Submittal to:
California Energy Commission
Advisory Committee Meeting and Public Workshop for the Alternative and Renewable Fuel and Vehicle Technology Program, Dec.4, 2012
2013-2014 Investment Plan Update
Re: Docket No. 12-ALT-02

California Energy Commission
DOCKETED
12-ALT-02
TN # 68969
DEC. 21 2012

Progress and Challenges for TOYOTA's Advanced Powertrain Development

December 20, 2012

Energy & Environmental Issues of the Automobile

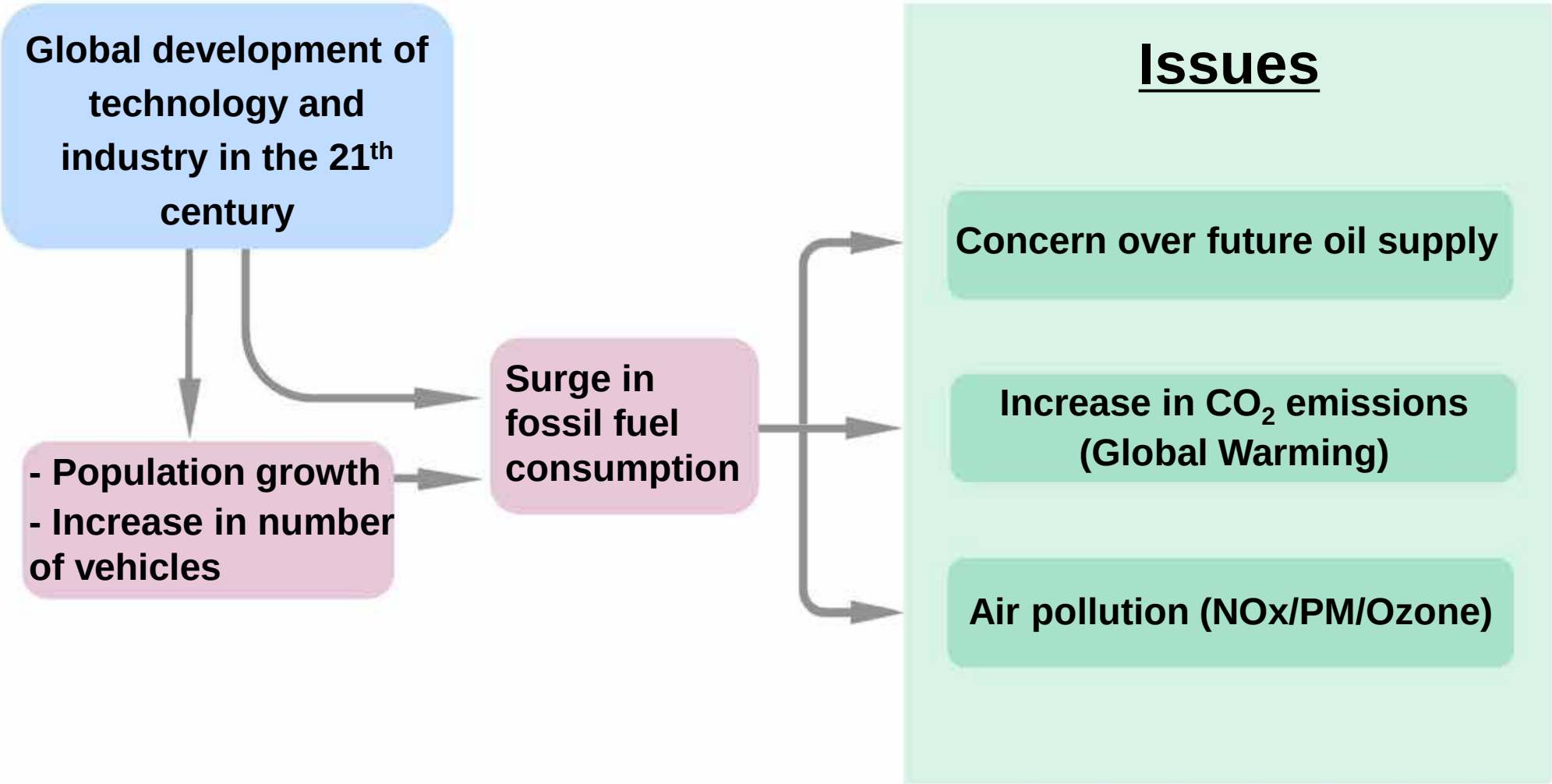
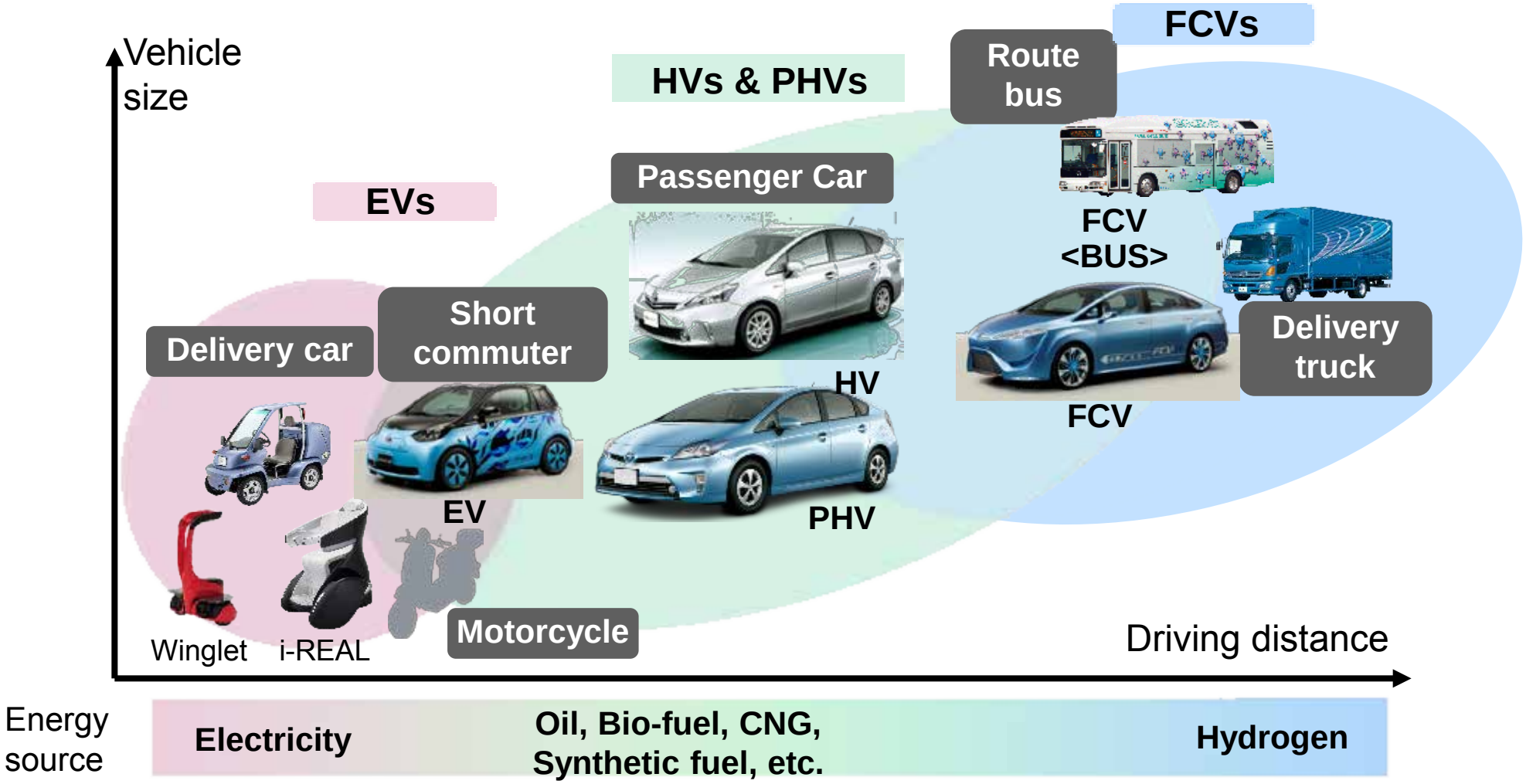
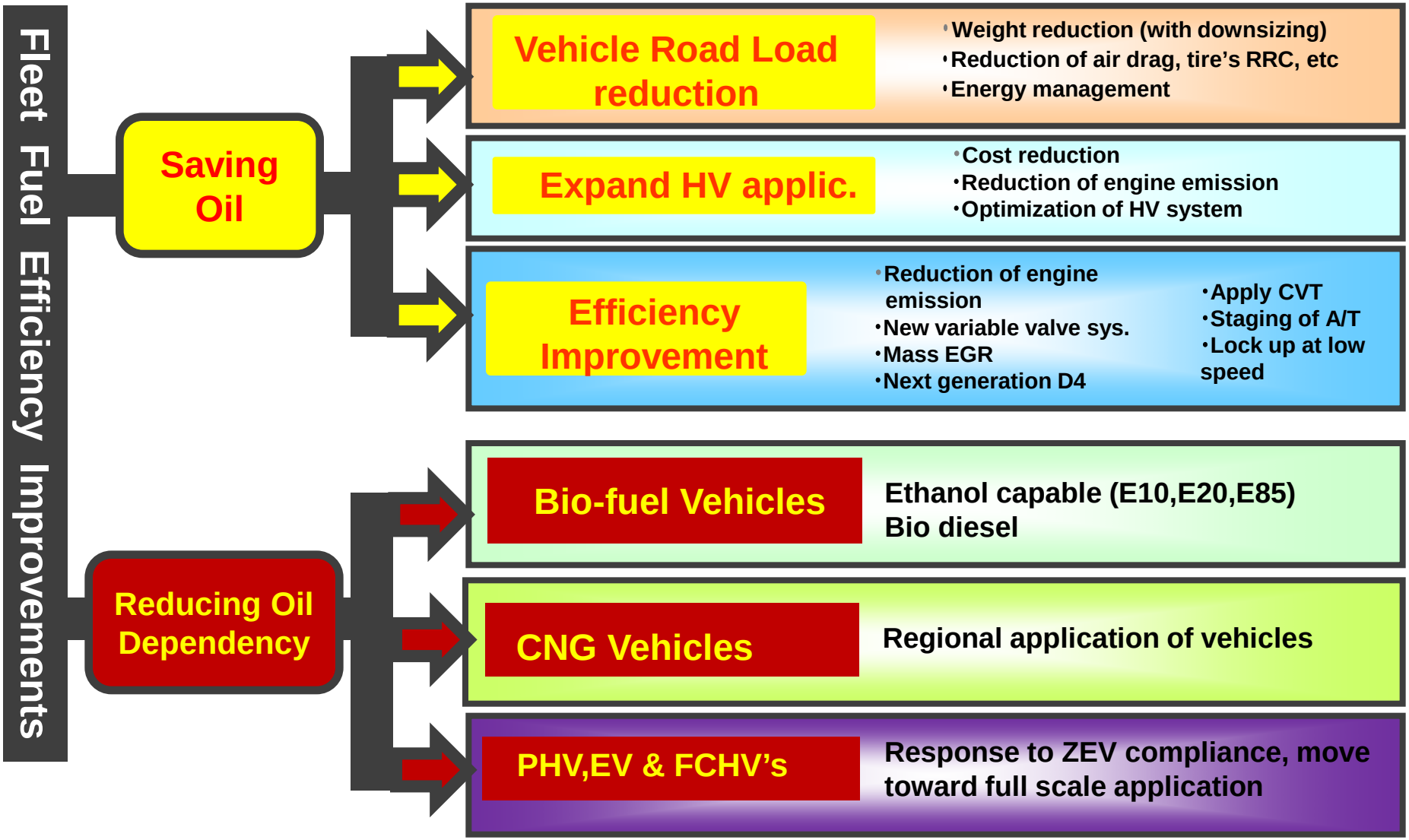


