

An Update on Toyota's Fuel Cell Vehicle Activities

Hydrogen and Fuel Cell Technical Advisory Committee

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Issues that Influence Automobile Business

Issues	*Action*	*Potential Solution*
Petroleum Supply	Energy & Fuel Diversification	Biofuels Green Electricity Natural Gas
Climate Change	Life Cycle CO_2 Reduction	Improved Efficiency Low Carbon Fuels
Balance of Trade	Reduce Imported Fuel	Fuels from Domestic Feedstocks
Energy Security	Reduce Imports from Unfriendly Countries	Fuels from Domestic Feedstocks

Hybrid is First Step

TOYOTA MODELS

Prius
Midsize 5 Door

Camry Hybrid
Midsize 4 Door

Highlander Hybrid
Midsize SUV

Averaging over 20,000 hybrids sold per month in 2008

LEXUS MODELS

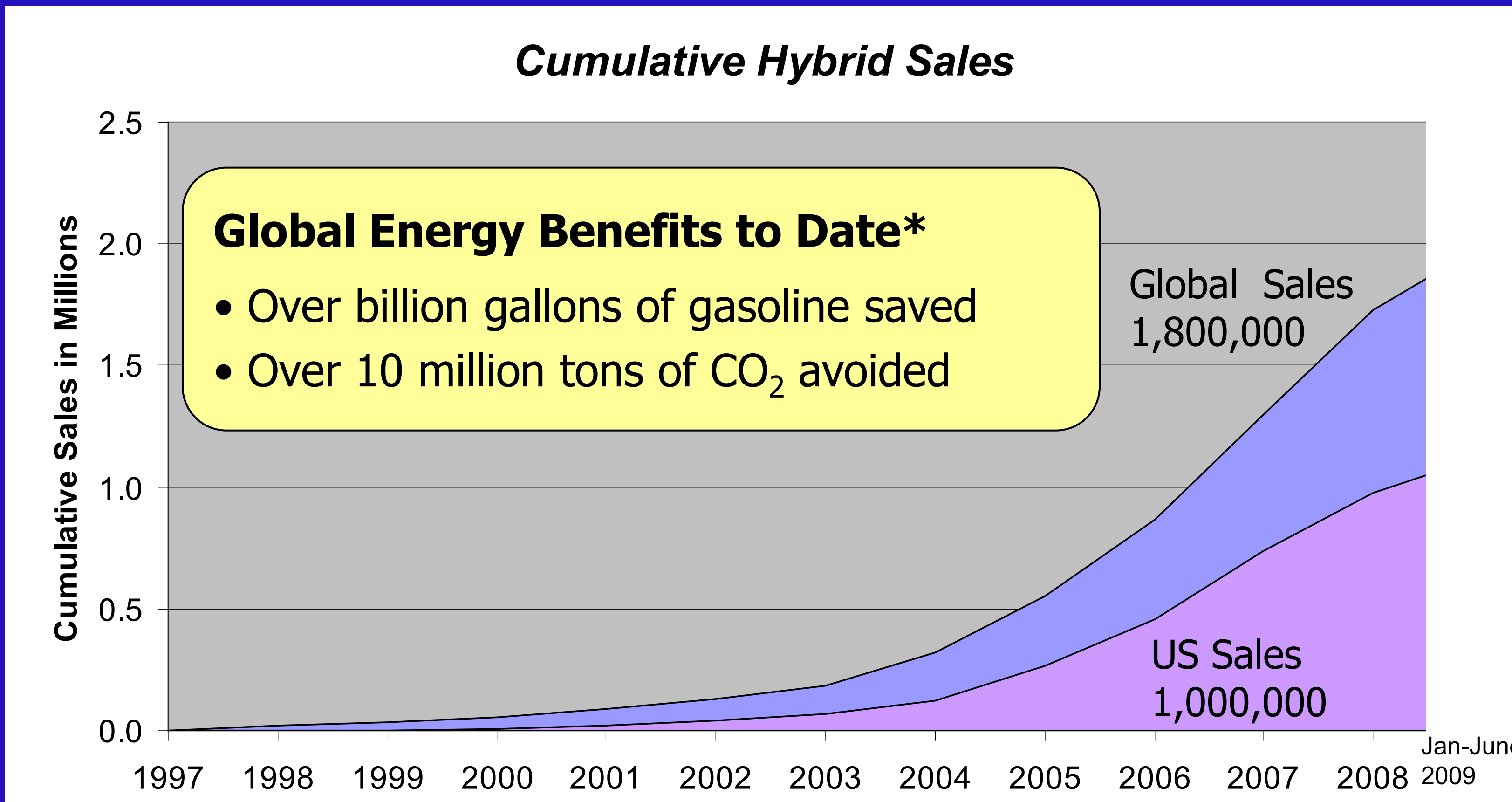
RX450h
Luxury SUV

HS250h
Midsize Sedan

GS450h
Premium Sport Sedan

LS600h
Flagship

The Big Picture



New technologies must be produced in large volumes to make a meaningful impact

*Toyota Estimate

Comparison of Energy Efficiency

	Energy pathway	Well-to-Tank (50%)	Tank-to-Wheel *1 (50%)	Well-to-Wheel *1 (20%, 40%)
FCHV-adv	Natural gas ↓ Reforming with membrane separation → Hydrogen (70MPa)	67% *2	59%	40%
EV	Natural gas ↓ Combined cycle power generation → Electricity	39%	85%	33%
Gasoline HV (Prius)	Crude oil ↓ Refine → Gasoline	84%	40%	34%
Gasoline ICE	Crude oil ↓ Refine → Gasoline	84%	23%	19%

*1 Tank-to-Wheel efficiency: measured in the Japanese 10-15 test cycle
*2 Difference of Well-to-Tank efficiency between 35MPa and 70MPa: approx. 2%

(Toyota Calculation)

FCs are tough to beat for well-to-wheels efficiency

Toyota FCHV Progress

			Present	2015
Vehicle	 Dec. 2002 ~ '02 FCHV (lease model)	 Jul. 2005 ~ '05 FCHV (lease model)	 '08 FCHV-adv (lease model)	FCCJ* / DOE Target * Fuel Cell Commercialization Conference of Japan Commercial Introduction → Mass Production
Technical Challenges				
1. Cold Start / Driving Capability	0degC ~	0degC~	-30degC	
2. Actual Cruising Range	210km	230km	500km or more	
3. FC Stack Durability				15 years or more
4. Cost reduction				1/10 or less (design / materials)

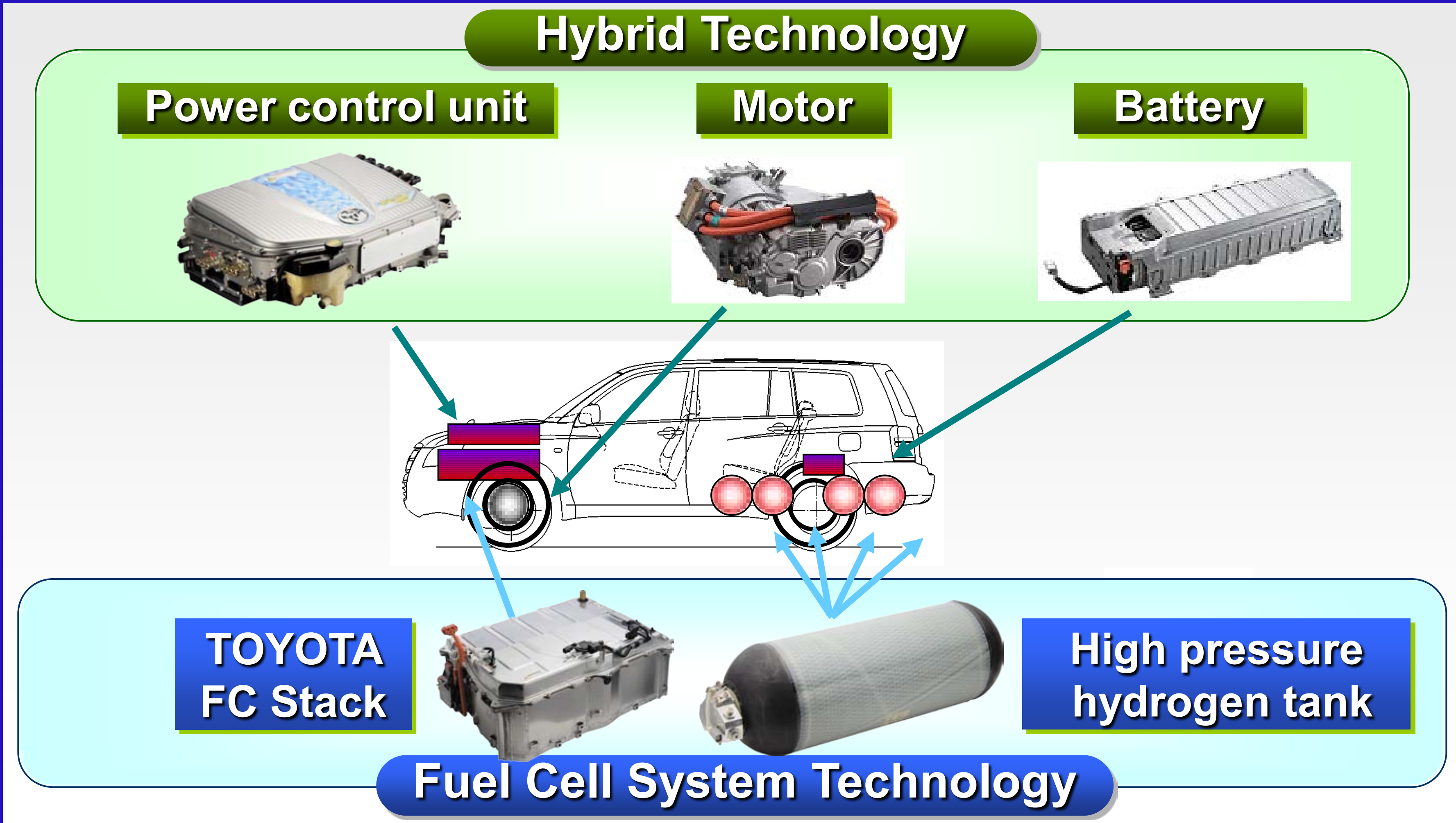
Toyota is making excellent progress resolving technical challenges

