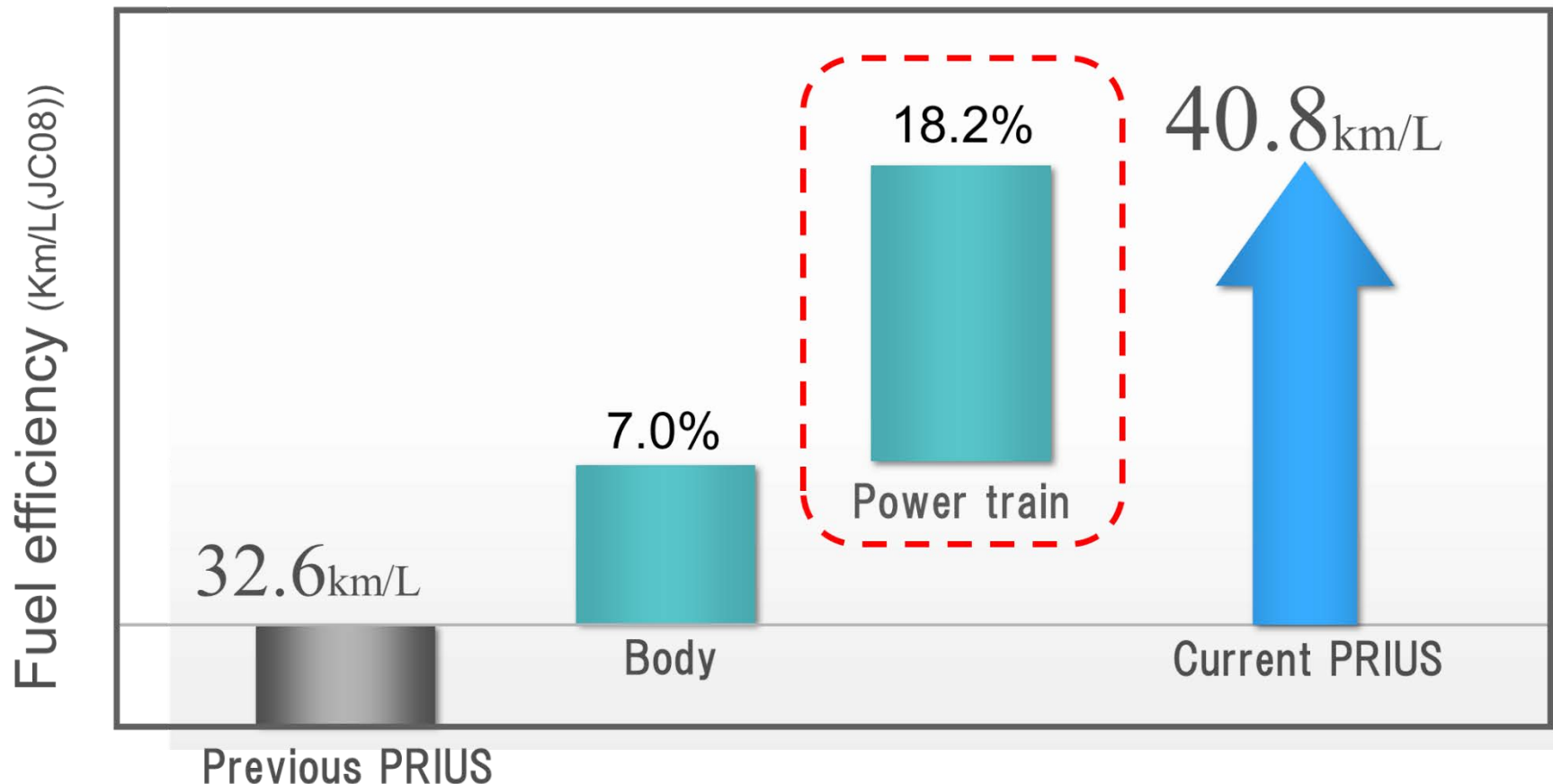
Fourth-Generation Prius: Fuel efficiency improvement

Prius has improved its fuel efficiency over the generations



Fourth-Generation Prius: Fuel efficiency improvement

25.2% improvement was made from previous Prius and powertrain has contributed to 18.2% of improvement.



Fourth-Generation Prius: Fuel efficiency improvement

Engine efficiency improvement and reduction in energy loss of HV electric units are the key improvements in powertrain.

