Toyota's Fuel Cell Development

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TOYOTA

BACKGROUND

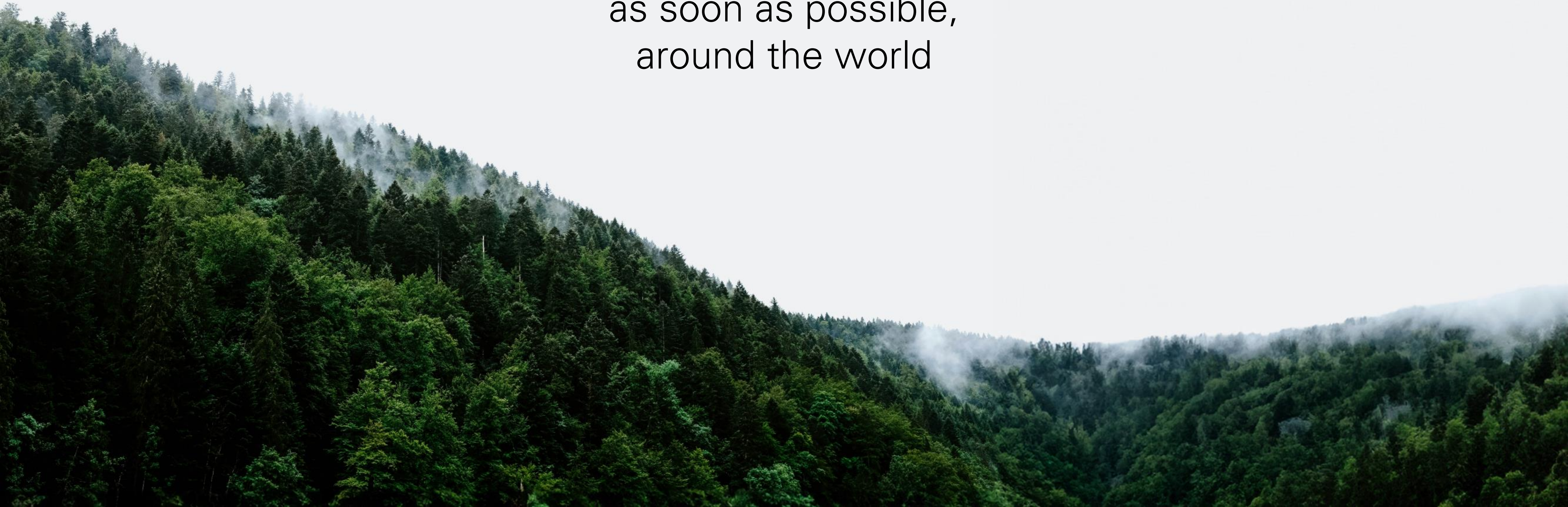

HILUX FCEV
PROTOTYPE


The only enemy is carbon!

