July 22, 2014
Nagoya University
Summer Intensive Program 2014

Technology Innovation and Challenge for Sustainable Mobility

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1972 Engineering Lab., Nissan Motor Co., Ltd.

R&D on Fuel cell electric vehicles

H2 engines, Methanol engines

1990 Engine Development Department

FFV, Emission Technologies,

Production engines

1994 Nissan R&D USA

Ultra low emission vehicles, EVs

1998 Development of FCV

2005 R&D Planning of Environmental technologies,

including EVs, FCVs and ICEs

2014 Retired Nissan Motor Co., Ltd.

2008 Waseda University

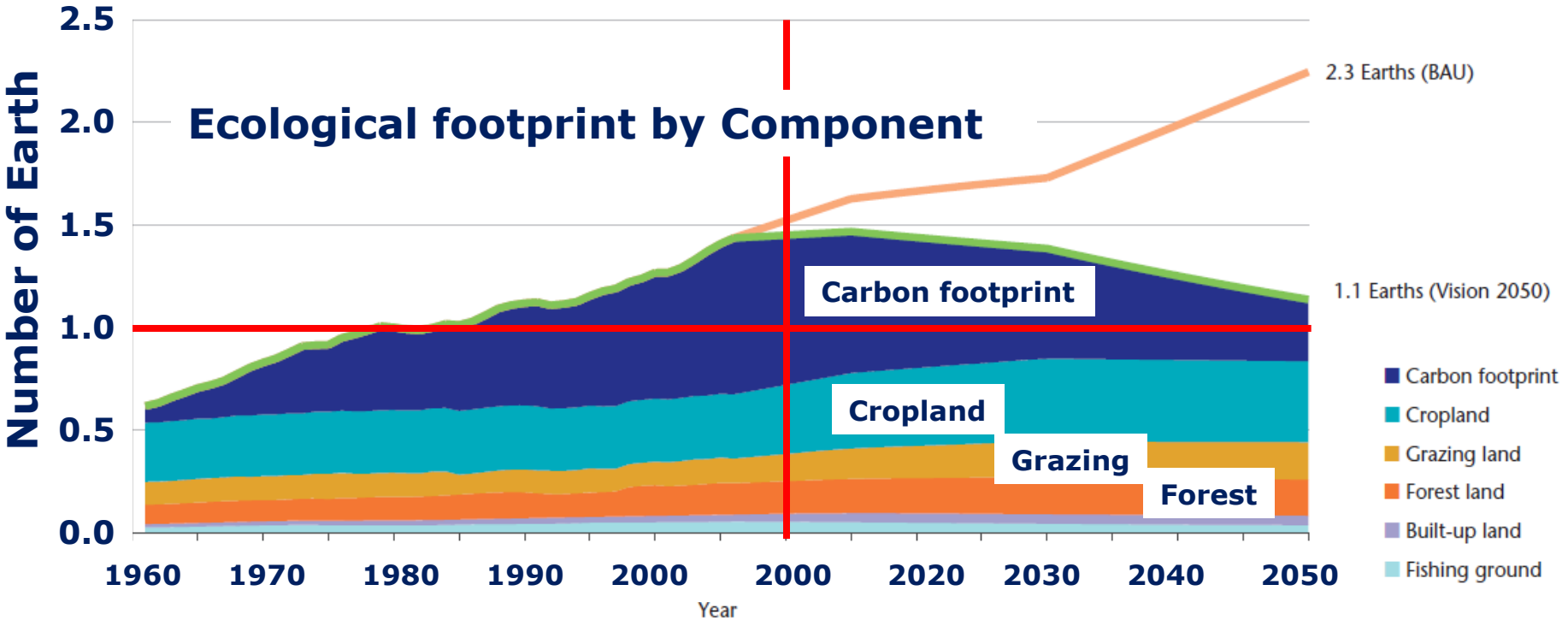
Research on EVs and Smart mobility

- **Conventional technologies**
  - **ICE: Internal combustion engines**
  - **HEV: Hybrid electric vehicles**
- **Alternative fuel vehicles**
  - **Biofuel engine vehicles**
  - **FCV: Fuel cell vehicles**
  - **BEV: Battery electric vehicles**
- **Smart mobility**
  - **Renewable energy**
  - **Harmonized transportation**
  - **Sustainable mobility**

Ecological Footprint

Vision 2050 by WBCSD,
***WBCSD: World Business Council for Sustainable Development**

- **Ecological footprint with human activity exceeded the Earth's natural ability to absorb these impacts in the late of 1980s.**
- **The requirement in 2010 was 50% larger than world bio-capacity.**
- **Key components: Carbon, Cropland, Grazing land, forest**