1. **Engine efficiency improvement**
~Advancement of TNGA Engine~

2. **Drastic energy loss reduction of HV electric units**

3. **Synergy effect between 1. and 2. as system**

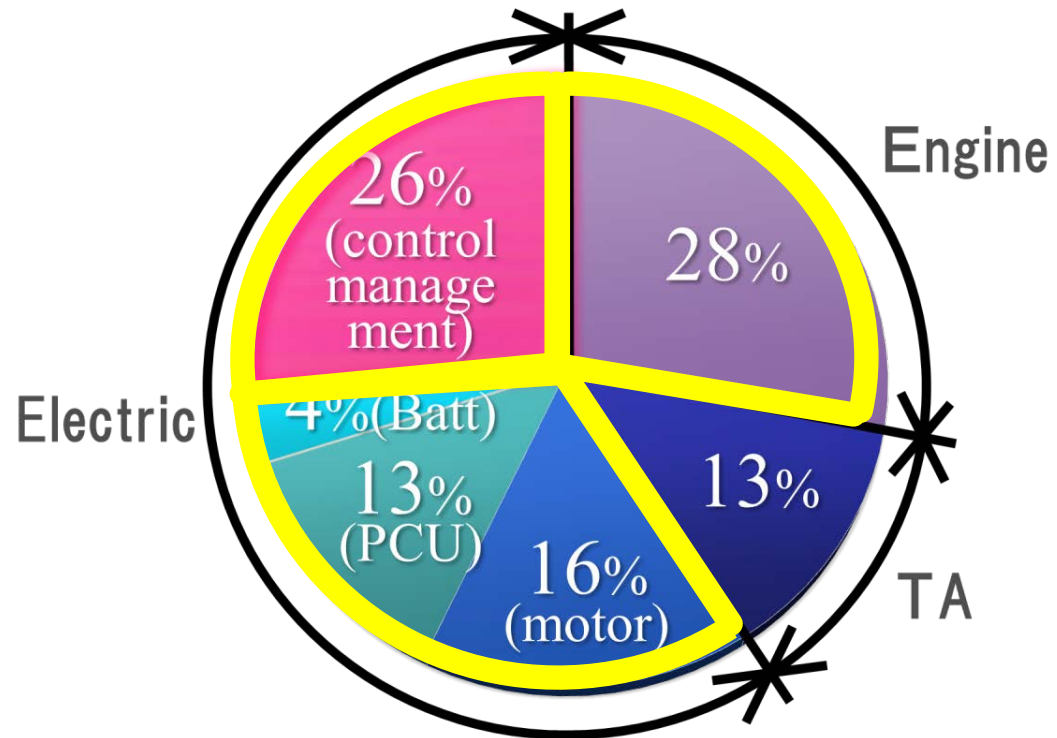


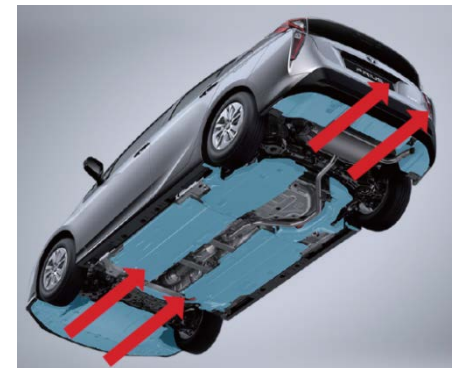
fig. Breakdown of powertrain fuel efficiency improvement

Fourth-Generation Prius: Advance fuel efficiency technology

To achieve the high fuel efficiency, not only the HV system, but aerodynamics has been improved as well

<Low fuel consumption>

- Improved 2ZR-FXE engine
 - Maximum thermal efficiency of 40%
- New Hybrid System development
- World-class aerodynamic performance
 - Cd* : 0.24 (Camry : 0.28)
 - Flat under floor
 - Grill shutter



*Drag coefficient

4 . Reliability Evaluation

Durability and safety of HVs

Many taxis use HVs
because of their durability and fuel efficiency



In Austria



Durability and safety of HVs

Many used HVs are imported into Sri Lanka, Myanmar, Mongolia, etc. as second hand vehicles which shows long life of vehicles