Image of Future Mobility Portfolio

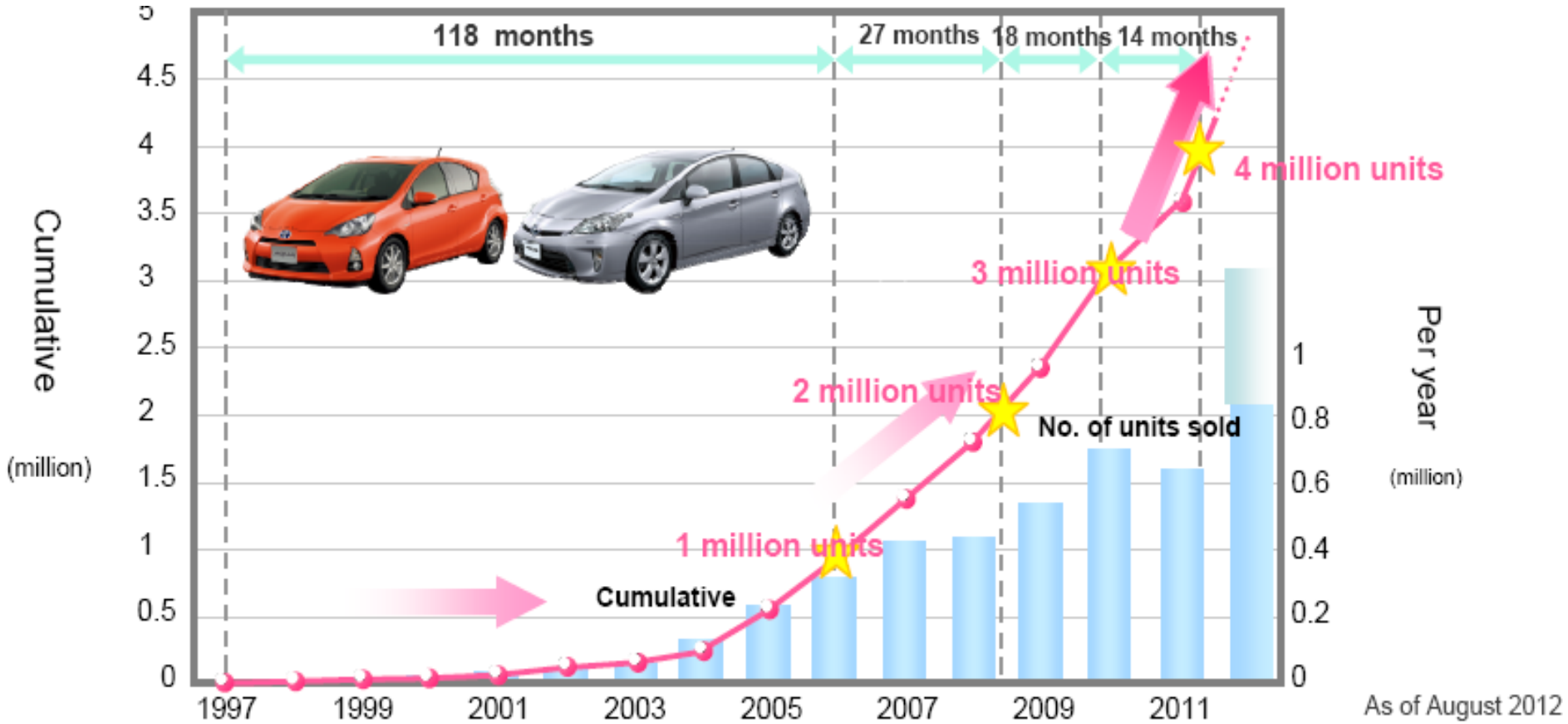


HV & PHV: Wide-use
EV: Short-distance, FCV: Medium-to-long distance

Pathways to Improved Fuel Efficiency

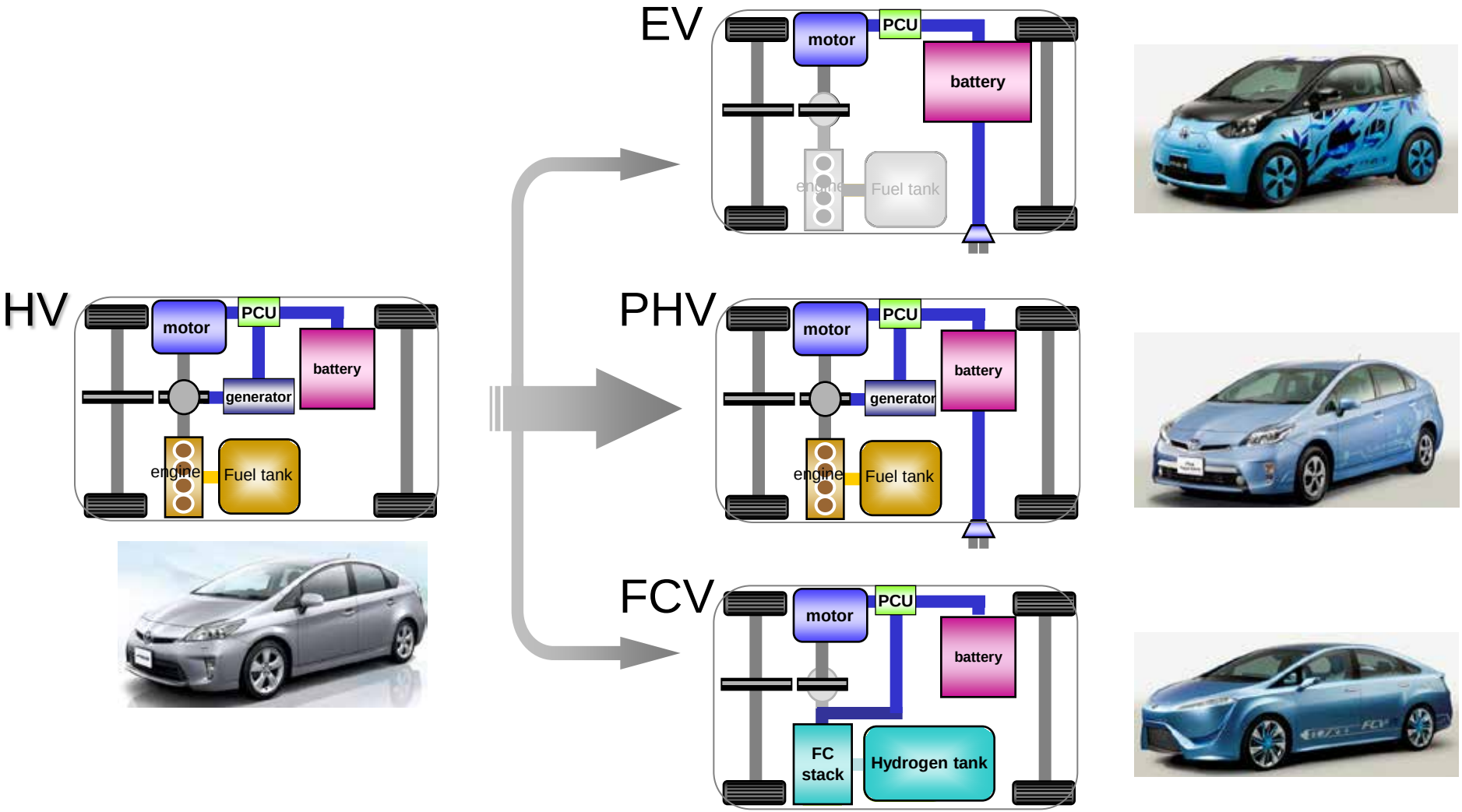


History of Hybrid Vehicle Sales



We estimate that over 1 million hybrids will be sold globally in 2012

Applying Hybrid Technology



Hybrid technology is a core technology of PHVs, EVs, and FCVs, and their fundamental technologies