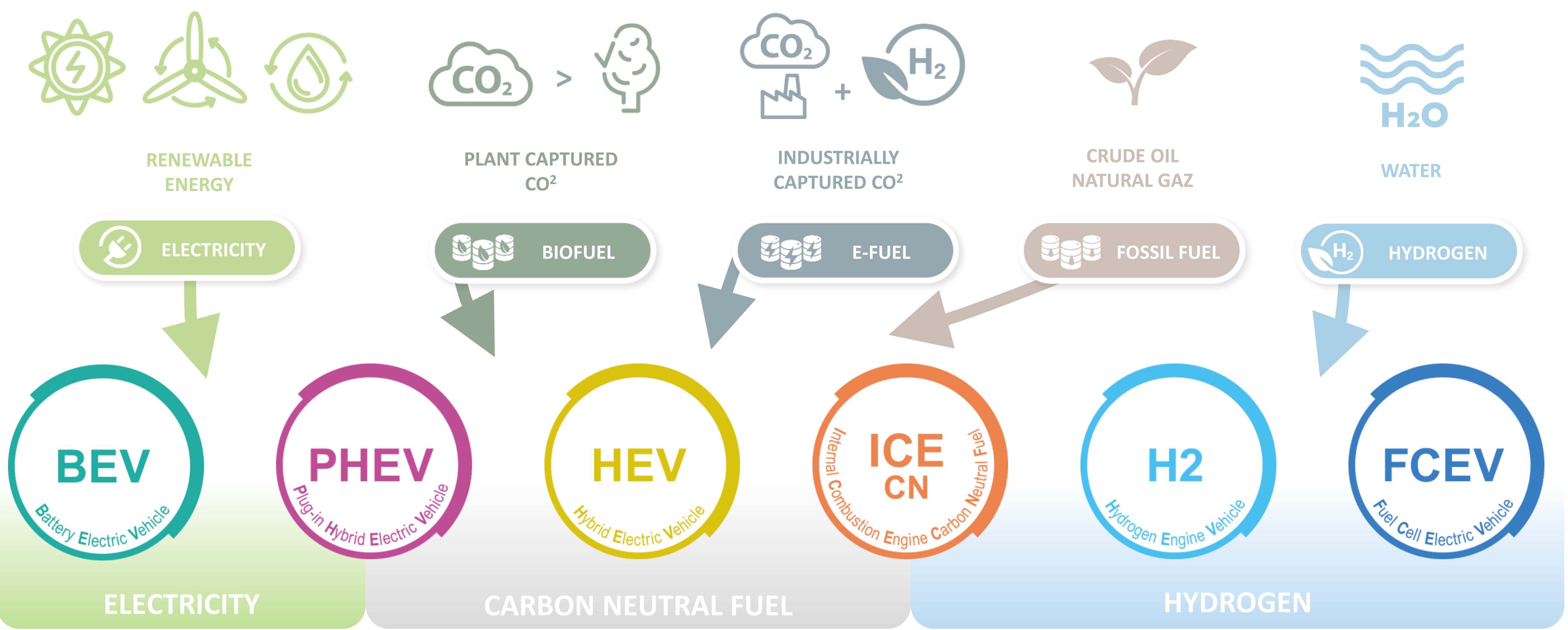
our goal today

REDUCE CARBON EMISSIONS

as much as possible,
as soon as possible,
around the world

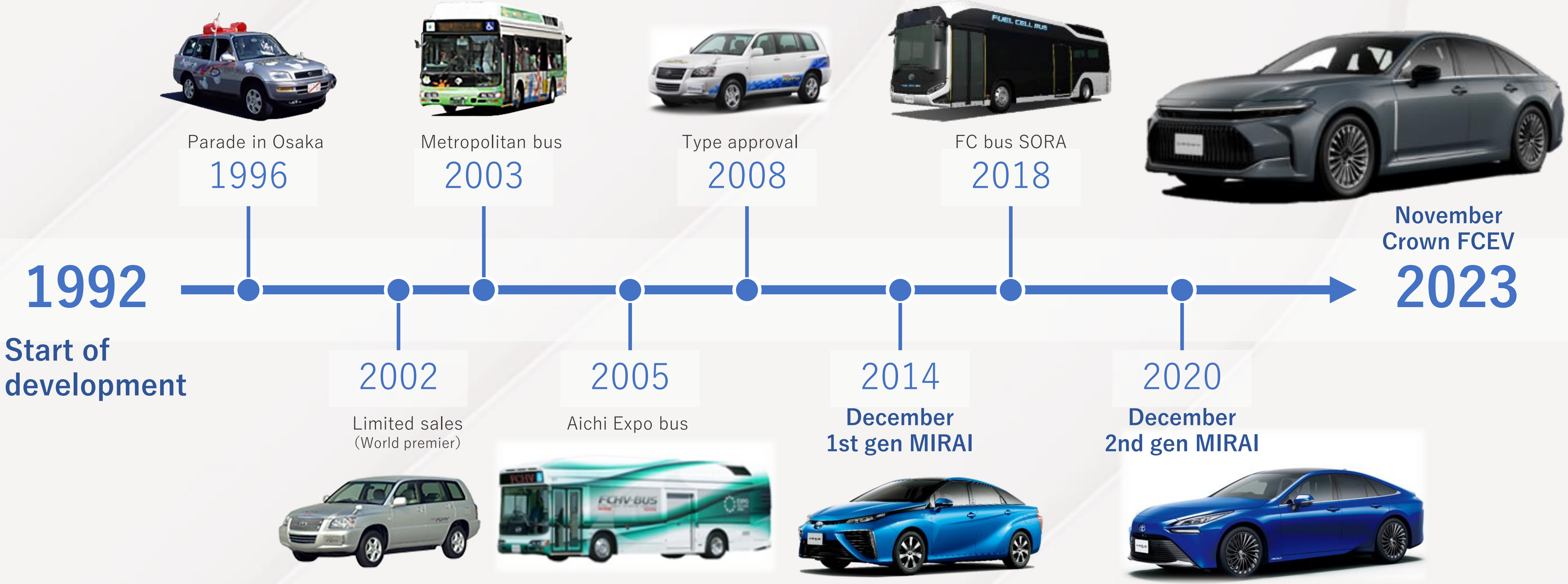


MULTI-PATH
FOR ENERGY AND MOBILITY



FCEV HISTORY AND SALES

Fuel Cell Electric Vehicle (FCEV) development history in Toyota



Started FC development in 1992. History of FCEV over 30 years.

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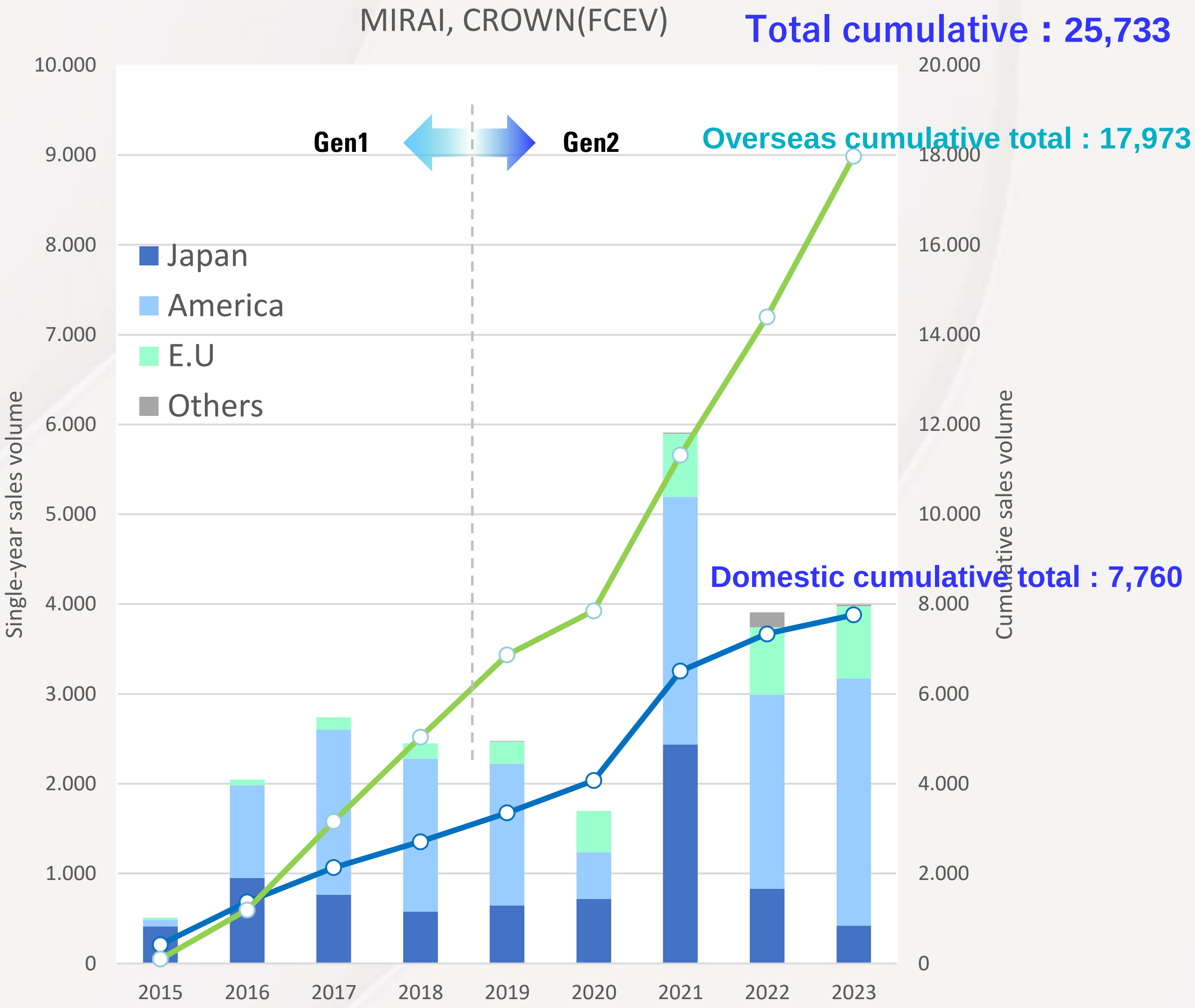
The evolution and sales status of the MIRAI and FC CROWN