FCHV-adv

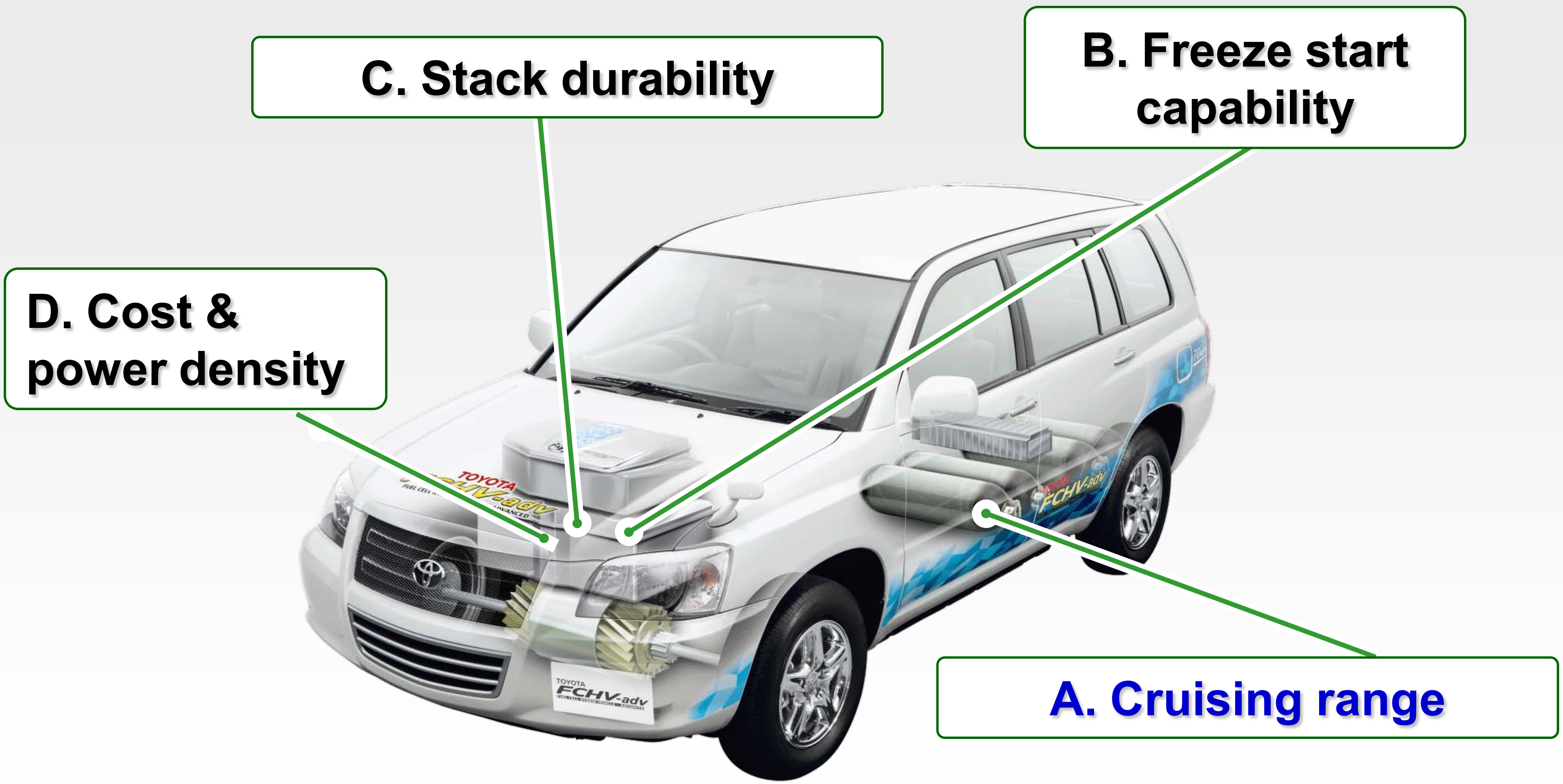
*1 in LA#4 cycle

Vehicle	Overall length/ width/ height (mm)	4,735/ 1,815/ 1,685	Fuel	Type	Pure hydrogen
	Max. speed (mph)	96		Storage system	High-press. H_2 tank
	Cruising range (mile)	455 *1		Max. storage pressure (MPa)	70
	Fuel economy (mile/kg H_2)	72.4 *1		Tank capacity (kg H_2)	6.0 (35 degC)

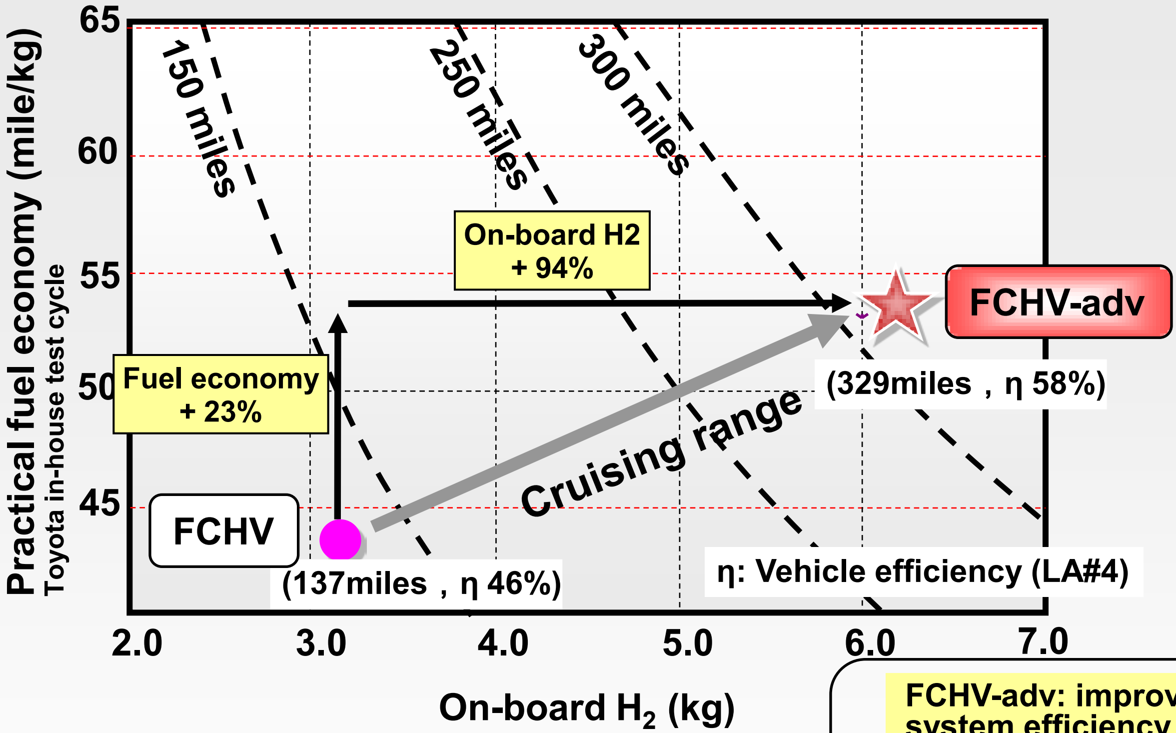
Fuel Cell System Technology



Key Technical Challenges for FC Vehicles



Cruising Range Improvement



Test cycle	FCHV-adv
LA#4	455 miles
Japanese 10·15 in-house test	516 miles

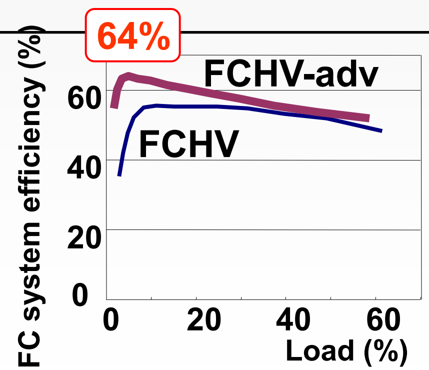
FCHV-adv: improved FC system efficiency at all loads