BEV Characteristics

Advantages

- No driving emissions
- Quiet running
- Rechargeable with household outlet

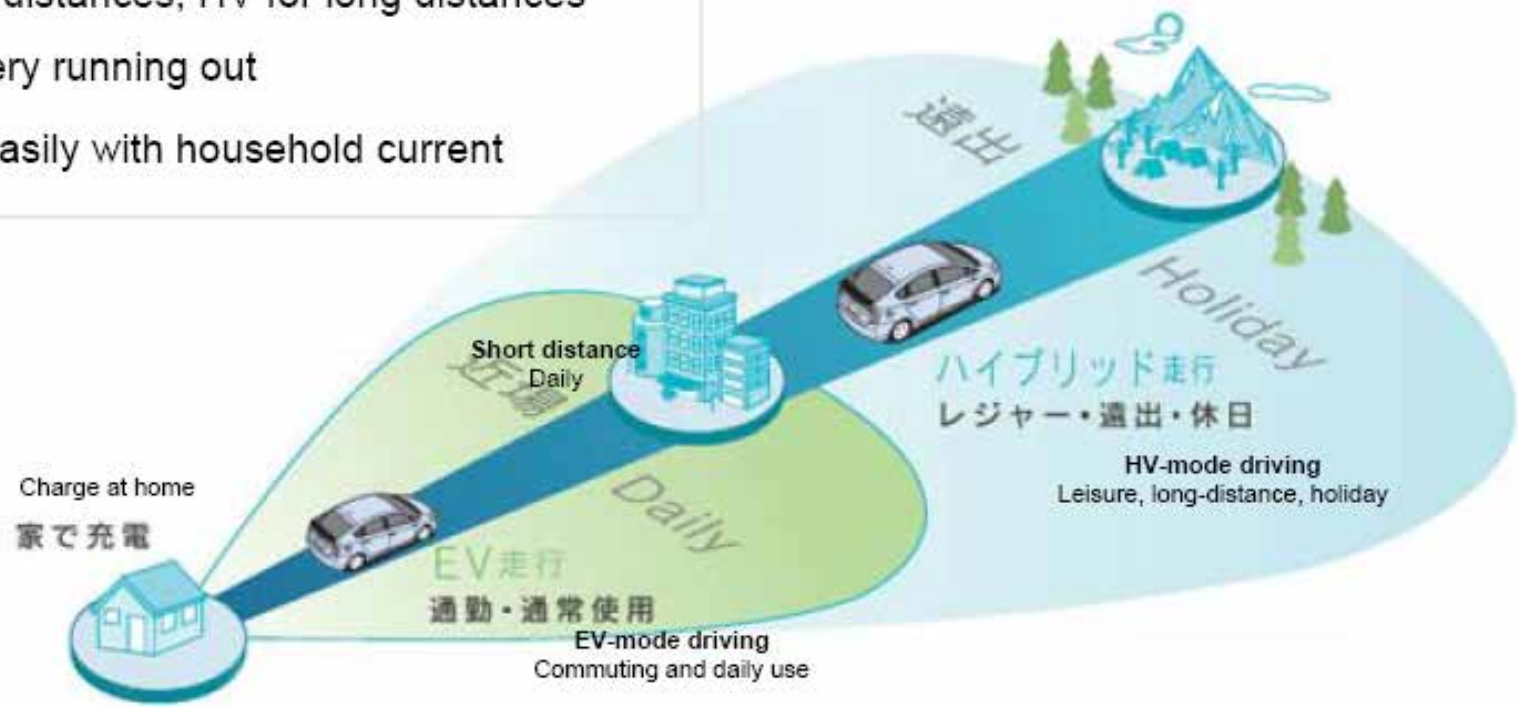
Disadvantages

- Shorter driving range
- High battery cost
- Long charging time
- Need for quick charger infrastructure

EVs are for short-distance commuting and fleet use

PHEV Characteristics

- Use as EV for short distances, HV for long distances
- No concern for battery running out
- Can be recharged easily with household current

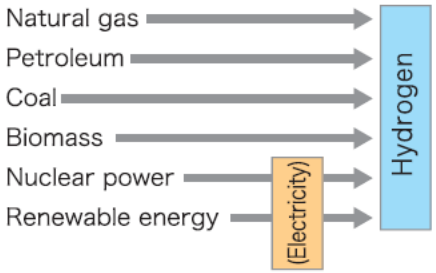


PHV is the integration and innovation of HV and EV technologies

Advantages of FCVs

Energy diversification

- Hydrogen can be produced from various primary energy sources



Zero emissions

- Zero CO_2 emissions during driving

Performance

- Practical cruising range (over 500 km)
- Refueling time (three minutes)
- Fuel cell start-up below freezing (-30ºC)

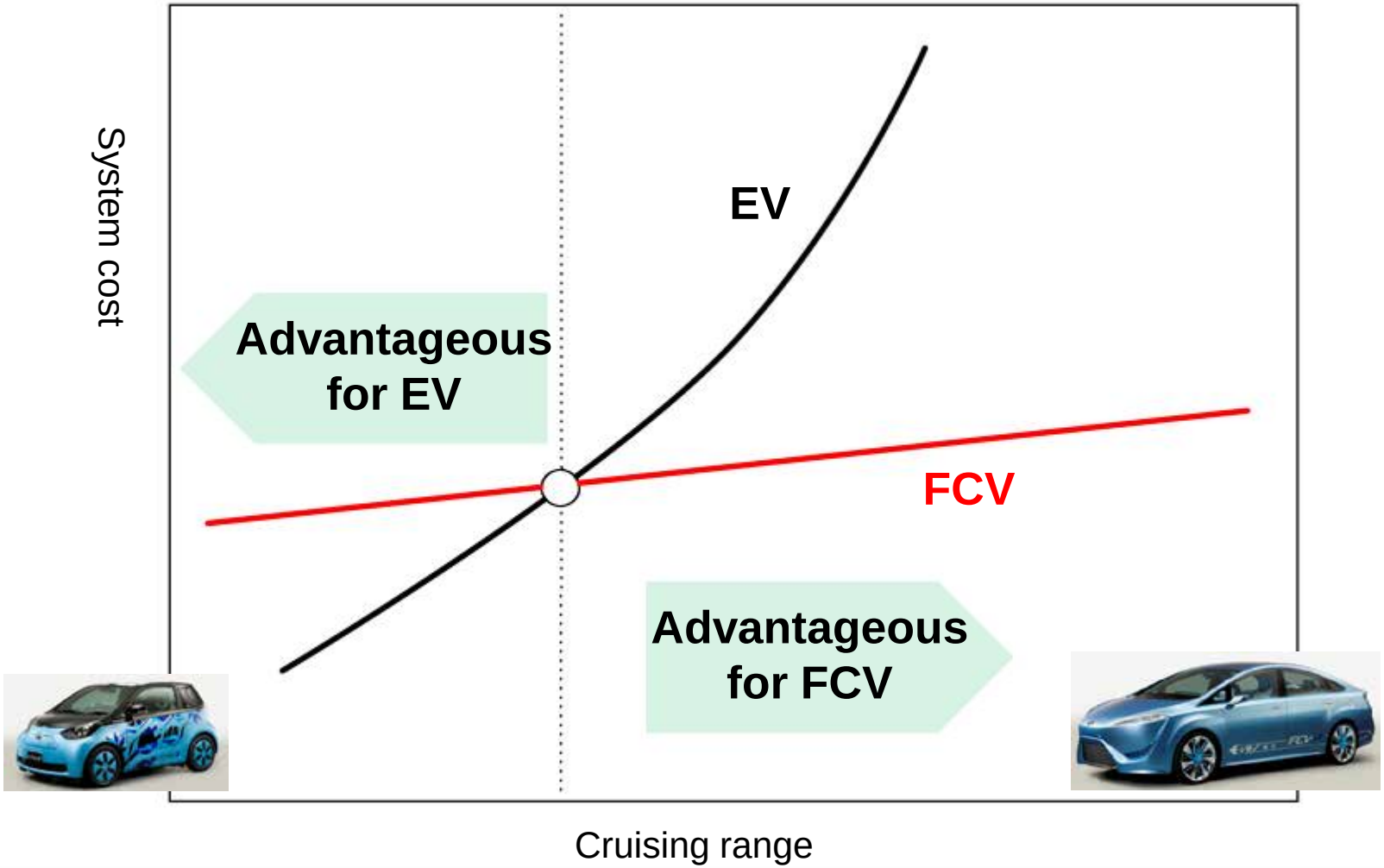
Driving pleasure

- Smooth and quiet operation
- Smooth start and good acceleration at low and medium speeds