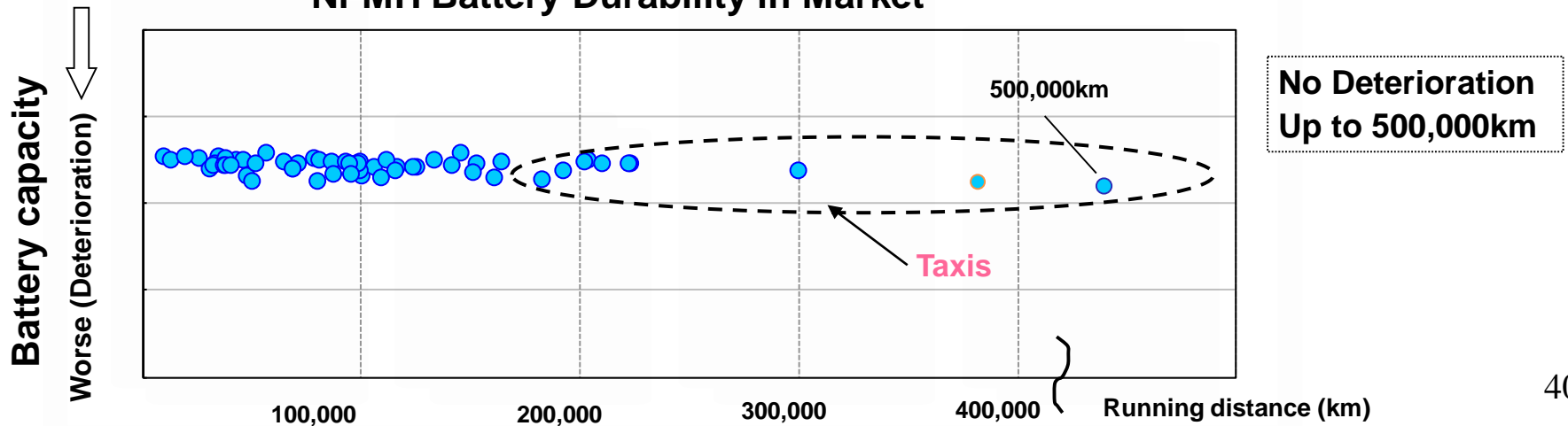
Batteries Durability Management

For good durability, hybrid electric vehicles control SOC and temperature of battery

Range of the State of charge (SOC)