+

Increased regenerative energy

↓

Improved vehicle efficiency (fuel economy)



FCHV-adv has achieved an practical cruising range of well over 300 miles

TOYOTA

FCHV-adv Real-World Range

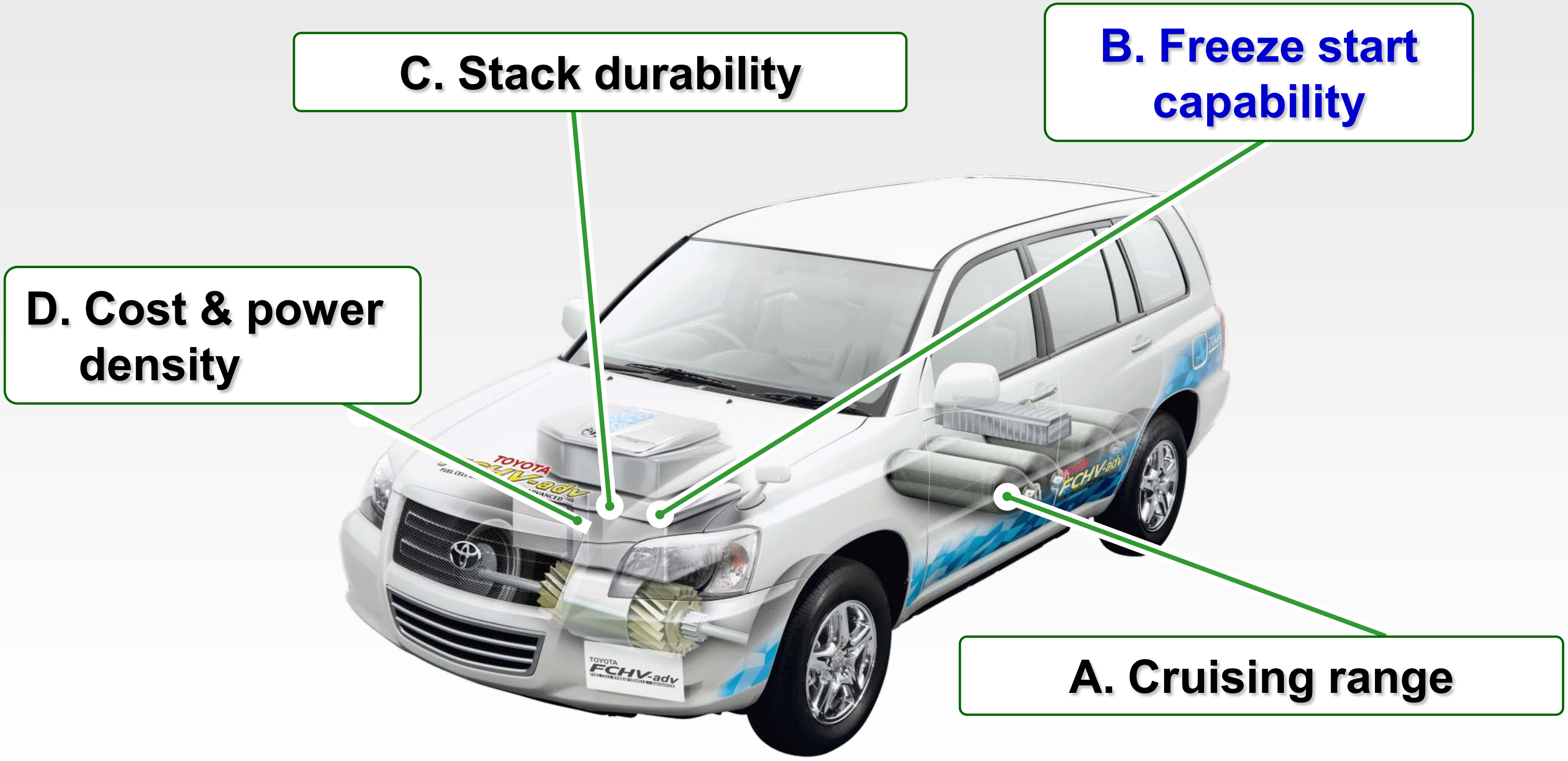
Rush Hour in Los Angeles

- 2 FCHVs
- Over 400 miles / tank
- 68.3 miles/kg of H_2

Fairbanks to Vancouver

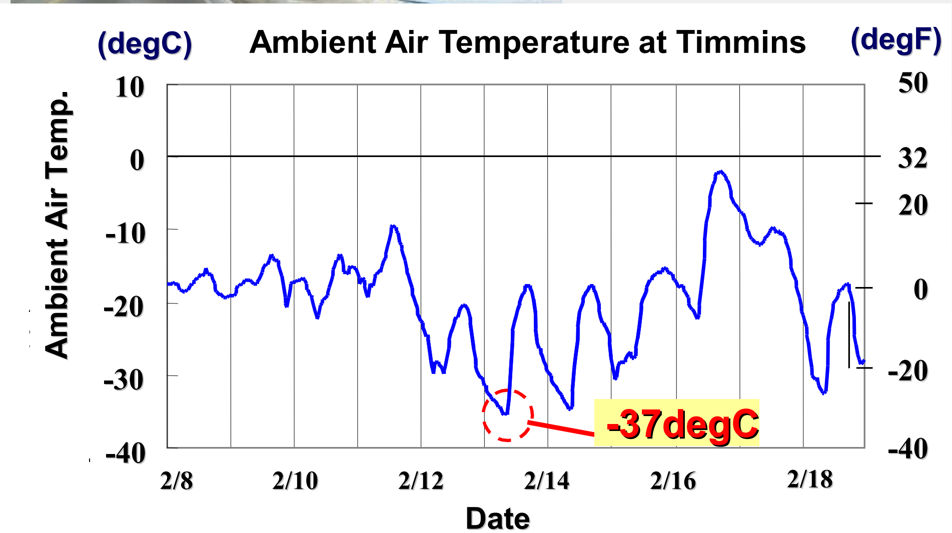
- 2300 miles
- Over 300 miles / tank
- No mechanical problems