Large power supply capability for emergencies

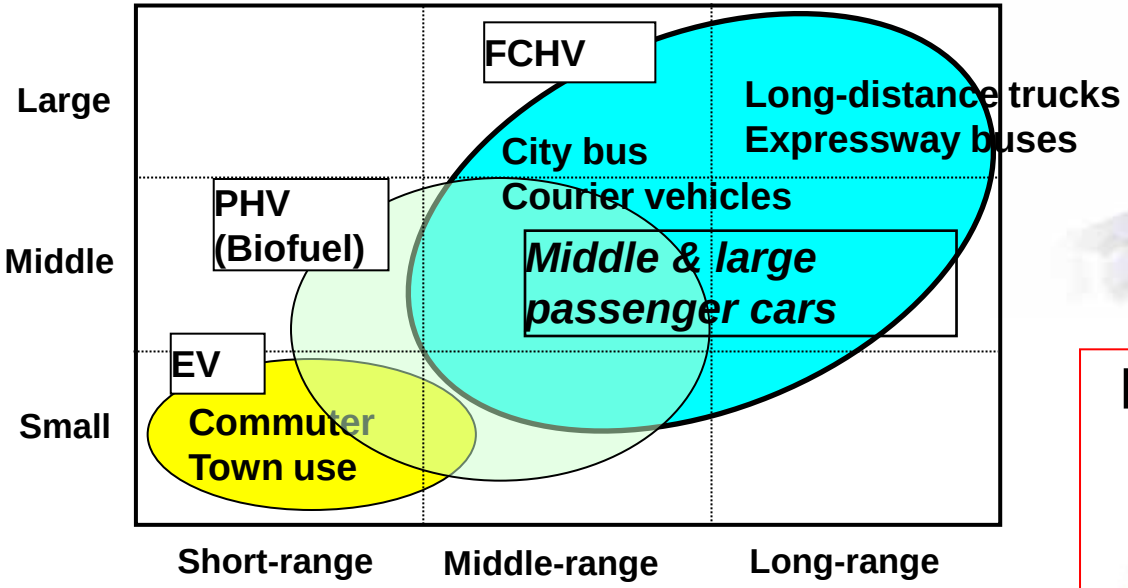
- Power supply capabilities are 4-5 times that of an EV, and can supply power to an average household for more than a week

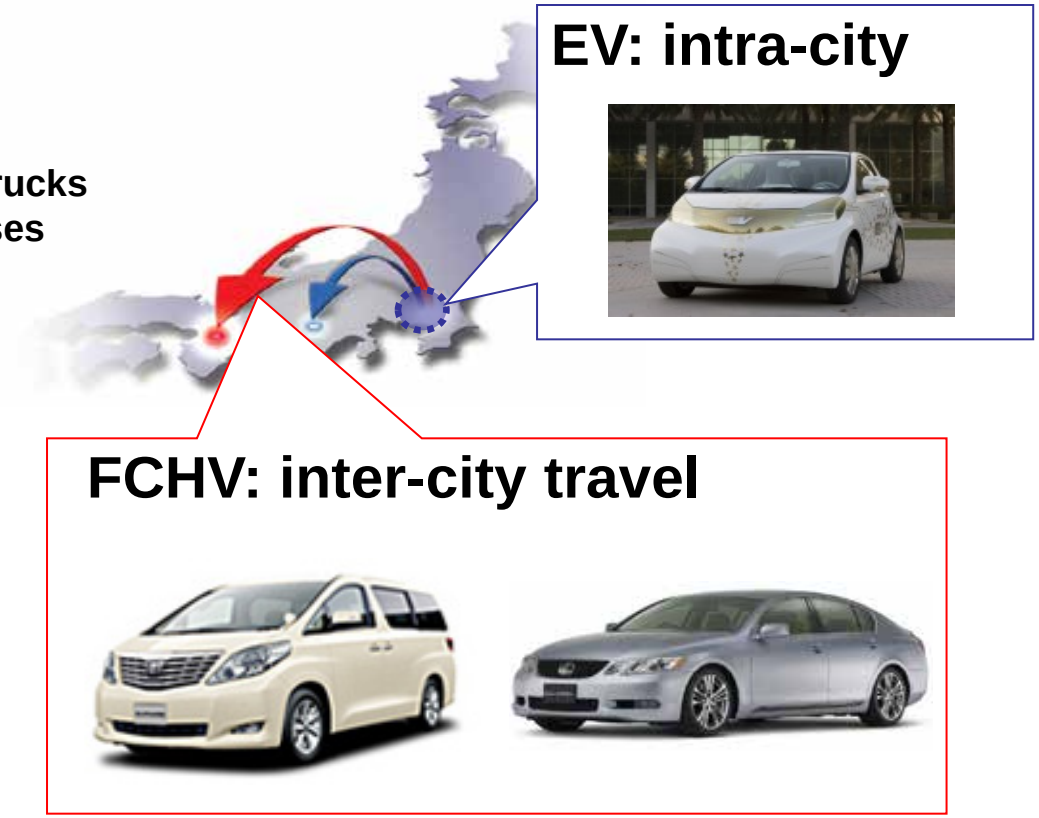
System Cost Comparison between FCV and EV



FCV's system cost increase to attain longer range is rather small
⇒ Has advantage for middle-to-long range drive

Driving Range Comparison



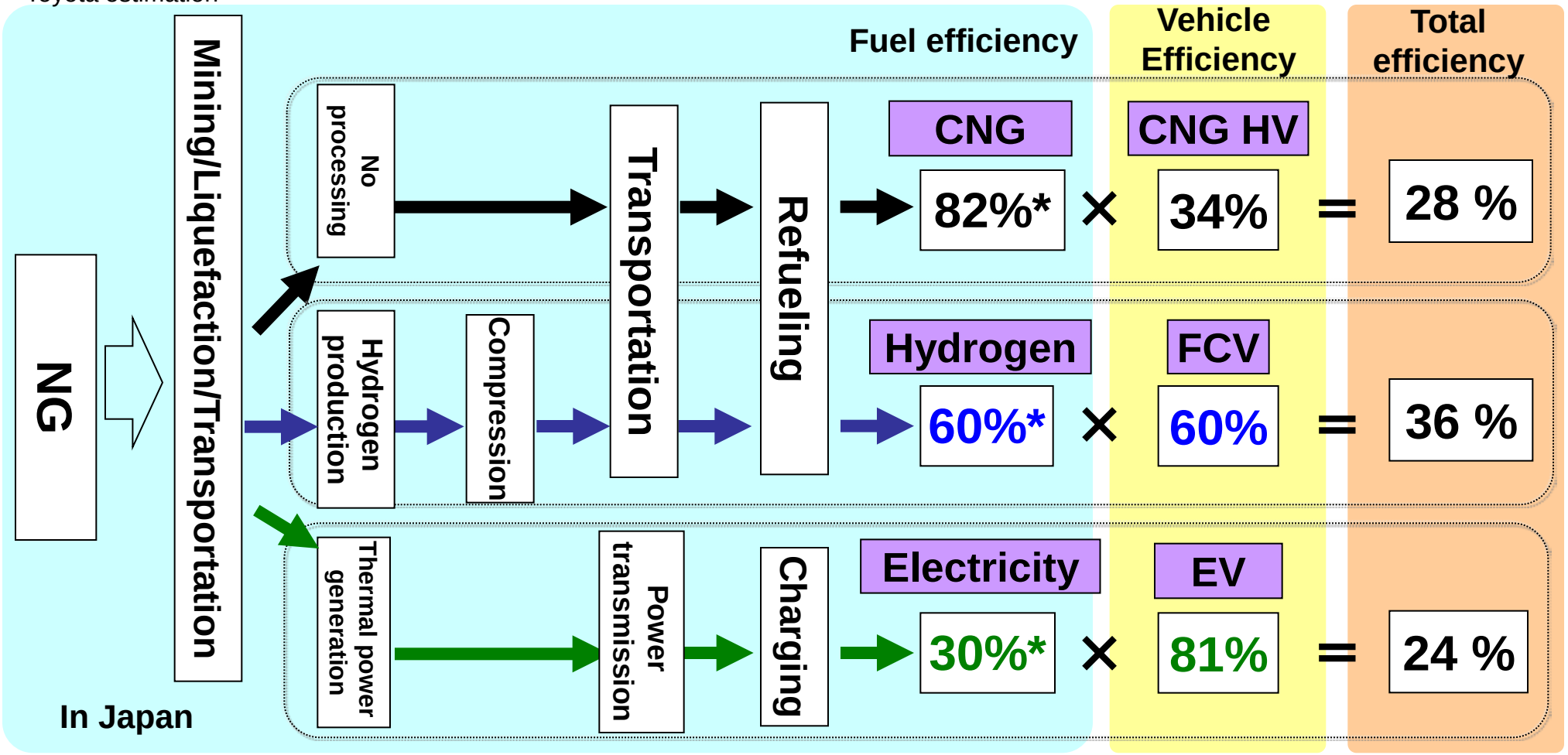


As personal mobility, EV is viable for intra-city travel, and FCHV for inter-city travel

Comparison of Total Efficiency

(in case of operation on the fuel originated from NG)