MIRAI
Sports
Concept

FC
CROWN

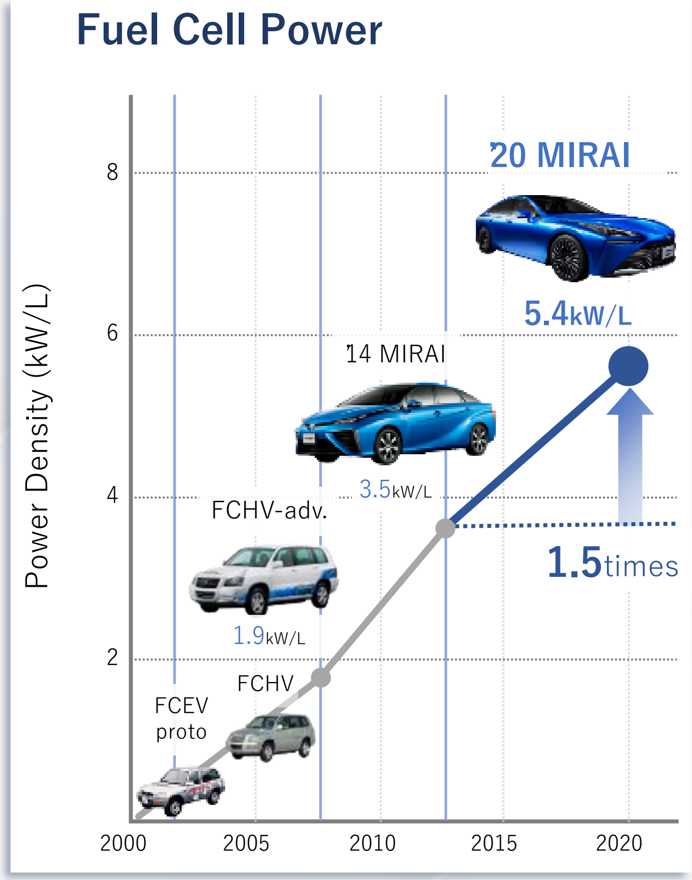
MIRAI taxis in France

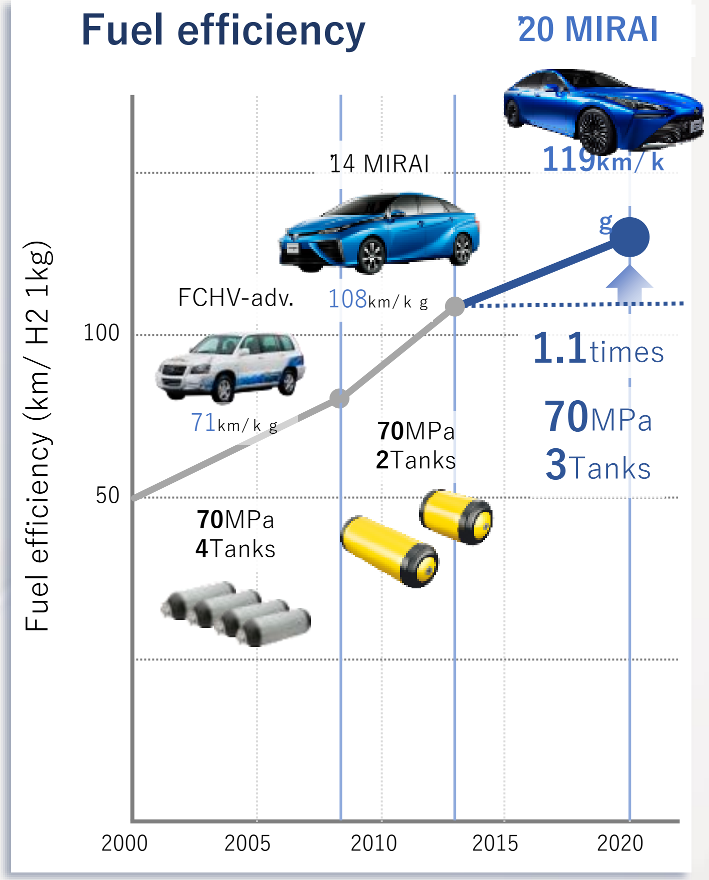


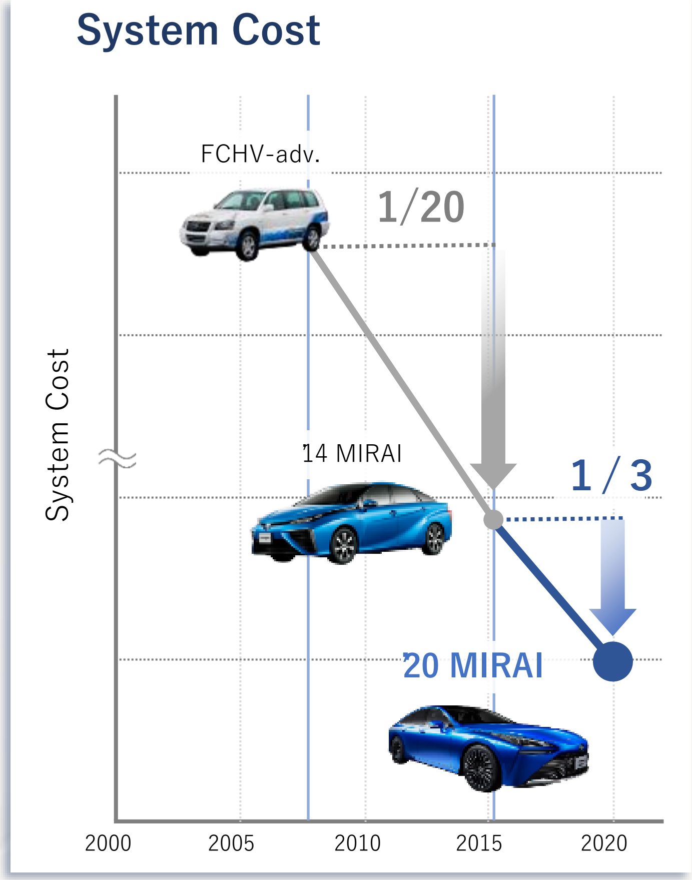
Over 25,000 FCEVs around the world,
Cumulative mileage reached over 675 million km without serious problem

FC SYSTEM DEVELOPMENT

Evolution of Performance

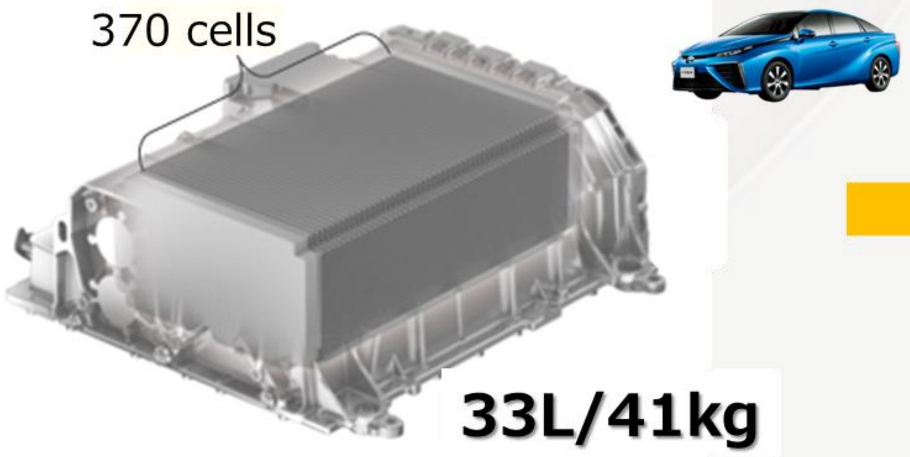






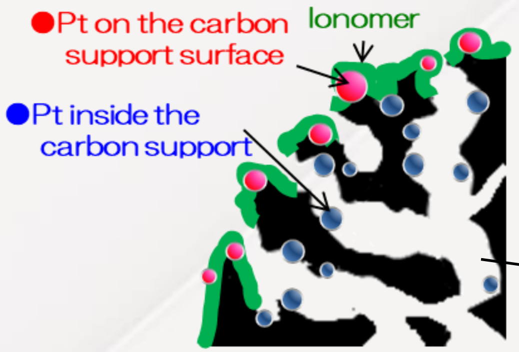
Steadily becoming familiar through improving technology