Key Technical Challenges for FC Vehicles



Demonstrated Cold Start Capability

Timmins, Canada

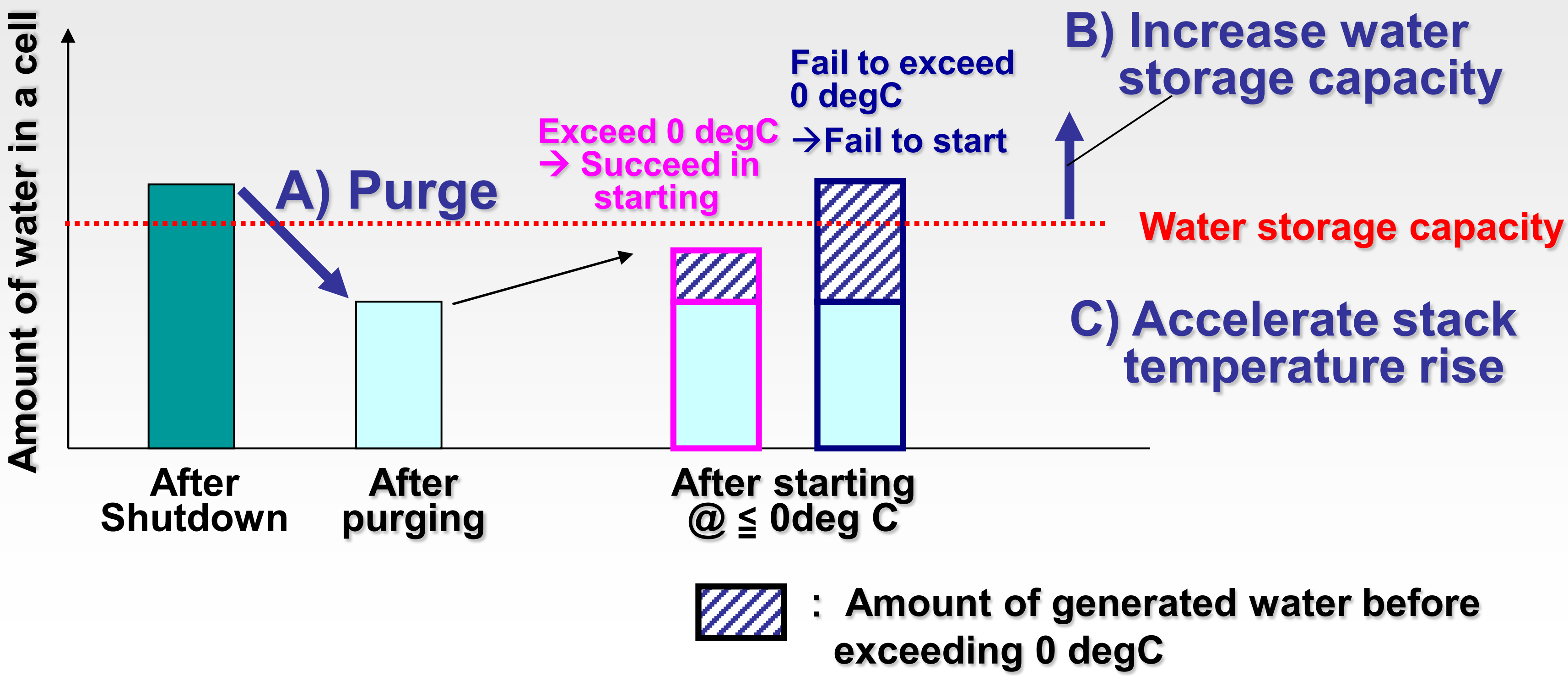


Yellowknife, Canada

Cold weather performance similar to conventional vehicles

Cold Start Countermeasures

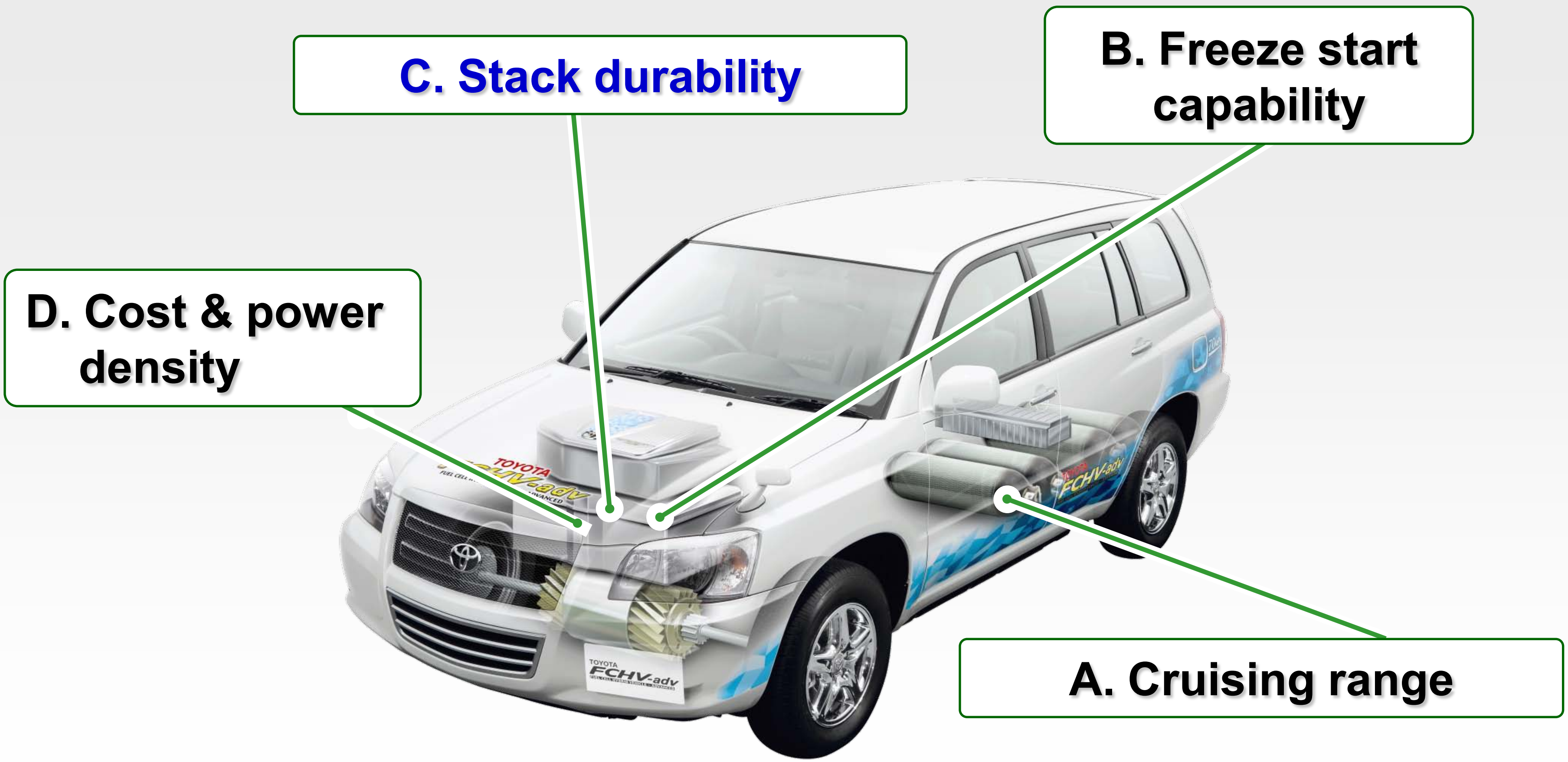
Management of water when starting at subfreezing temperature



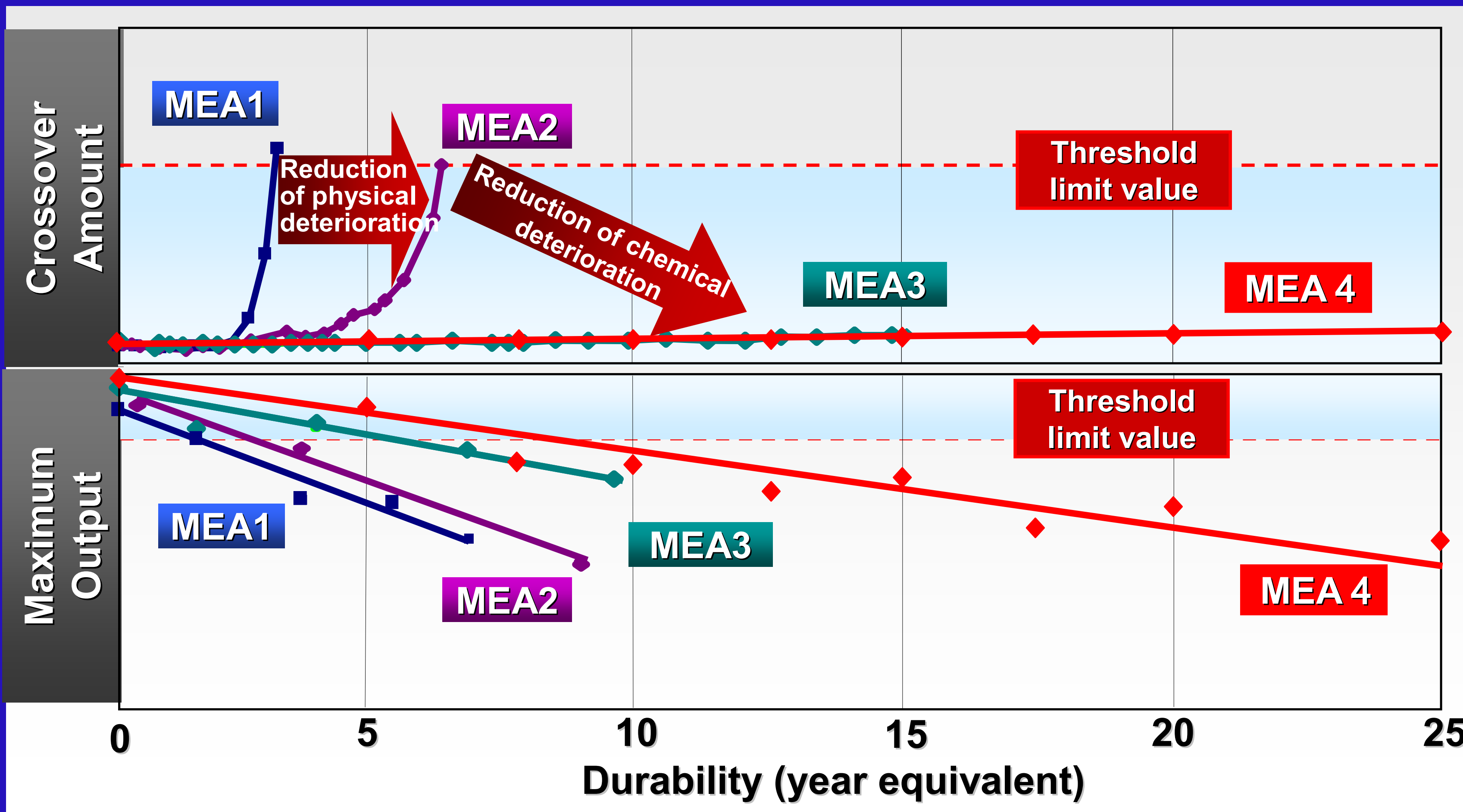
Measures important for cold start capability:

- A) Optimum purge to reduce remaining water
- B) Increase of water storage capacity
- C) Accelerating stack temperature rise