Toyota estimation

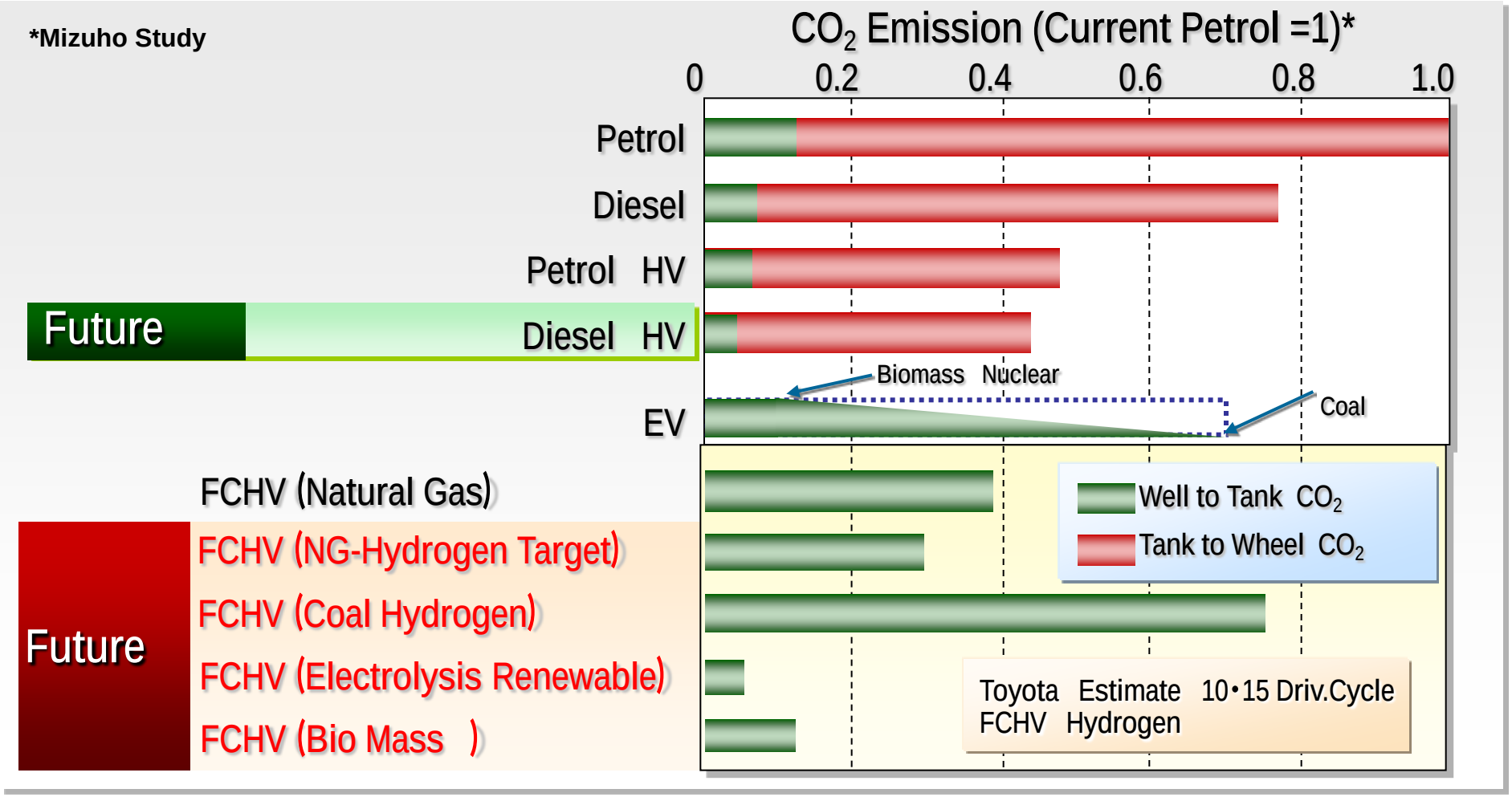


*JHFC Report

Based on a NG source, the total efficiency of Hydrogen/FCV is the highest and about 1.5 times higher than that of Electricity/EV

Life Cycle Well to Wheel CO_2 Comparison

à FC has high potential with advanced hydrogen production



à We need to follow low-emission pathways for transportation

Status and Challenges of FCV

Achievable challenges

- Cruising range： approx. 800km
- hydrogen refueling time： ~3 min
- Low-temperature starting： -30ºC

Remaining challenges

- Cost reduction
- Smaller and lighter vehicle
- FC stack durability improvement

Start commercial launch of sedan type FCV around 2015

Tokyo Motor Show 2011 Concept “FCV-R”

Conditions for FCV's Commercialization

Self-sustaining increase of FCV sales together with H_2 supply network

Customers
Purchase and drive FCV

Green-conscious
+ economic advantage
(Vehicle cost, fuel cost)

Auto OEMs
Manufacture & sell FCV

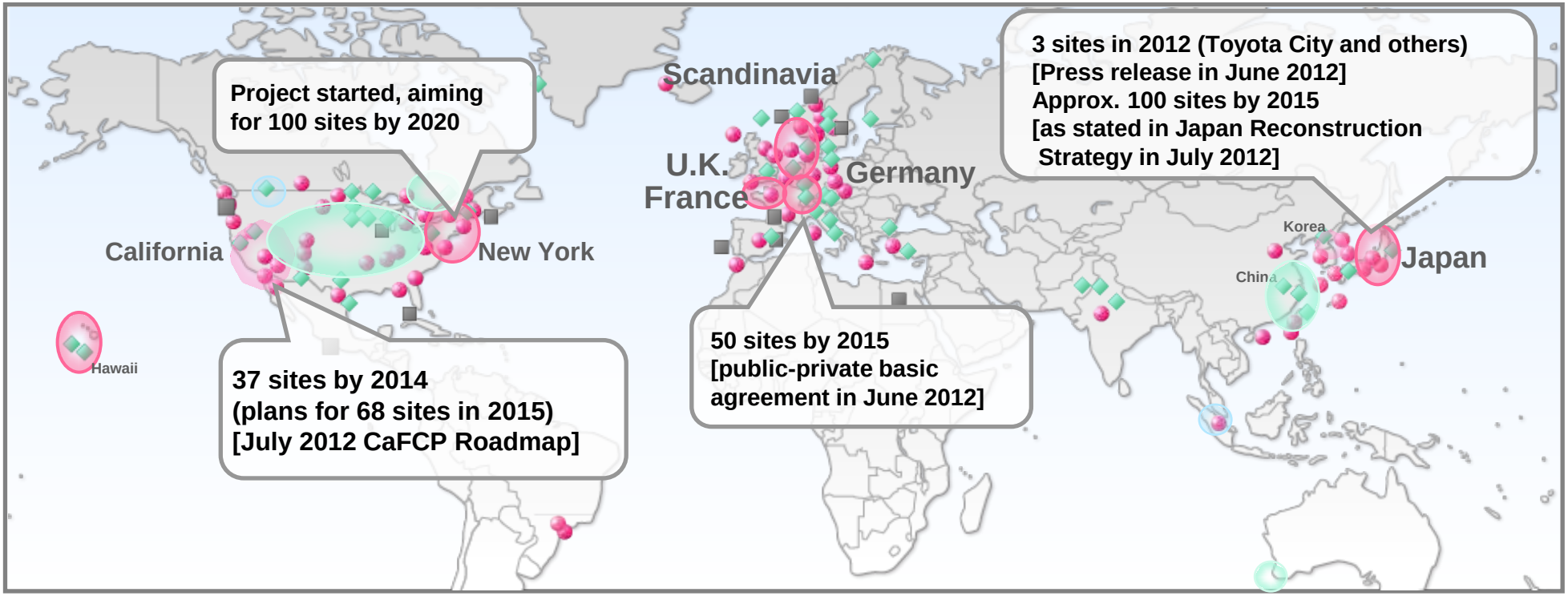
Profitability
(vehicle manufacturing & sales)

Energy suppliers
Produce & sell H_2

Profitability

For mass introduction of FCV/hydrogen, profitability of every stakeholder is essential

Worldwide Locations of Hydrogen Stations



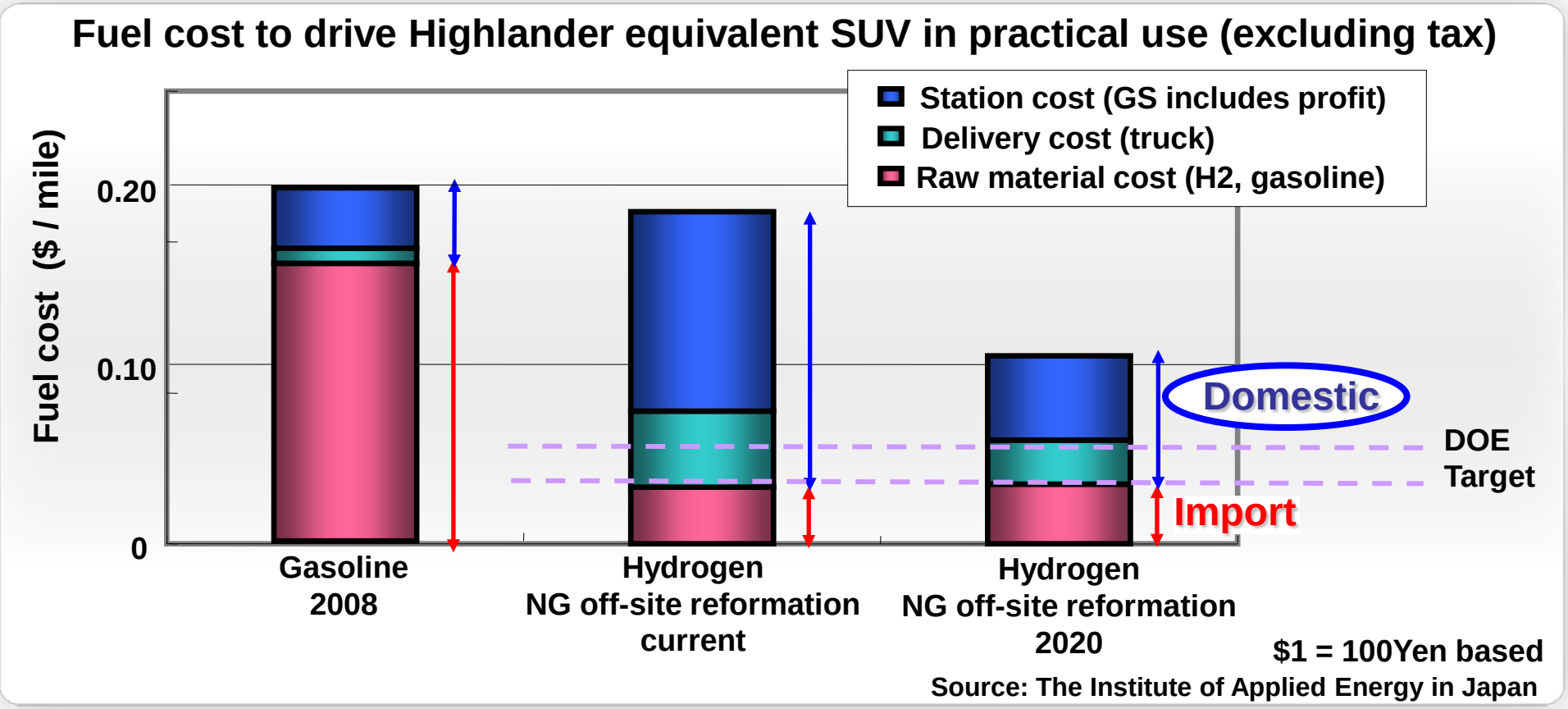
- In operation
- Not in operation
- Planned