Improvement of FC stack

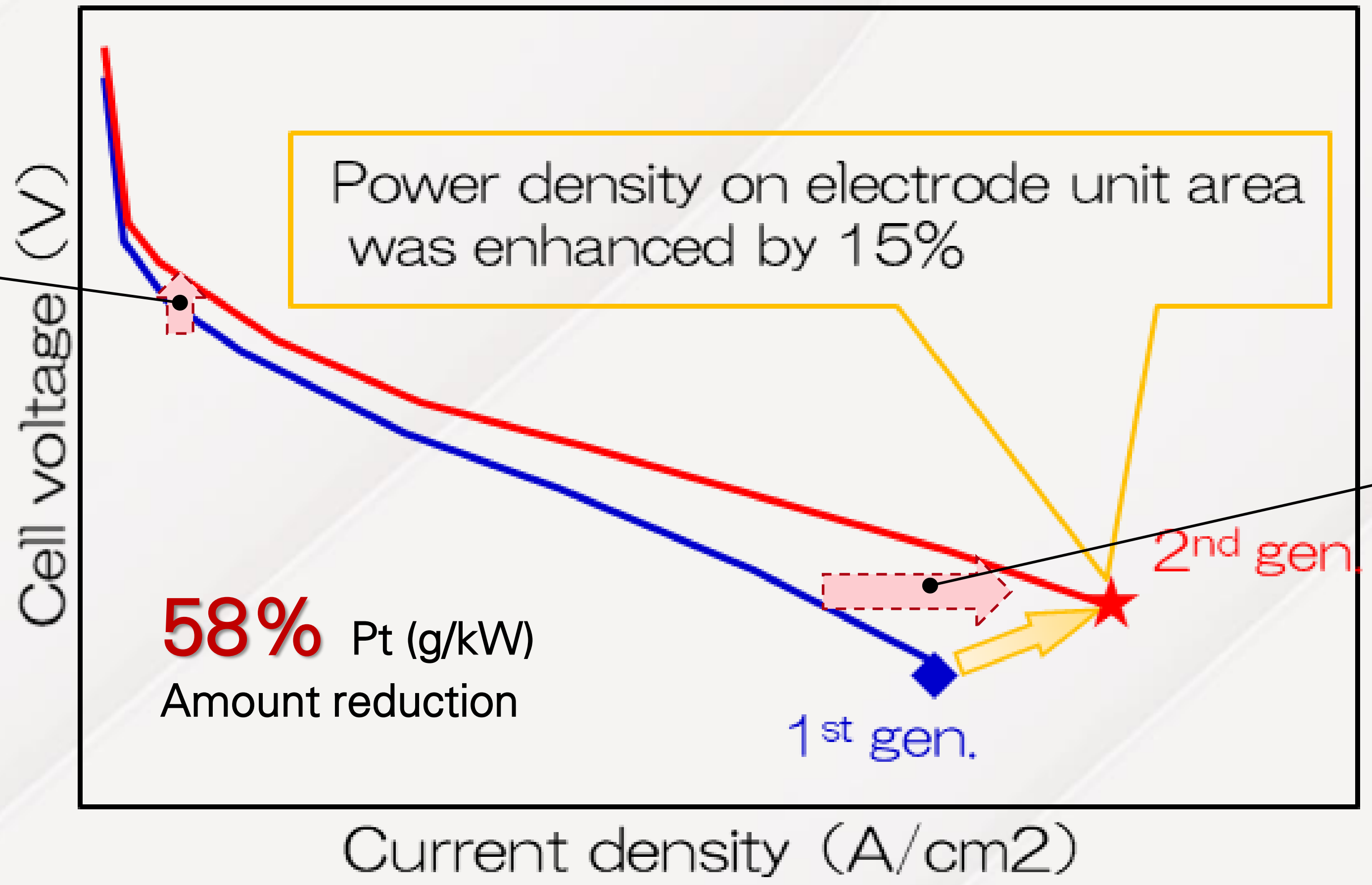
	1st Gen. MIRAI	2nd Gen. MIRAI
Size Weight		
Max. Power	114kW	128kW
Volumetric Energy Density	3.5kW/L	5.4kW/L
Hydrogen storage amount	4.6kg	5.6kg

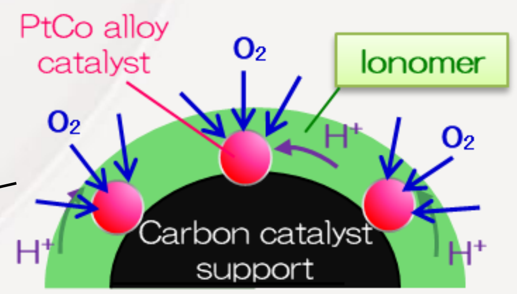
High power and long mileage was achieved in GEN2

Example) Improvement of electrode materials



Catalyst development



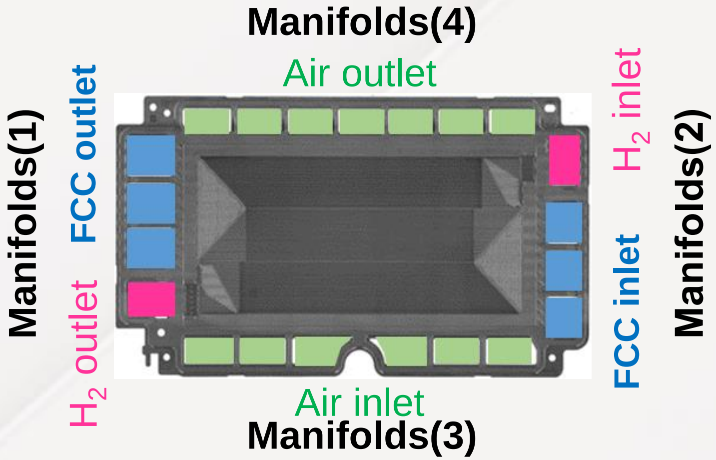


Example: Enhancing Proton conductivity

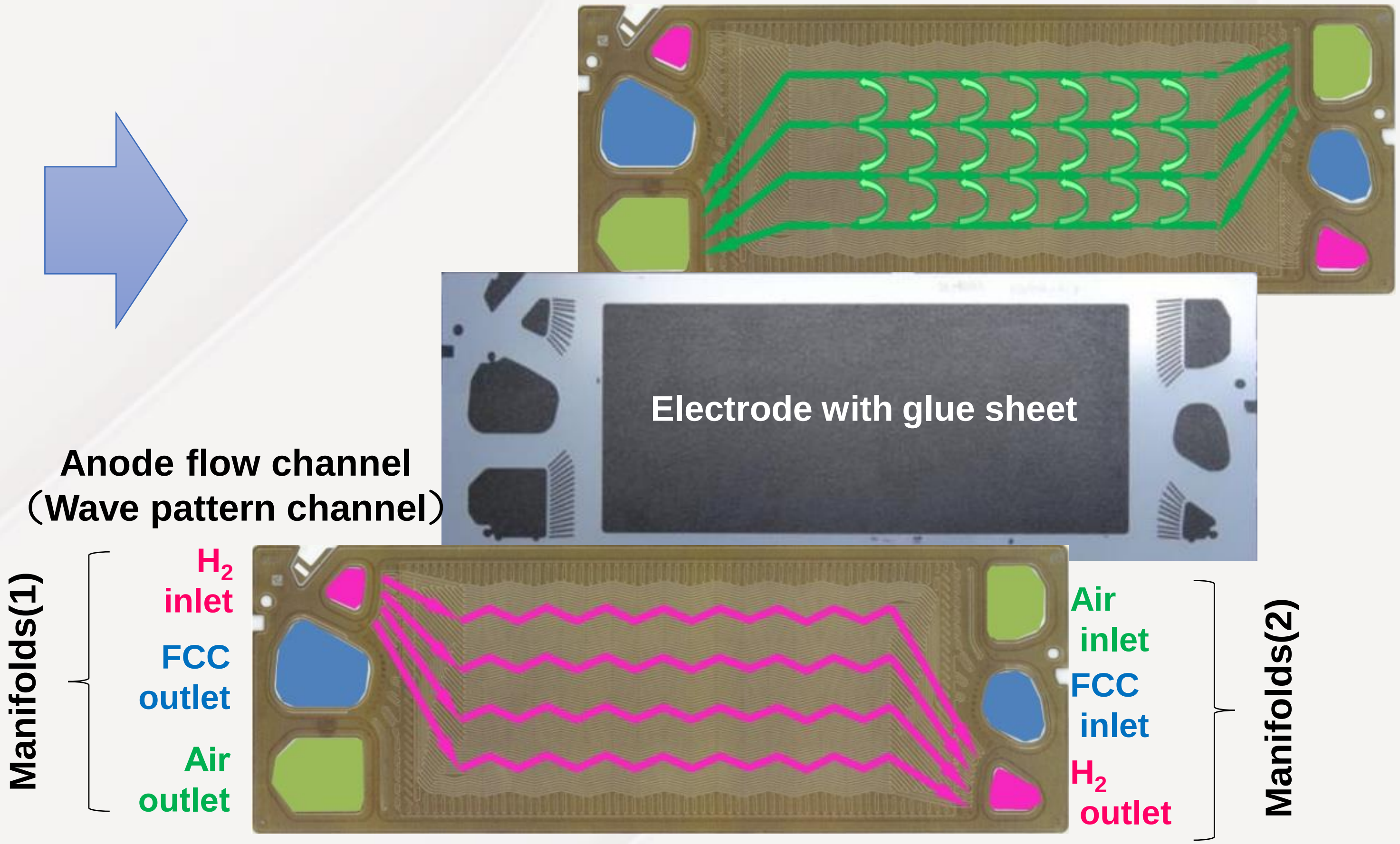
Power density on the electrode unit area was improved by 15% with newly developed electrode