Key Technical Challenges for FC Vehicles



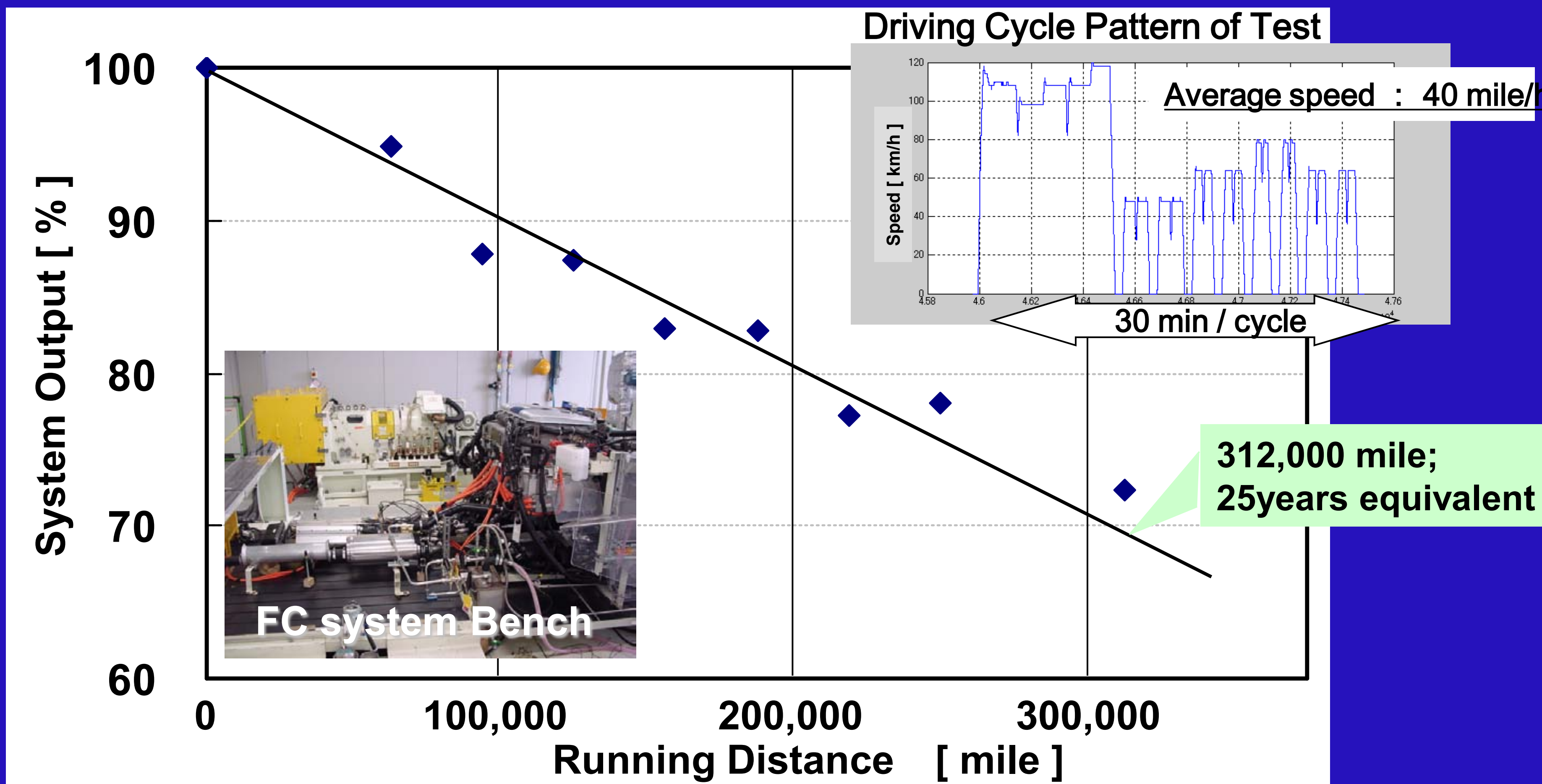
Toyota FC Stack Durability



MEA durability is steadily improving under real-world conditions

TOYOTA

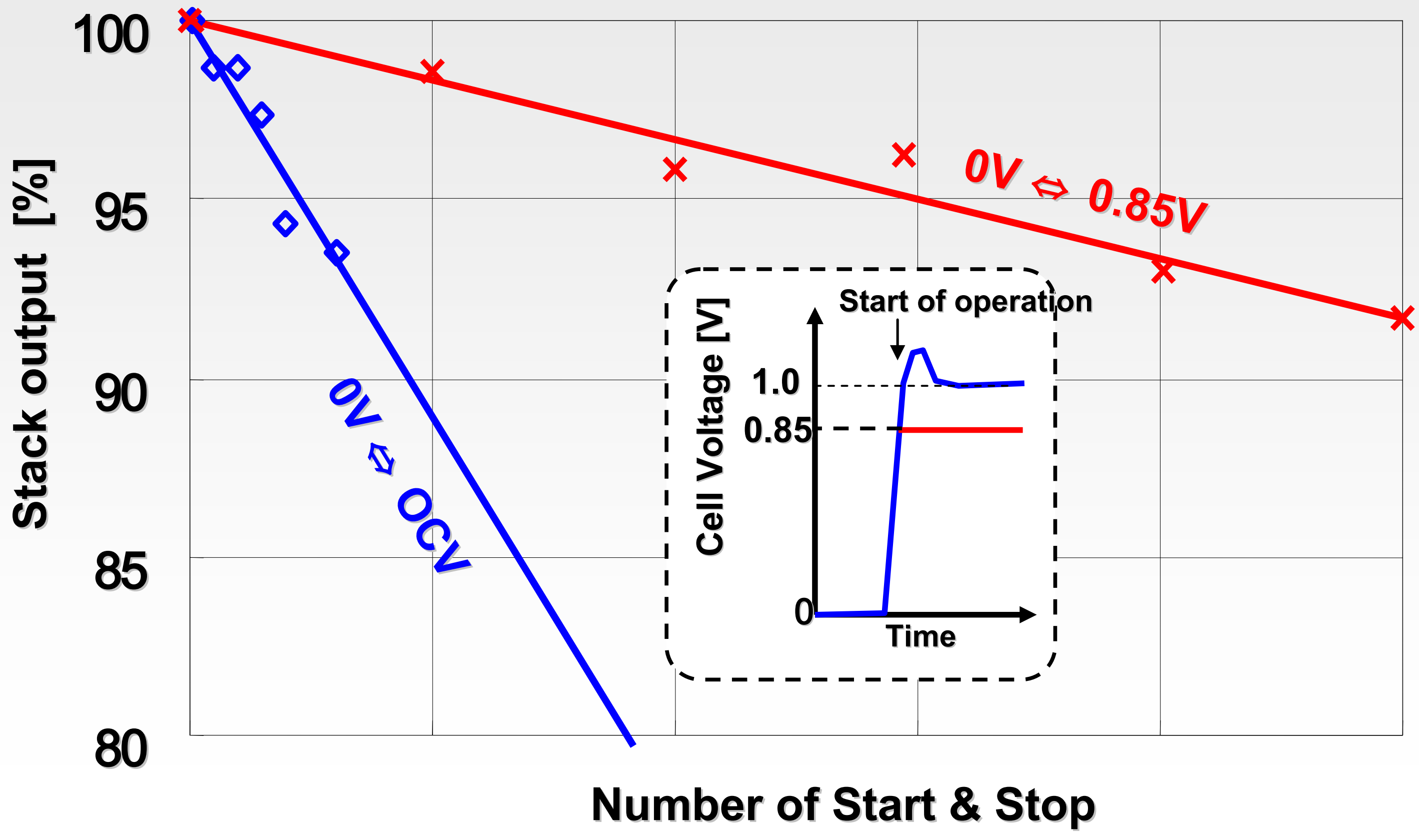
FC System Durability



Testing indicates linear degradation to the equivalent of 25 years

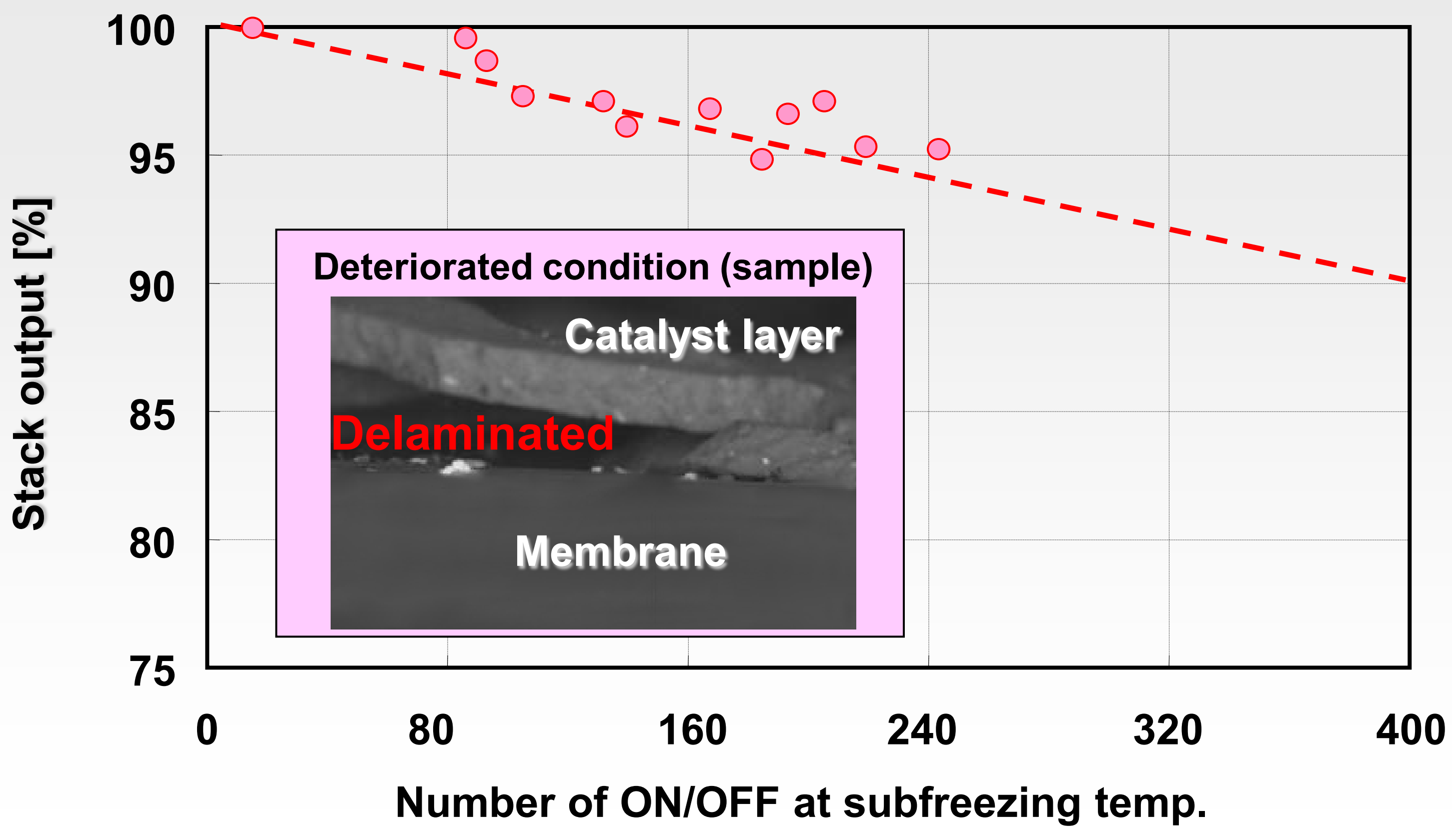
Degradation During Start-up & Shutdown

1. Degradation due to potential change at starting