Areas where infrastructure development can be expected from early 2015

Areas where infrastructure development can be expected after 2015

Several hundred stations are expected to be set up by 2015

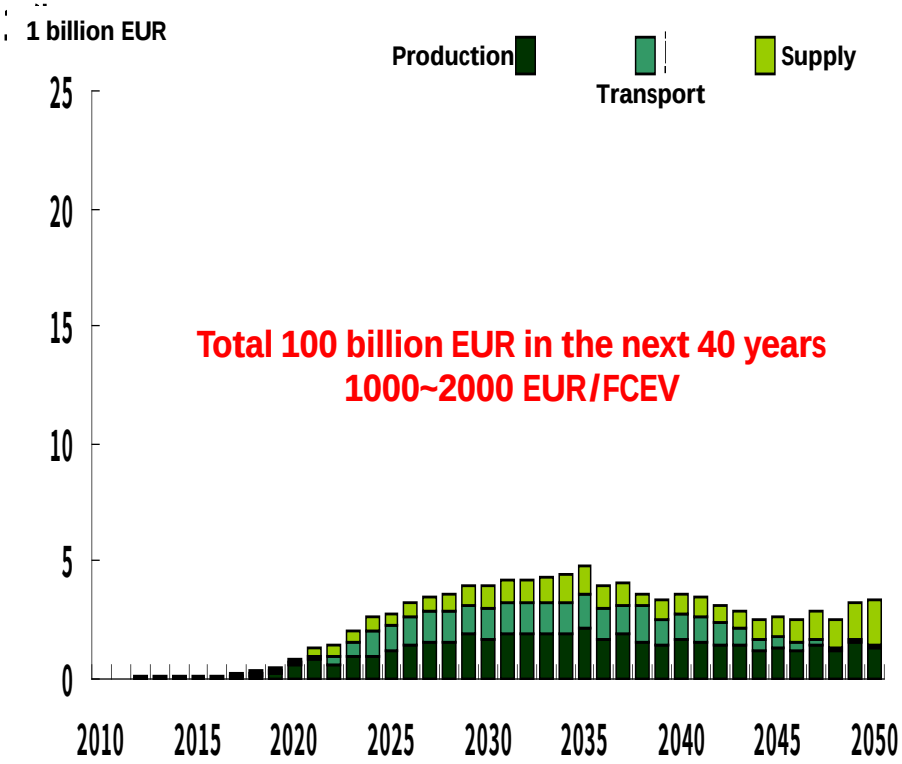
Potential Hydrogen Cost Comparison (Japan)



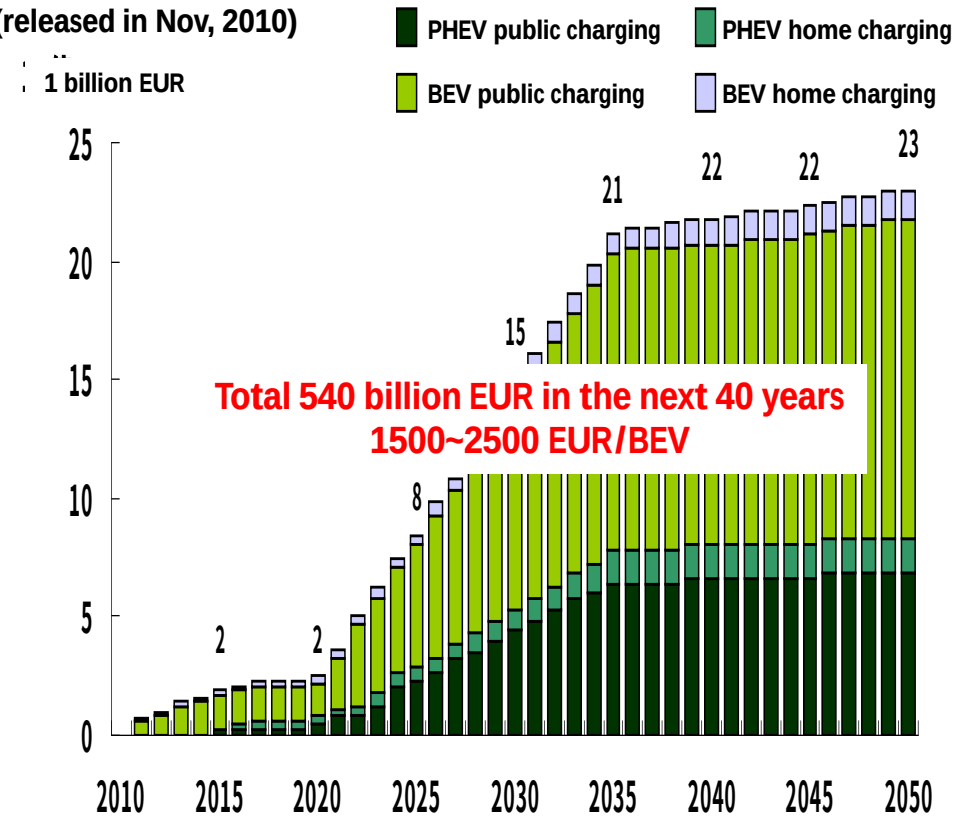
- H2 station cost accounts for large portion of total H2 fuel cost
- Considering advances in H2 production technologies there is potential for the cost per mile to be significantly lower than gasoline vehicles
- Imported H2 molecule has lower value compared to gasoline

Estimation of Infrastructure Establishment Cost in EU

McKinsey study "A portfolio of power-trains for Europe: a fact-based analysis" (released in Nov, 2010)



Hydrogen infrastructure
(assuming 1 billion FCEVs)



Charging infrastructure
(assuming 2 billion EVs/PHVs)

From medium- and long-term perspective,
Hydrogen infrastructure investment < Charging infrastructure investment

Toyota's Fuel Cell Vehicle Development History (1)

Toyota's FCV development started in 1992

1992: Start of development

Overall development of FCV on material, components, system, controls, and production engineering

1996: Parade in Osaka

FCV appeared in Parade in Osaka with original fuel cell stack and metal hydride hydrogen tank.

EVS13 in Osaka (Oct.1996)

Toyota's Fuel Cell Vehicle Development History (2)

2002 Model FCHV (Dec 2002 ~)

World's First Limited sale in the US and Japan

- Ministry certificate in Japan
- Total 18 vehicles in the US and Japan

2005 Model FCHV (July 2005 ~)

First Type Approval Japan

- Ministry certificate => Type Approval conformed to FC vehicle safety regulation
- 20 vehicles lease in the US and Japan

2008 Model FCHV-adv (June 2008 ~)

Improved range & freeze startability

- More than 100 vehicles run in the US, Japan and Europe

Max speed	155 km/h
Range	830 km (10-15 test cycle)
Passenger	5
Max pressure of tank	70 MPa
Tank capacity	6 kg @ 35ºC

Total leased vehicles are over 100, and total range is over 2 million km in the US, Europe and Japan

Toyota's Fuel Cell Bus Development History

Operation ended

Tokyo Metropolitan Bus
Aug 2003 ~ Dec 2004

"AICHI EXPO"
Mar 2005 ~ Sep 2005

Chita Bus
Mar 2006 ~ Dec 2009

In operation

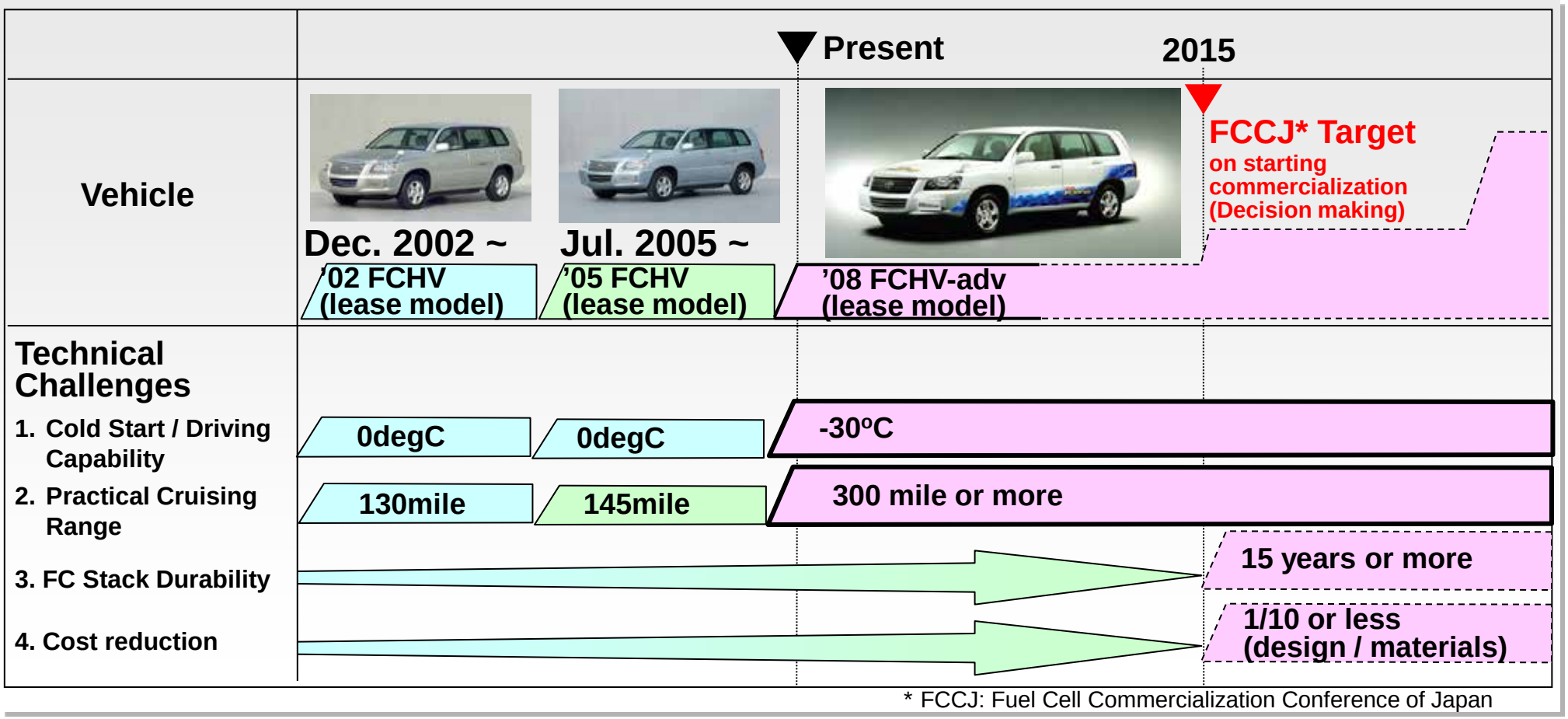
Central Japan Airport Plane-Terminal Bus
Mar 2006 ~