Example) Improvement of flow channel

1st Generation

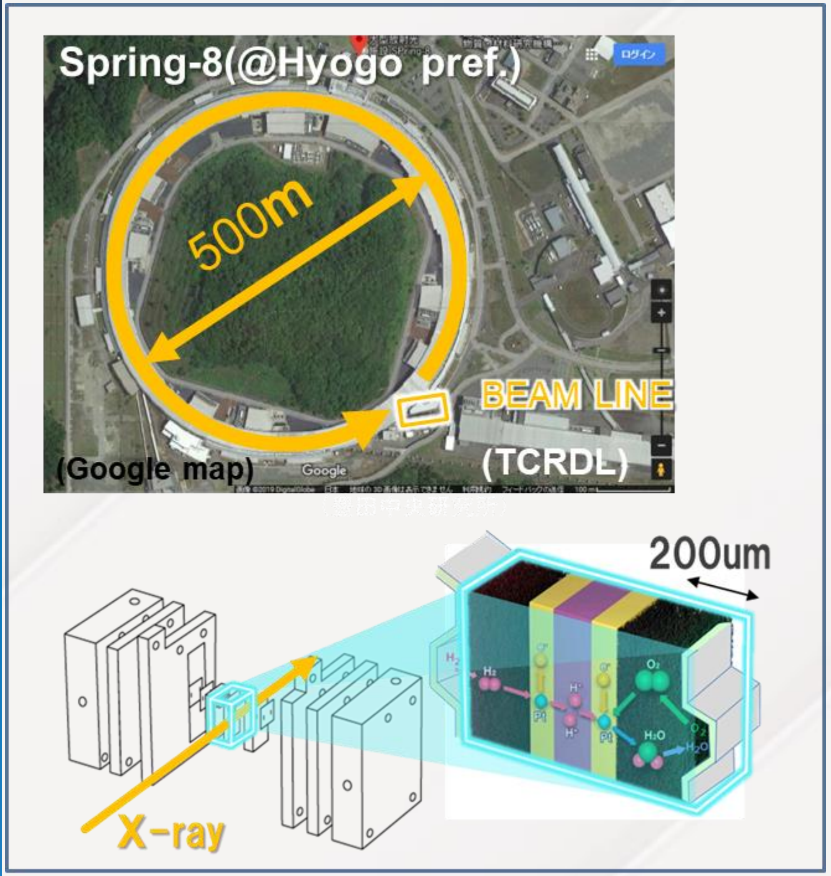


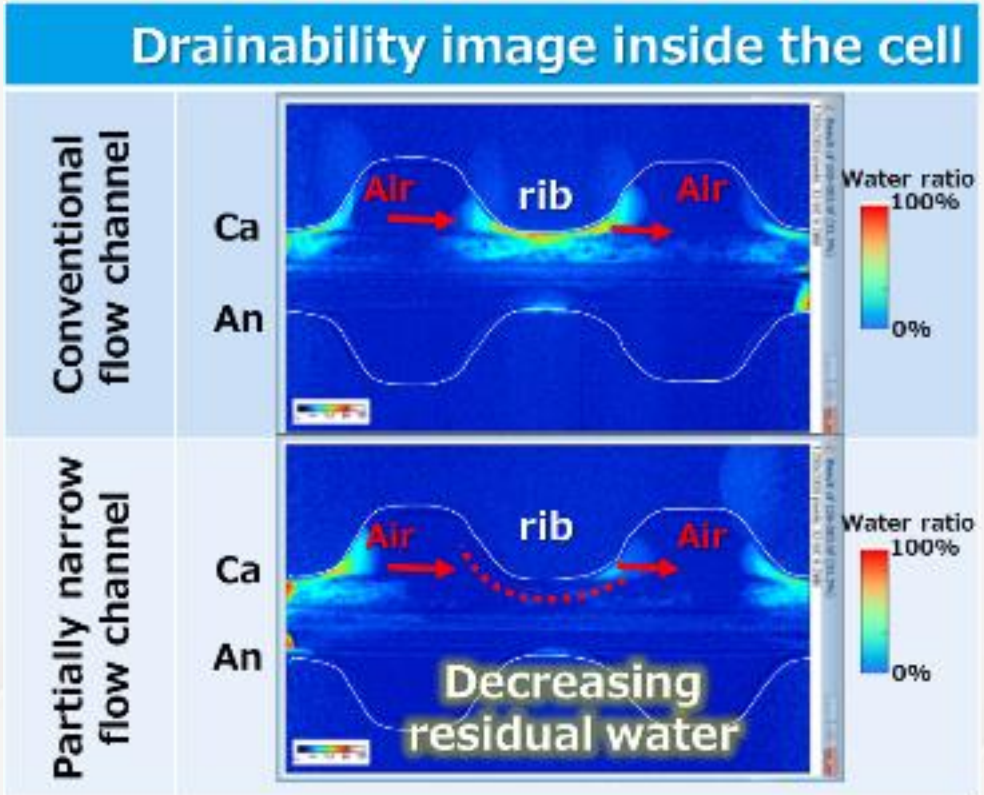
Cathode flow channel
（Partially narrow straight flow channel）