Votage at start-up and shutdown must be managed

Cold Start Degradation



Must minimize degradation from cold starts

FC Stack Durability Summary

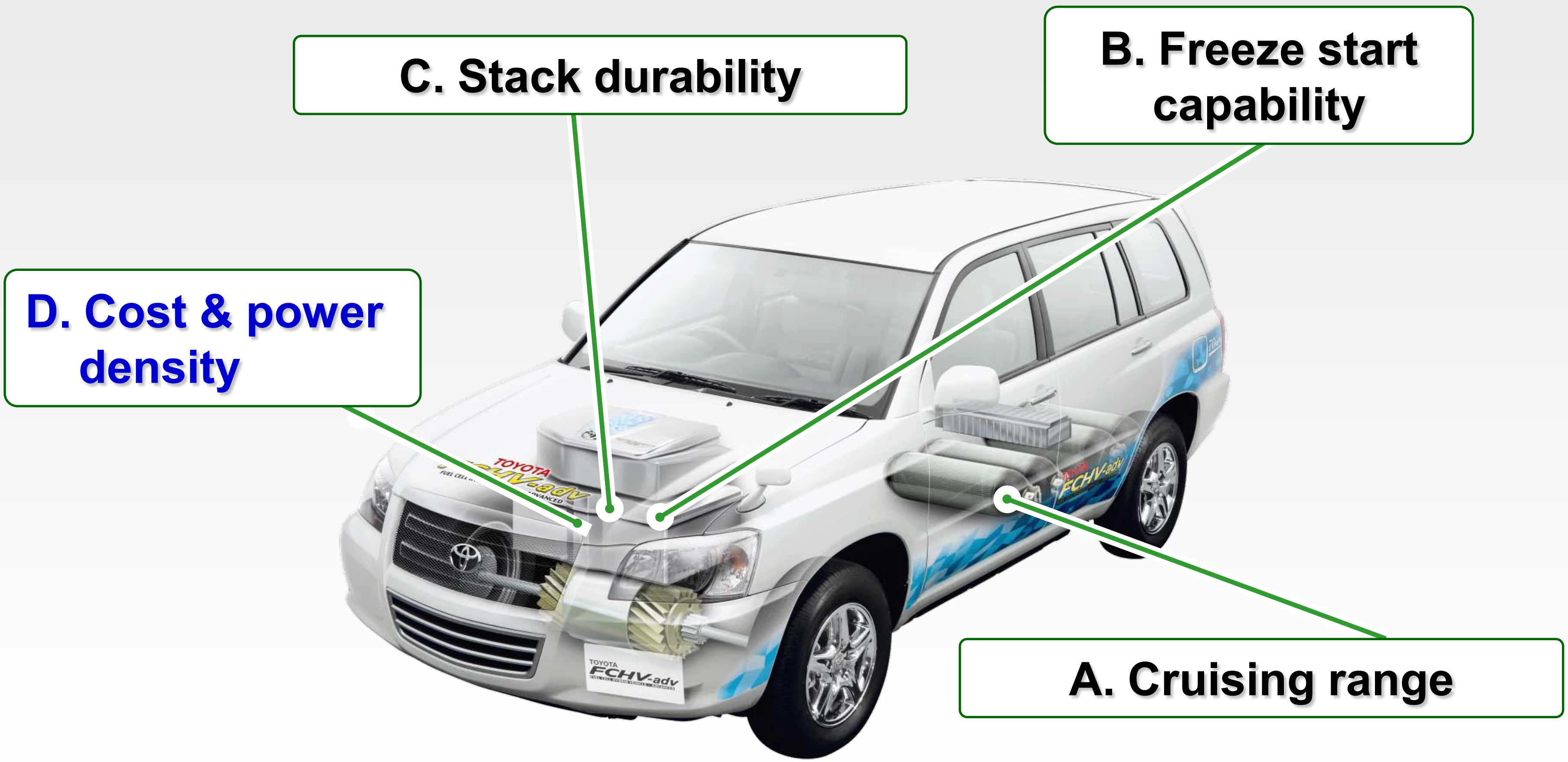
Confirmed system durability of FCHV-adv:

- 25-year equivalent durability on crossover
- Approximately 70% of initial performance after the equivalent of 25 years operation

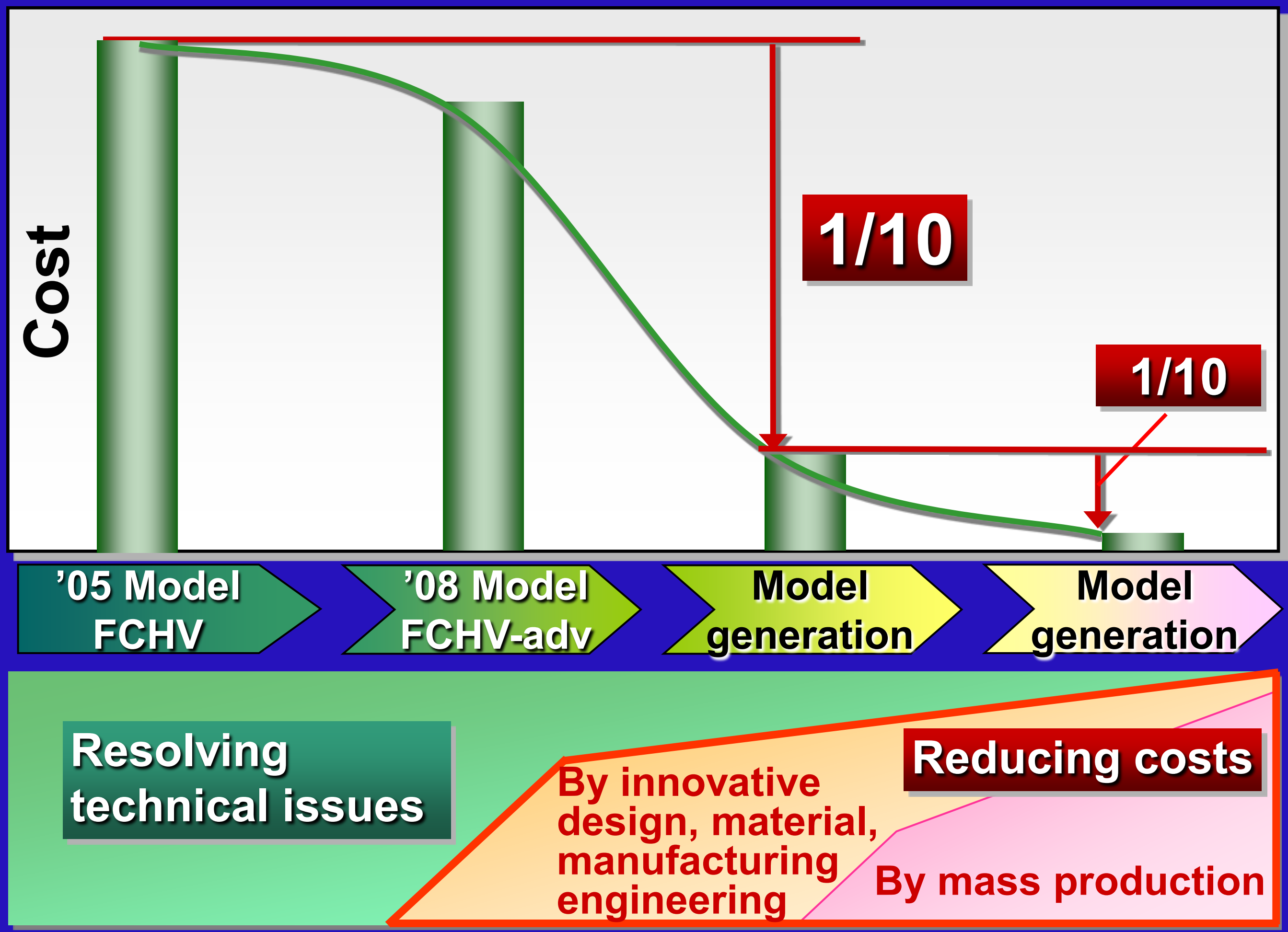
Next steps:
Develop countermeasures to enhance durability