Toyota Oiden Bus
Oct 2010 ~

Shinjuku-Haneda Airport Bus
Dec 2010 ~

The smooth and quiet ride with zero emissions of harmful substances has been well-received by passengers

Evolution of the TOYOTA Fuel Cell Hybrid Vehicle (FCHV)

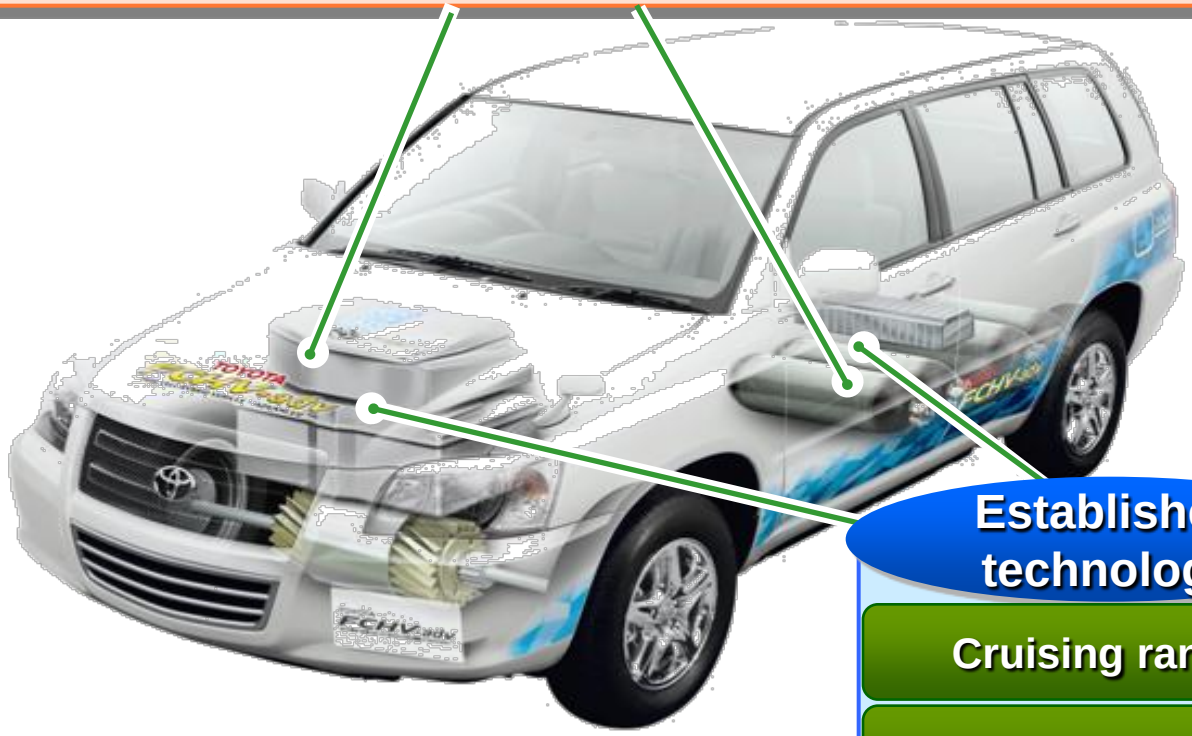


- Actual cruising range and cold start / driving capability has been significantly improved
- Toyota continues efforts especially on FC stack durability and FC system cost reduction targeting commercialization in 2015

Major Technical Challenges for FCVs

Issues to be solved

Balance in Cost / Compactness & high performance / Stack Durability



Established technology

- Cruising range
- Cold start / Driving performance

FCHV-adv Range Evaluation with DOE, NREL & SRNL

Joint evaluation of FCHV-adv was performed on June 30th, 2009 on mixed traffic condition in Southern California

Trip distance: 331.5 miles

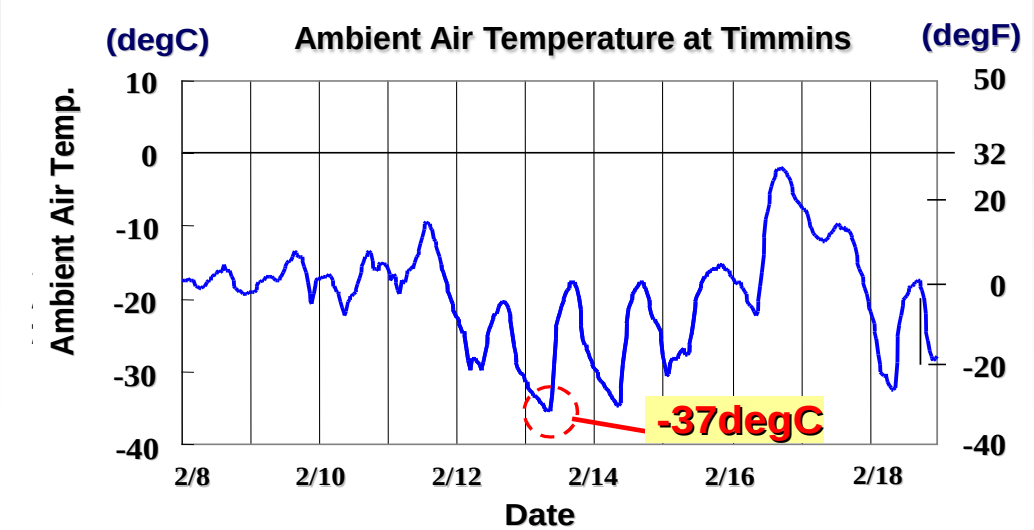
Fuel Economy : 68.3mile/kgH_2

Calculated full-tank range : <u>431 miles</u>

1 kg H2 ~ 1 gal gasoline energy equiv.