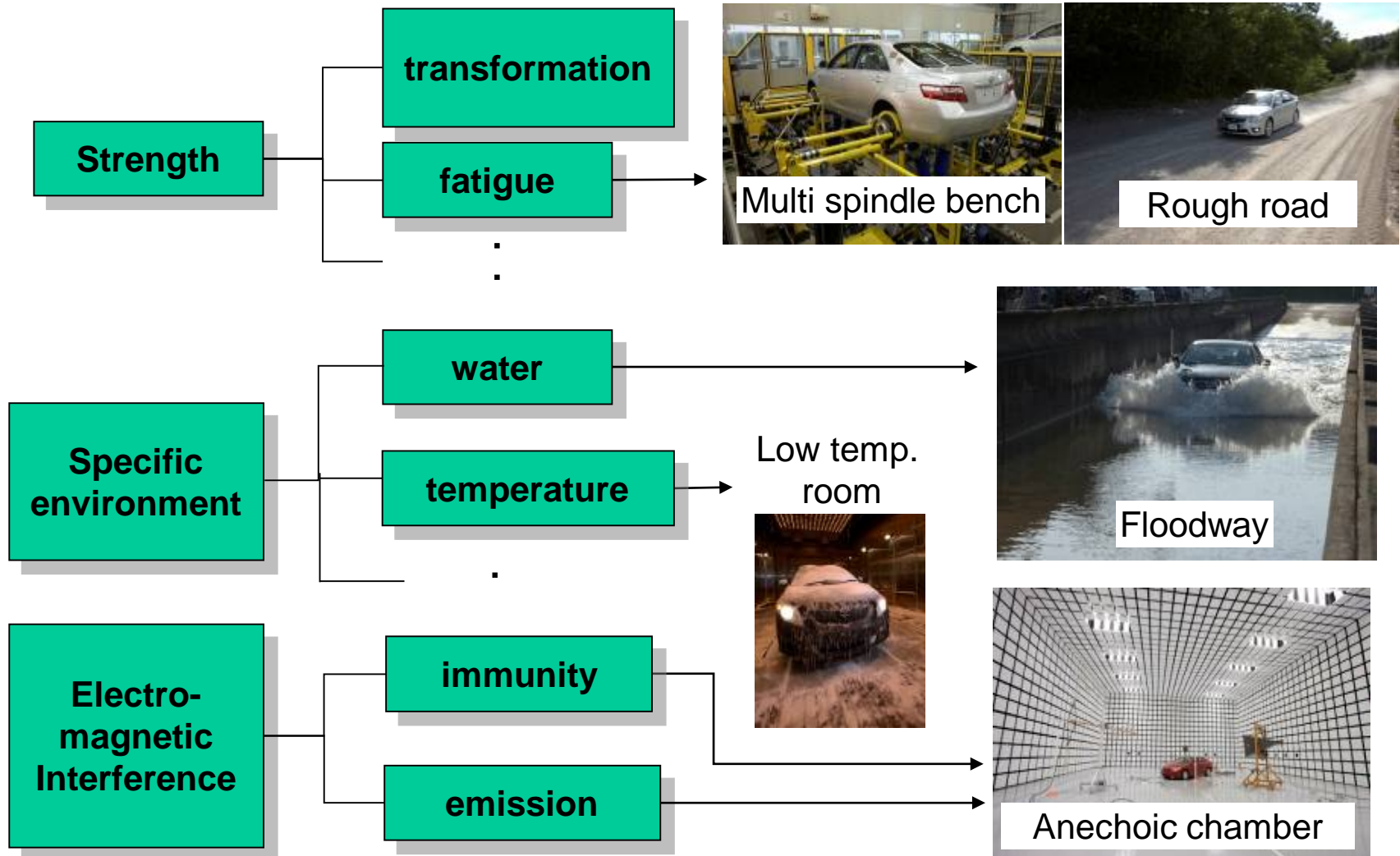


Ni-MH Battery Durability in Market



Example of reliability evaluation

Hybrid vehicles are evaluated with all the same reliability test as conventional vehicles



Example of the reliability evaluation of battery

Batteries unique to Hybrid vehicles are evaluated through many reliability tests

1. Charge and discharge durability

Inside of thermostat room



wiring condition

2. Durability vibration

vibration machine with thermostat room



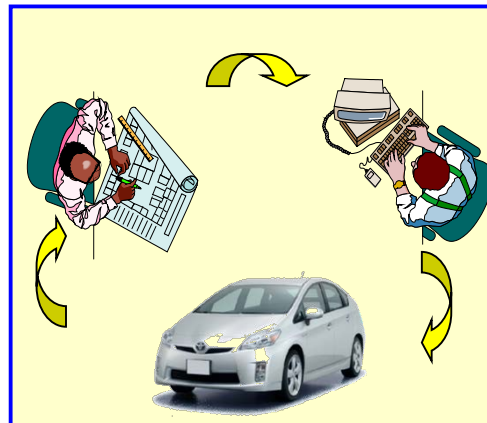
controller



3. Inspect collected parts from the market



4. Battery control management

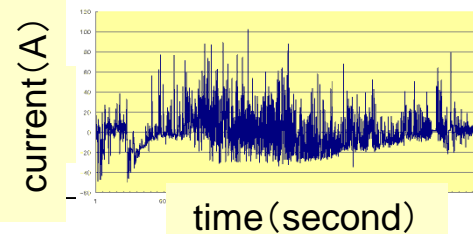


Laboratory evaluation

Ensuring market suitability by conducting battery evaluation tests;
simulating the real-world environment

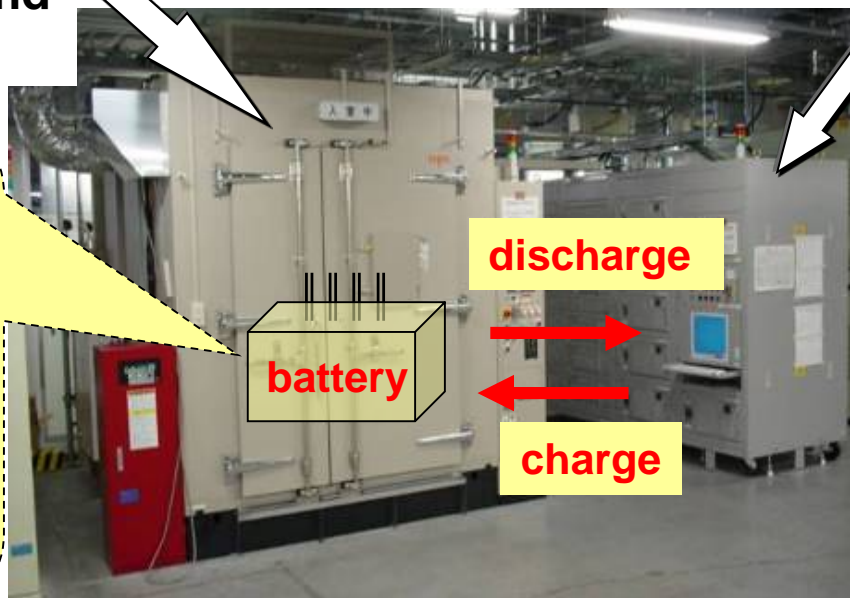
**Temperature and humidity room:
simulate actual environment**