- Reduce start/stop and cold start degradation
- Confirm correlation between laboratory and field test data

Key Technical Challenges for FC Vehicles



FCHV Cost Reduction



Approaches to FCHV Cost Reduction

TOYOTA FCHV

(1) Design

1. Simplify the system
2. Downsize and reduce weight of FC stack

(2) Materials:

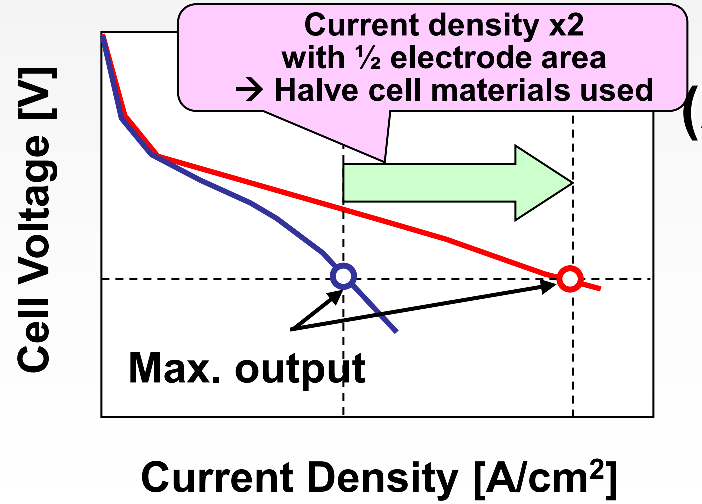
Reduce the cost of FC-system-specific materials

=> **Important to cooperate with materials manufacturers**

(3) Improve production technology

FC Stack Cost Reduction

TOYOTA FC Stack



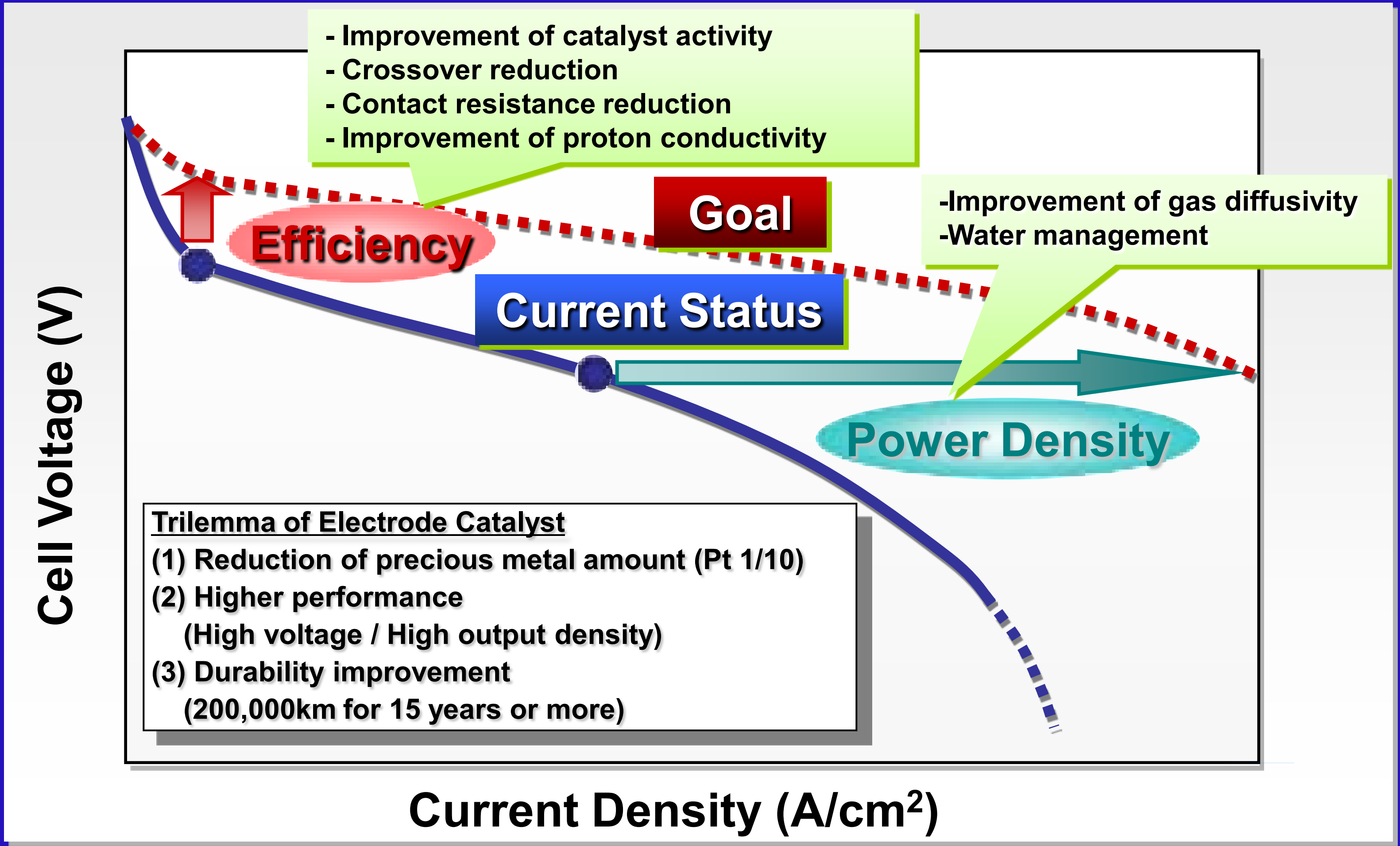
(1) Design: Downsize & reduce weight (minimize materials)

1. Increase output density
2. Reduce number of parts
3. Improve joint/seal method
4. Decrease Pt catalyst loading

(2) Material: Improve durability & reduce cost

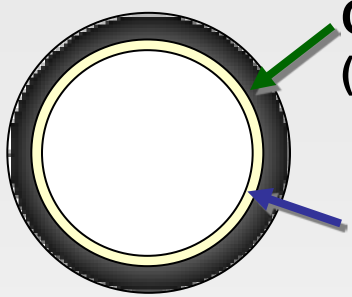
1. Electrolyte membrane
2. Separator (incl. surface treatment)
3. GDL, etc.

Electrode Catalyst "Trilemma"

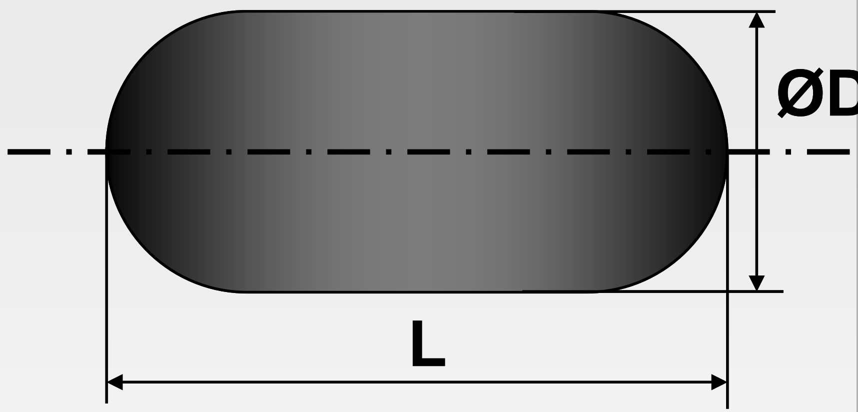


Must solve electrode catalyst "trilemma" to achieve FC stack cost targets

Hydrogen Tank Cost Reduction



Cross-section of tank body



Tank dimension

(1) Reduce CFRP used (by making thinner)

- Optimize laminar structure (hoop winding / helical winding)
- Optimize L/D
- Optimize boss size