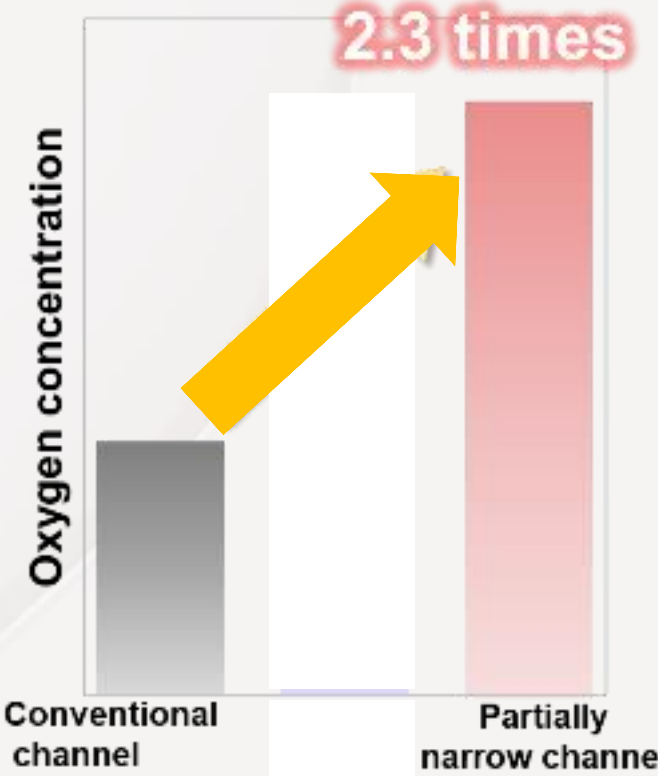
The flow channel geometry was further optimized,
Enhancing the water control inside the cell

Water behavior analysis



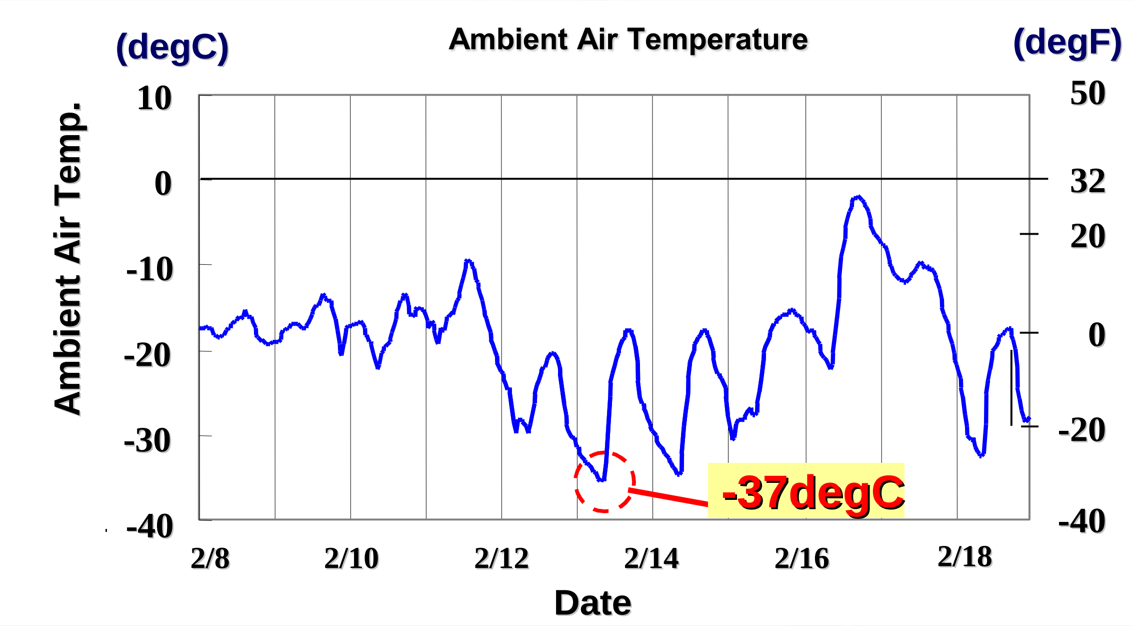


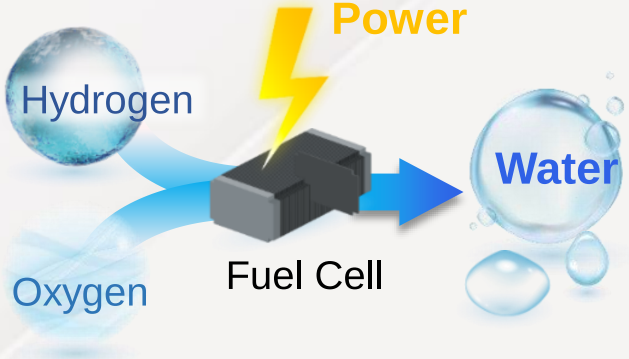
X-ray CT image of water moving by Spring-8(@Hyogo, Japan)



In-situ study of water behavior using synchrotron X-ray radiation to ensure the sufficient oxygen delivery through the new flow channel

Environmental test under severe conditions: Low temperature





Water freezes at sub-zero temperatures.

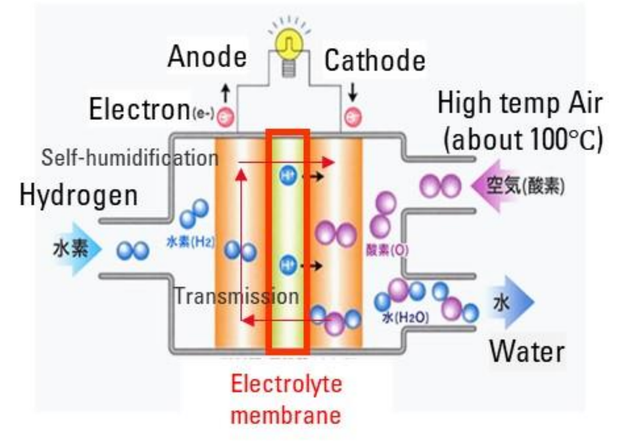
- Push the water out of the stack with air
- Rapid warm-up control

Proper “water management” allows us to start quickly even in sub-zero conditions

Environmental test under severe condition: High temp, altitude

■High Temperature

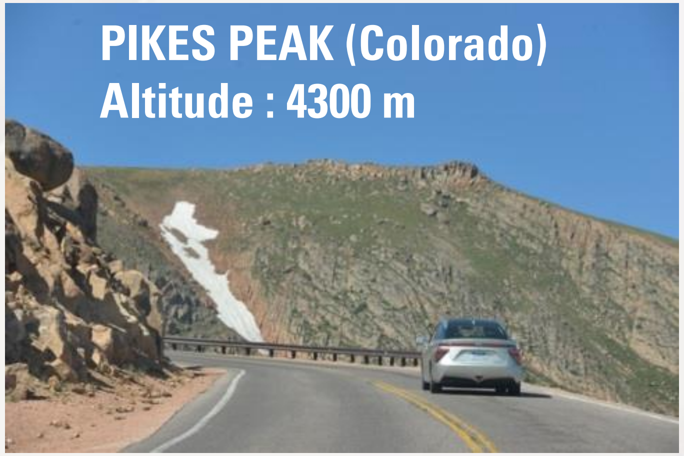
Issue : Deterioration of proton (H+) conductivity due to the dry-up of the electrolyte membrane