FCHV-adv Cold Start Performance

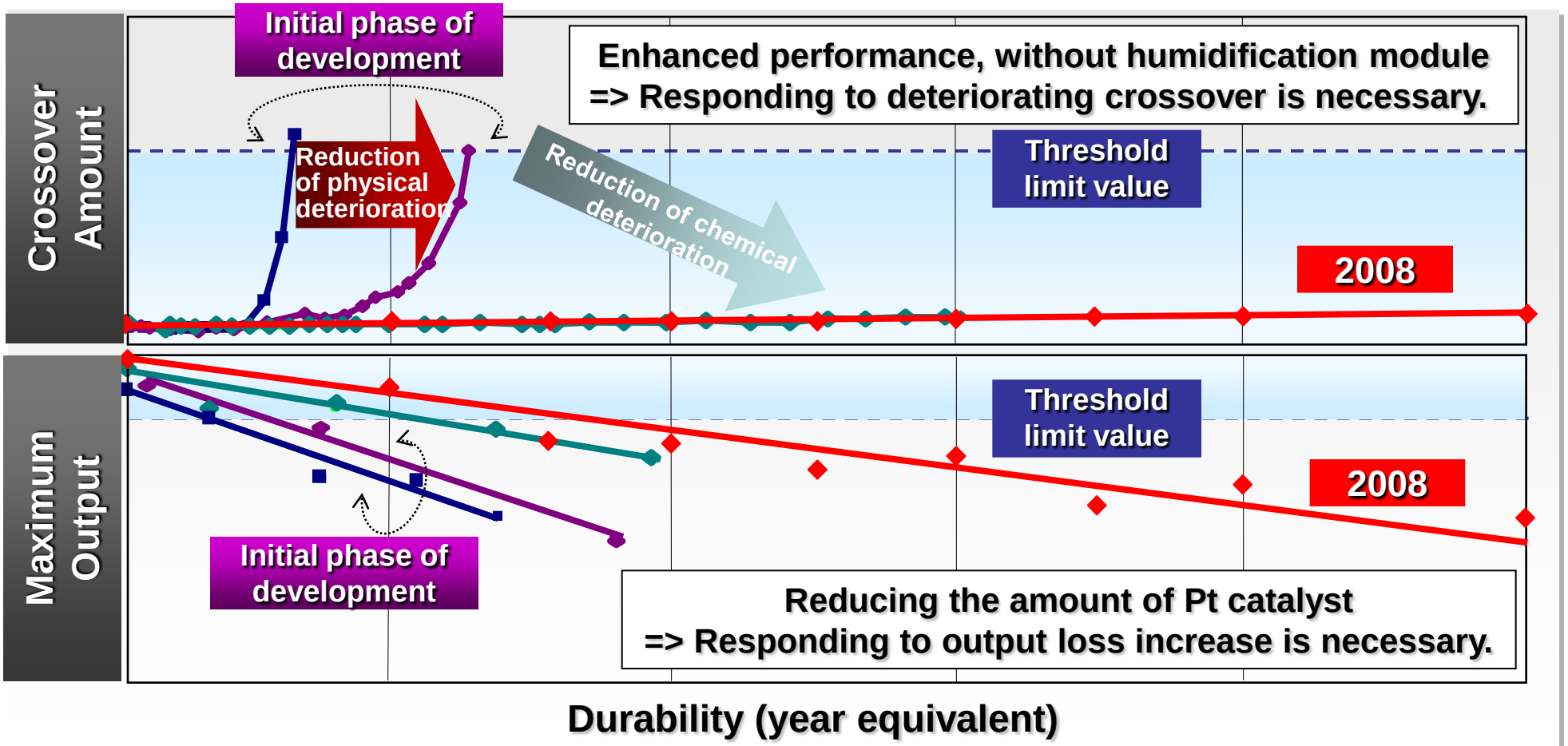
Timmins, Canada



Yellowknife, Canada

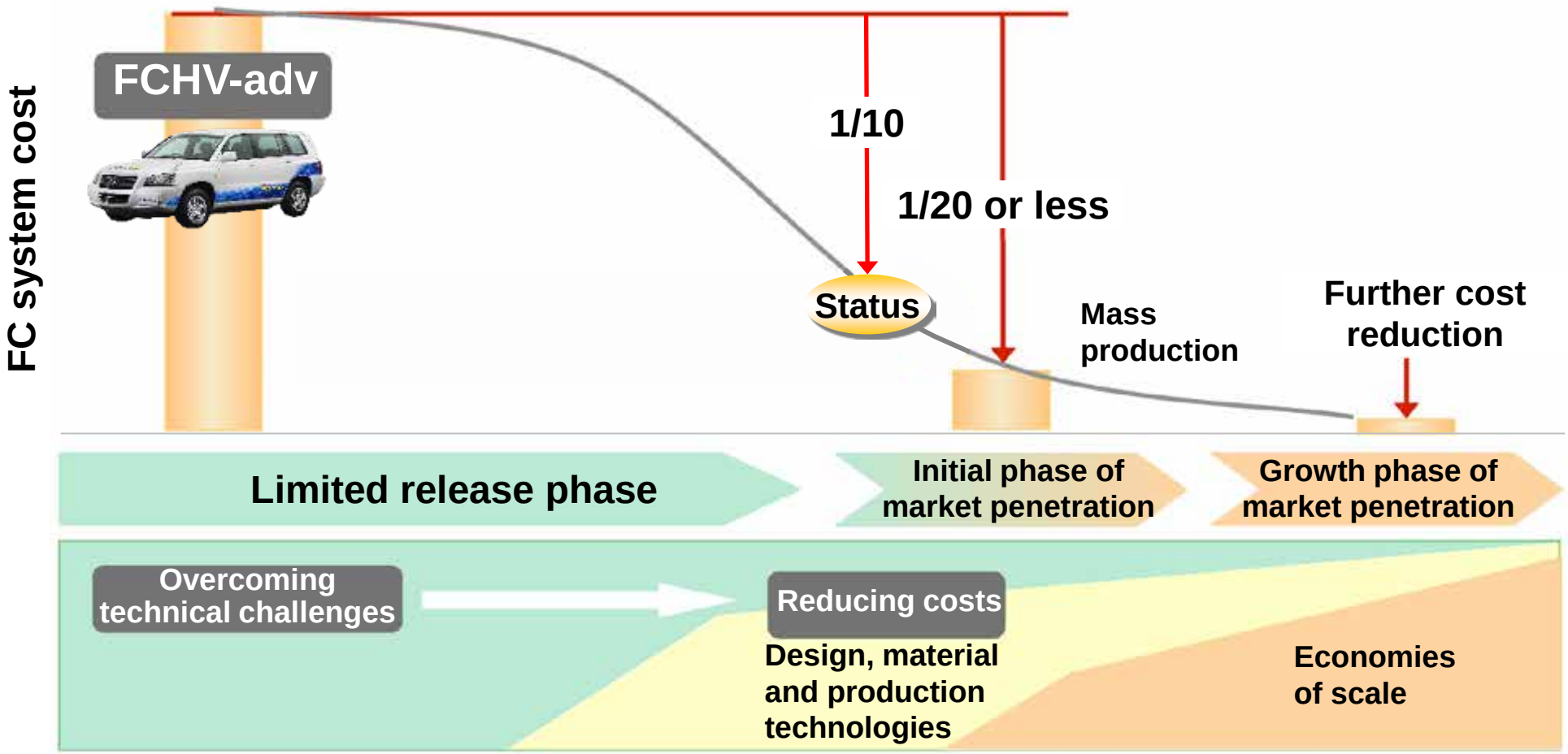
The cold-weather performance tests verified that the cold start and driving performance of the TOYOTA FCHV-adv was equivalent to that of gasoline-powered vehicles

Durability of TOYOTA FC Stack



Durability is steadily improving; it is important to balance performance, durability and cost

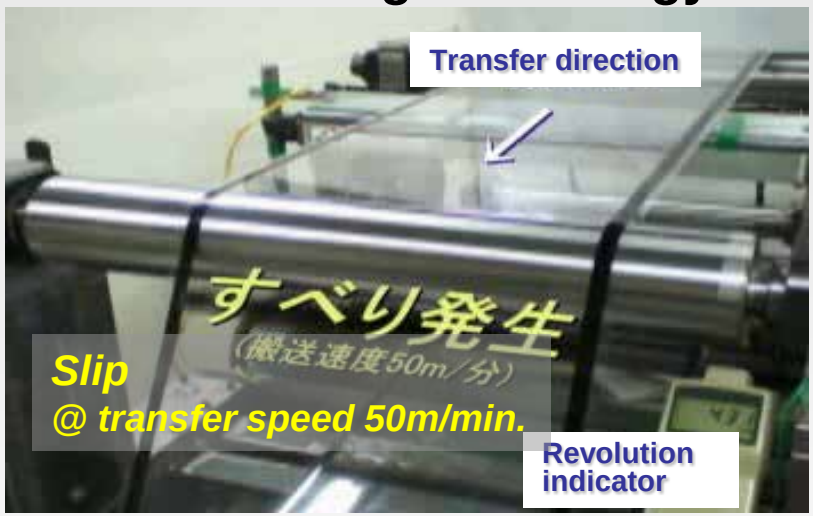
FCV Cost Reduction Progress of Toyota



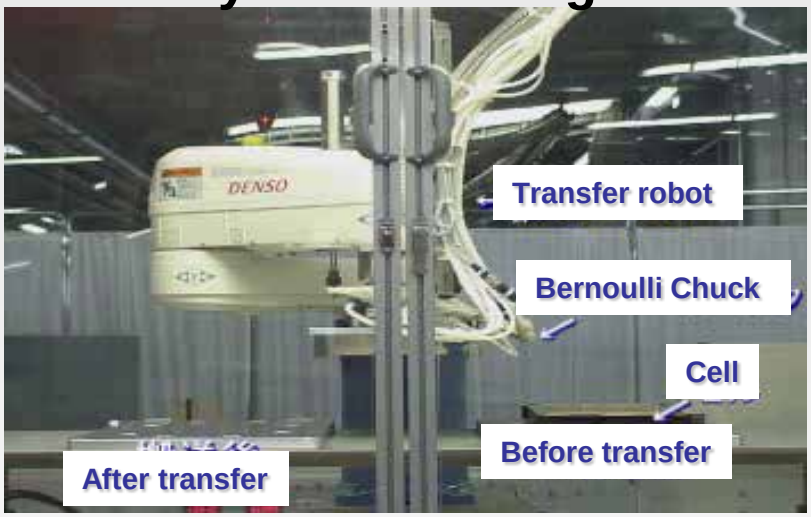
Current status: FC system cost reduction of 1/10 has been achieved !
In 2015: Aiming at another 1/2 FC system cost reduction

Development of Mass Production Technology

(1) FC web handling technology



(2) FC one-by-one handling technology



(3) High speed winding of 70 MPa hydrogen tank

Summary

1. **Fuel Cell Vehicles are more suitable for longer-range, larger vehicle applications compared to EVs.**
   (EVs remain well suited for short range commuter and intra-city use)

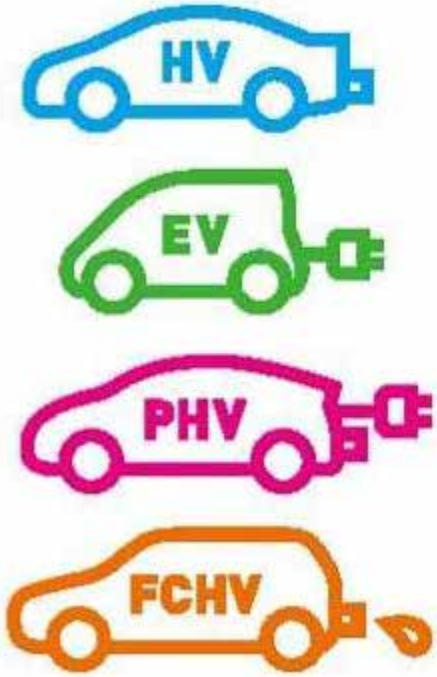
2. **Toyota's FCHV technology has been steadily moving forward including more than 300 miles of practical range and -30ºC cold-start capability.**

3. **Toward the 2015 target of a larger scale FCV introduction, Toyota is making maximum effort to overcome the remaining technical challenges such as Cost reduction and Durability improvement.**

4. **Conditions for FCV's Commercial Introduction:**
   - **Low-cost and easy-access hydrogen fueling network are critical**
   - **Variety of incentives are critical to form initial market beginning around 2015-2020**

Towards the 2015 goal, Toyota challenges private industry and government to work closely with the Automakers to develop a clear pathway to ensure customers have convenient and reliable access to hydrogen fueling

“The eco-car for you.”



Today for Tomorrow