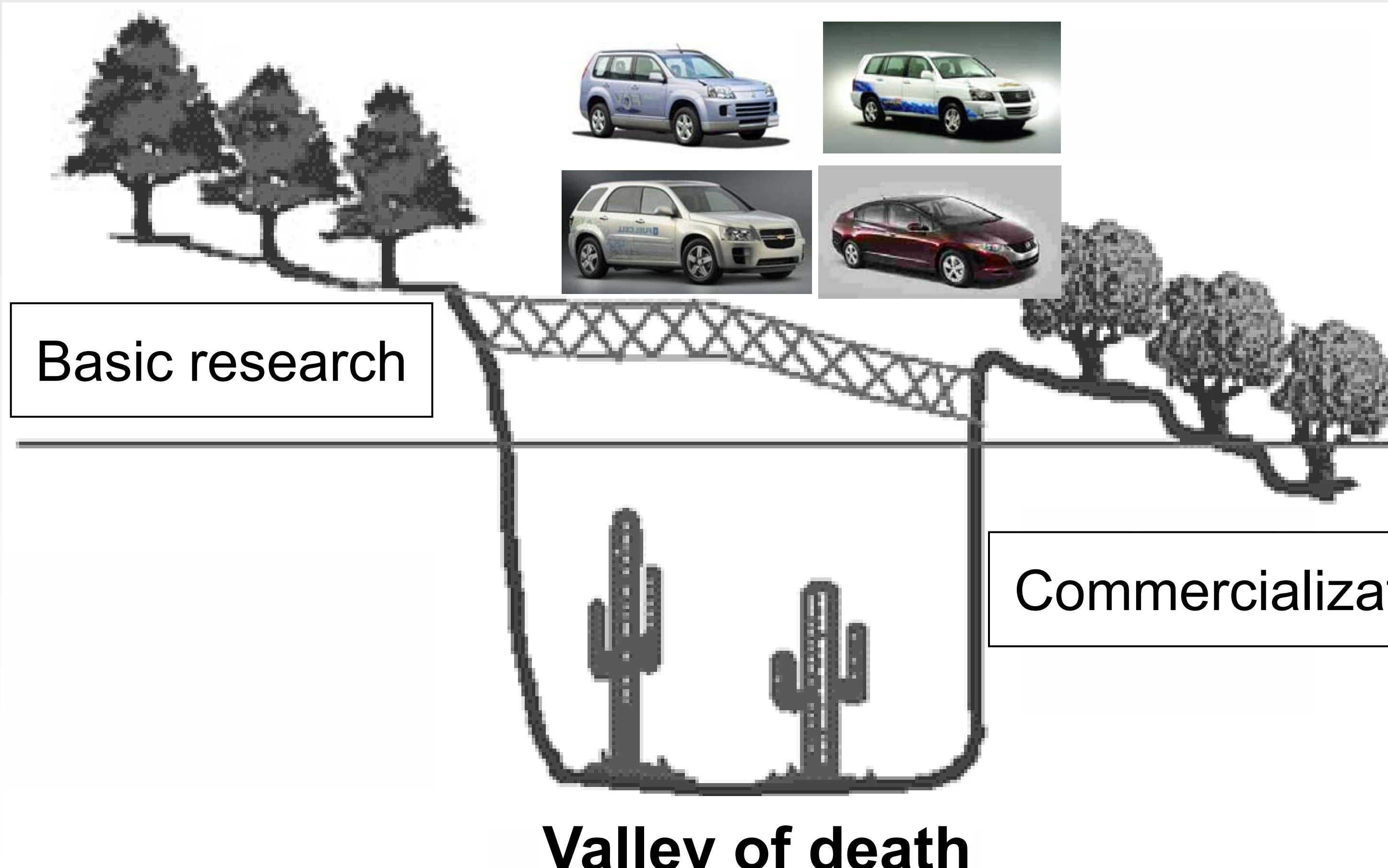
(2) Reduce cost of CFRP

- Aviation grade => general-purpose grade
- Develop low-cost CFRP for high-pressure tank

Development of Production Technology

(1) Web handling technology

Progress of FC Technology Development



Source of pictures: each automaker's web site (excluding TOYOTA FCHV)

FC development is more than half way over the "Valley of Death"

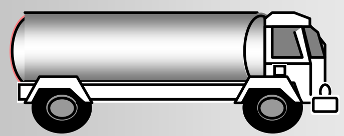
Steps for Commercialization

Production

- Solar / biomass
- Coal
- Petroleum
- Natural Gas
- Electricity

→ Hydrogenated compounds →

Delivery, Supply



→ Hydrogen →

Vehicle

Issues (Production)

- Production
- Storage method
- CO_2 Stabilization
- Cost

Issues (Delivery, Supply)

- Transportation Method
- Infrastructure Development
- Codes & Standards
- Hydrogen Delivery Cost

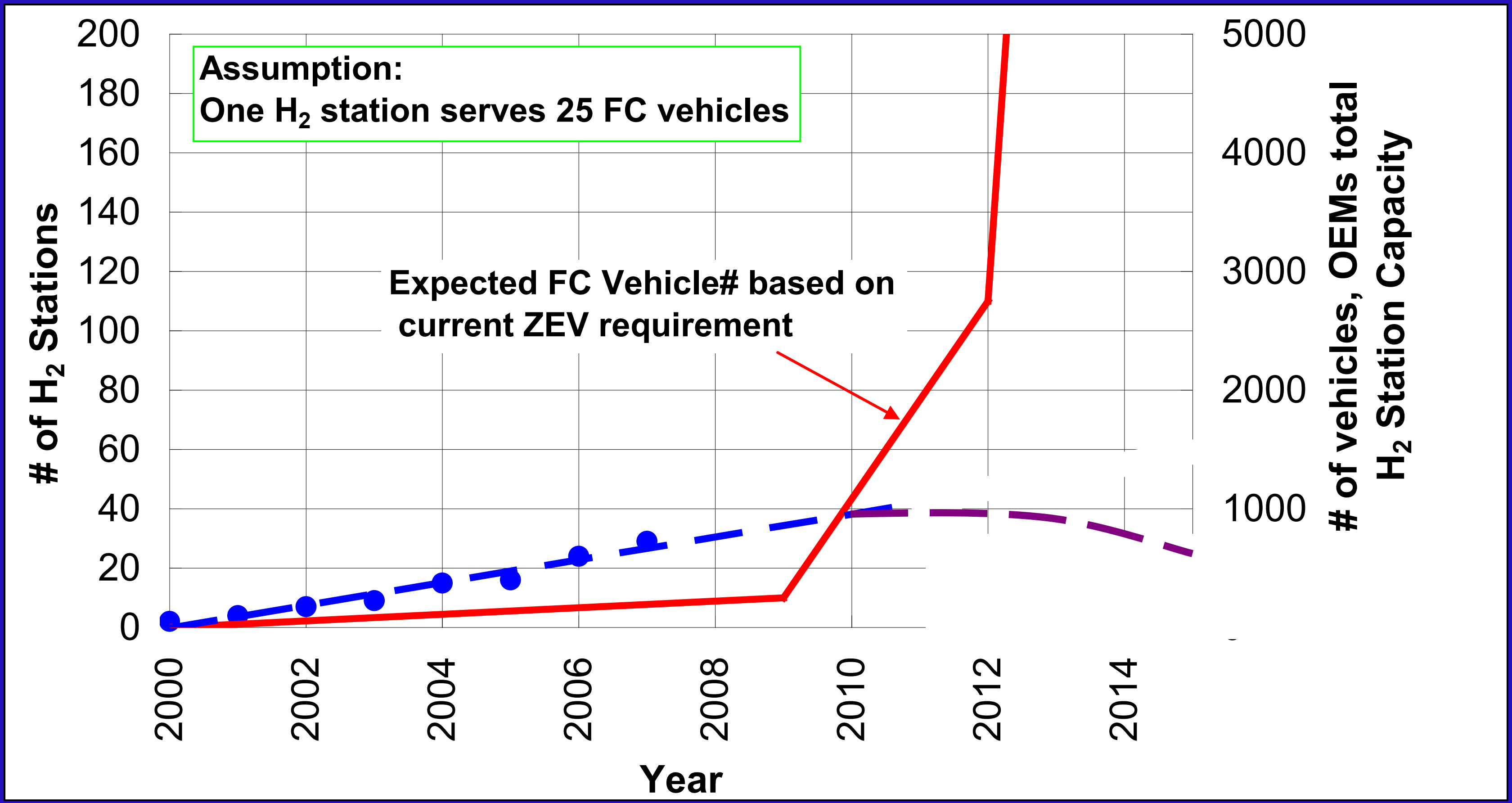
Issues (Vehicle)

- Stack Durability
- Power Density
- Freeze Start Capability
- Driving Range
- Vehicle Cost

Government, Energy Suppliers

Car makers

California Infrastructure Concern



By the 2012, the demand for H_2 stations will far exceed supply if station deployment is not accelerated

Conclusions

- Hydrogen is one of the future fuels Toyota is pursuing
- We continue to devote considerable resources to bringing a FC vehicle to market in the 2015 time frame
  - Cold start & range issues are mostly resolved
  - Durability & cost challenges remain
- "Green" fuels and high volumes are required for meaningful GHG benefit
- Deployment of hydrogen refueling infrastructure must accelerate for fuel cell vehicles to succeed

Thank You!