Temperature : 50°C

■High Altitude

Issue : Insufficient mass flow rate and low air pressure



Turbo Air Compressor

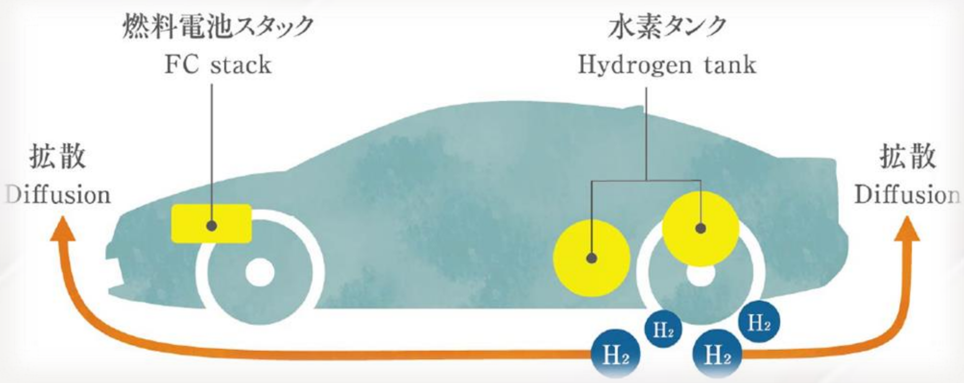
Proper "water management" allows us to drive in severe condition

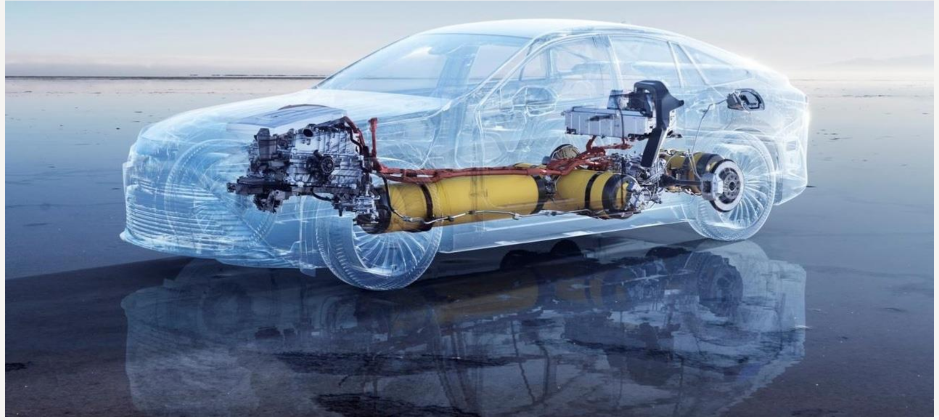
HYDROGEN SAFETY

Fundamental safety considerations for GH2 storage system

■Vehicle Level

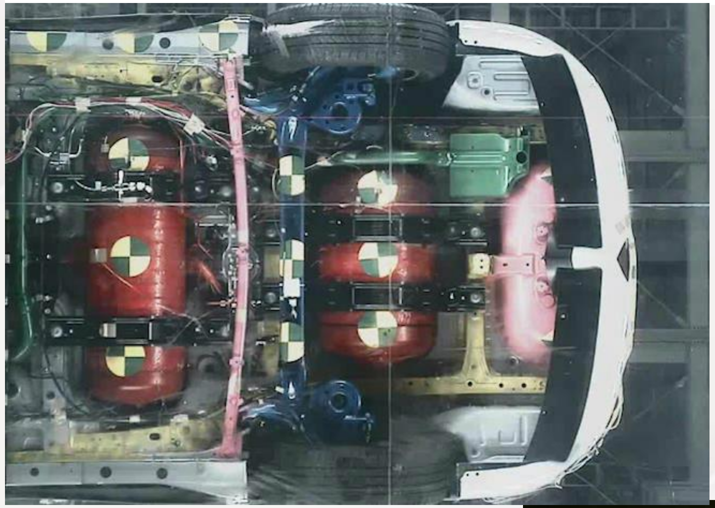
- No hydrogen leakage
- In event of a leak, immediately detect H2 leakage and stop H2 flow
- No H2 accumulation from leaks





■Storage System Level

- Pass required in-vehicle crash tests
- Must not rupture



Crash Test for Light Duty Vehicles

High strain impact (gunfire) test (SAE J2579)

Tanks must not leak or burst, and must vent H2 safely

Defined requirements set by technical experts, applied globally

SAFETY REQUIREMENTS

- Baseline tests → Manufacturing quality
- Durability tests (hydraulic) → Structural integrity
- On-road tests (gaseous) → Liner integrity
- Performance in fire
- Post-crash requirements

MANUFACTURERS CHOOSE DESIGN OF:

- Vehicle
- Storage tank
- Storage system
- Integration of system to vehicle
- Materials










Informal WG Members (subset shown here) :

Regulators / Technical Services
NHTSA, METI JAPAN, TÜV Rheinland CERTIFIED

OEMs / Suppliers
TOYOTA, DAIMLER, HEXAGON, HYUNDAI

Research / Academia
Joint Research Centre, JARI, Sandia National Laboratories, KATRI

GTR13 Phase 1		GTR13 Phase 2			
'09	'13	'17	'18-'21	'22	'23
Est. GTR13 project	Adopt GTR13	Start Phase 2	IWG mtgs (x 11)	Approved by experts	Approval UN Exec Comm, establish GTR13 Amd 1 regulation

Addendum 13: Global technical regulation No. 13

Global technical regulation on hydrogen and fuel cell vehicles

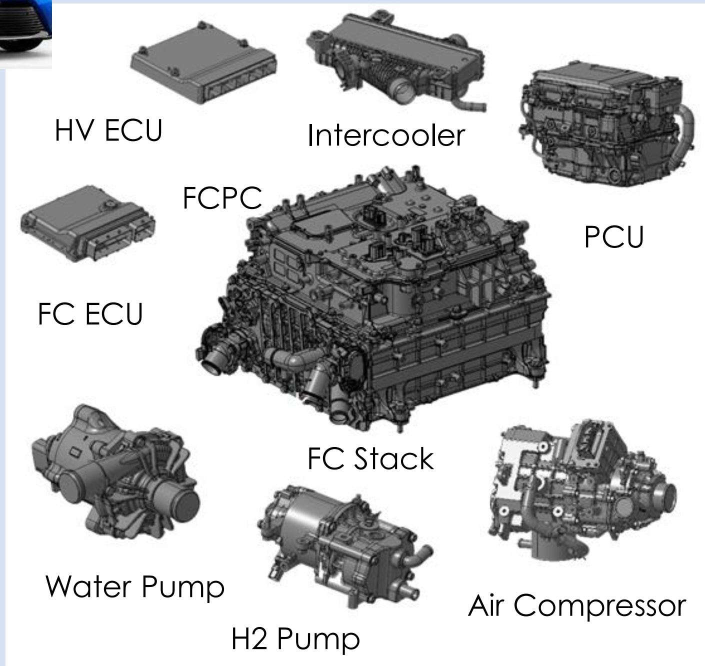
Ensure safety, but not design restrictive