**Charge and discharge controller:
simulate actual current**



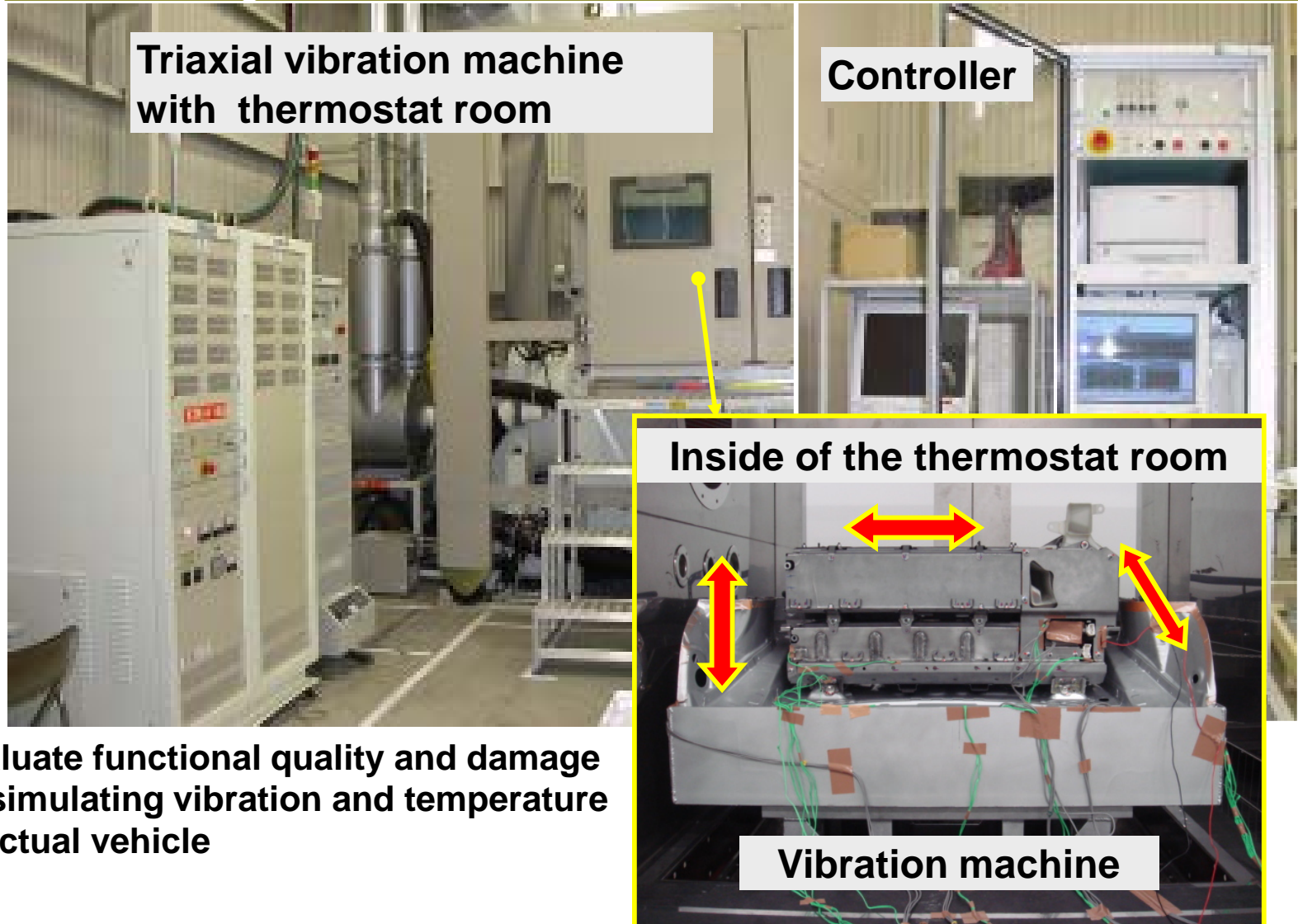
(ex) simulate
mountain drive
and others

**Inside of temperature and
humidity testing room**



Vibration test simulated uneven rough road conditions

Toyota conducts vibration tests on batteries by simulating the various road conditions around the world



Battery drop evaluation

Battery test example: Drop battery from great heights



Battery drop evaluation



Water leak evaluation

Battery test example: Water immersion



Water leak evaluation





TODAY for TOMORROW