FOR FURTHER EXPANSION

FC module application beyond light duty vehicle

Vehicle technology applicable to other applications

Gen2 System

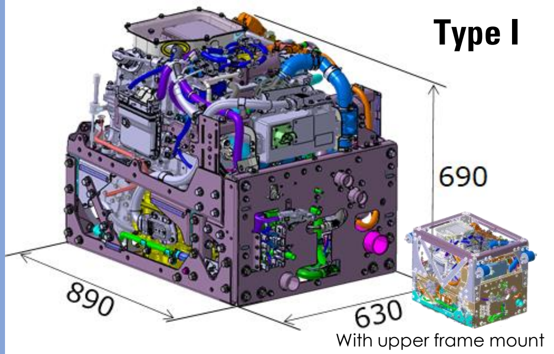


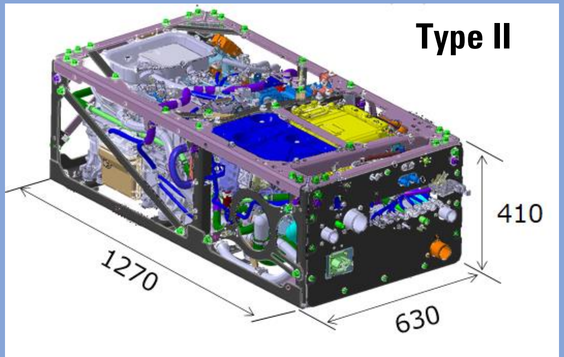
PCU Power Control Unit; FCPC: FC Power Control Unit

Gen2 Modules

- Compact
- Reliable
- Proven Mass Production Technology

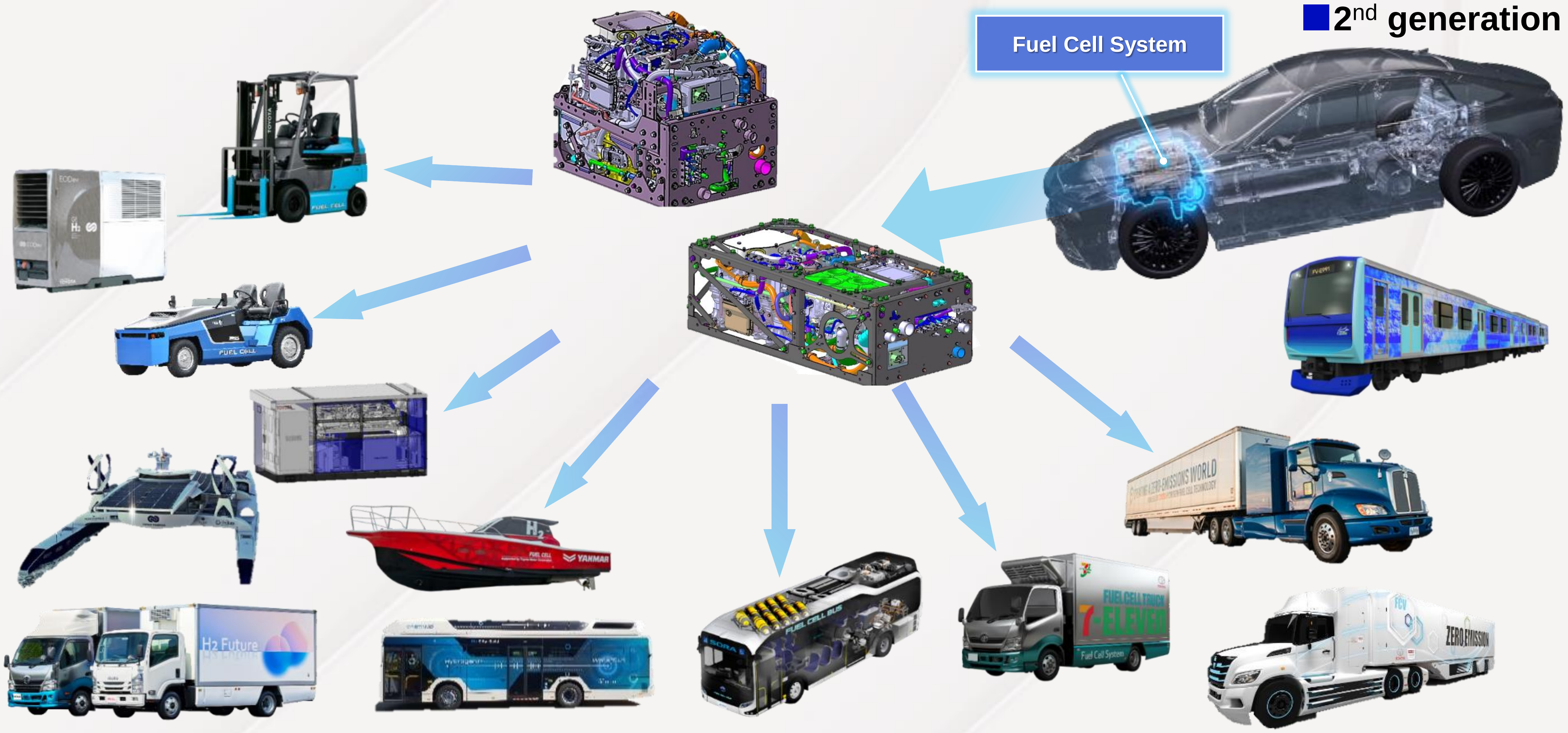
Specifications	
Weight	240kg
Rated Power [EOL]	60kW & 70kW
Voltage	400 – 750 VDC
Temperature Range	-30℃ to 45℃





Toyota's proven FC technology repackaged into 2 type of modules for use in on-road and off-road applications

Evolution of expandability



Various applications can create sufficient demand of hydrogen

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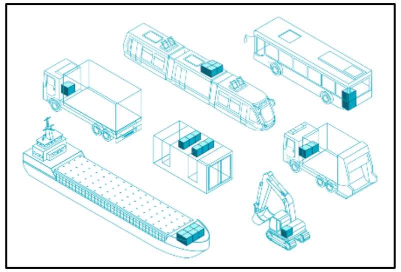
Examples of consortiums

FC module

STASHH

FCH FUEL CELLS AND HYDROGEN JOINT UNDERTAKING



Original equipment manufacturers:

ALSTOM, AVL, CETENA, DAMEN, FutureProof Shipping, SOLARIS, VDL, VDL Energy Systems, VOLVO

Fuel cell module suppliers:

BALLARD, elringklinger, FUEL CELL POWERTRAIN, FREUDENBERG INNOVATING TOGETHER, HYDROGENICS, Nedstack, Intelligent Energy, PM Fuel Cells · Power Systems, SYMBIO, NUVERA, TOYOTA

Research, test, engineering and/or knowledge institutes:

cea, FEV, SINTEF, TNO, WaterstofNet

H2 Refueling

H_2 PRHYDE Protocol for heavy-duty Hydrogen refuelling

Clean Hydrogen Partnership

Air Liquide, cea LE RIPAULT, ENGIE Lab CRIGEN, ITM POWER Energy Storage | Clean Fuel, ludwig bölkow systemtechnik, MAN, nel, NIKOLA, Shell, TOYOTA, ZBT

Ship

H2nor

10M+ USD Budget

TOYOTA, equinor, Corvus Energy, maritime cleantech, NORLED, USN, Wilhelmsen, LMG MARIN

Funded by Innovasjon Norge — H2NOR; Forskningsrådet — HyLOCD

Train

FCH2RAIL

renfe, DLR, CAF, Stemmann-Technik, Infraestruturas de Portugal, adif, Centro Nacional del Hidrógeno, TOYOTA

Creating a "society" cannot be done by one company alone

We will continue to work hard together with like-minded partners

TOYOTA is on the way to realizing a hydrogen society.
We are moving towards that goal by continuing to develop a FC system for a wider range of customers!

Thank You