CO2 Emission from Gasoline Vehicle

■CO2 emissions per gasoline 1L

- Vehicle driving:2.3kg
- Refinery:0.5kg
- Total:2.8kgCO2/L

For example:
Fuel economy: 10km/L
Mileage: 10,000km/year

- CO2 emissions:280g/km
- 10,000 km runs a year : 2.8t/year

Amount of CO2 Emissions 0.5kgCO2 (Per Gasoline 1L)

Amount of CO2 Emissions 2.3kgCO2 (Per Gasoline 1L)

Technology Innovation and Challenge for Sustainable Mobility

- **Conventional technologies**
  - **ICE: Internal combustion engines**
  - **HEV: Hybrid electric vehicles**
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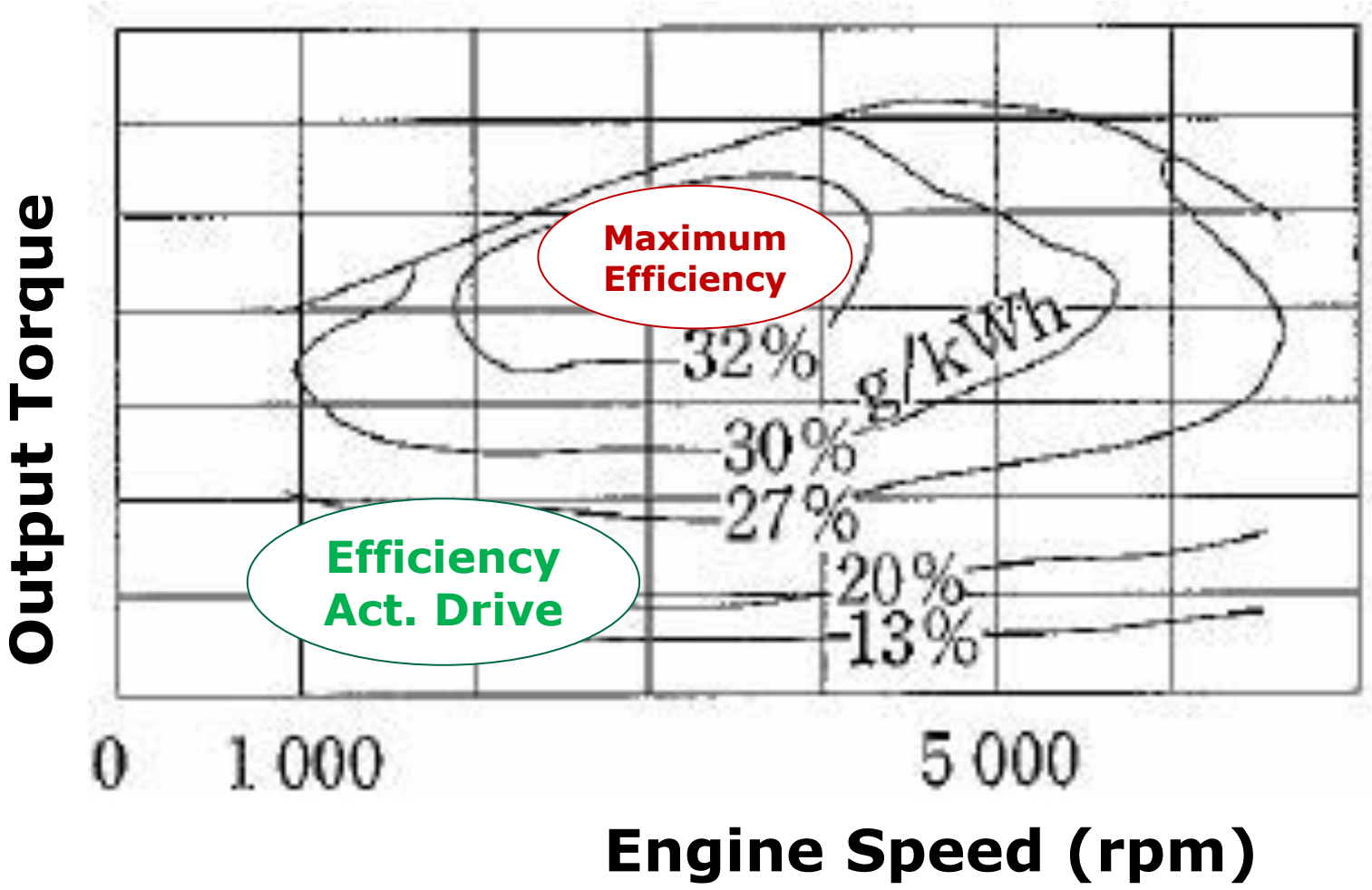
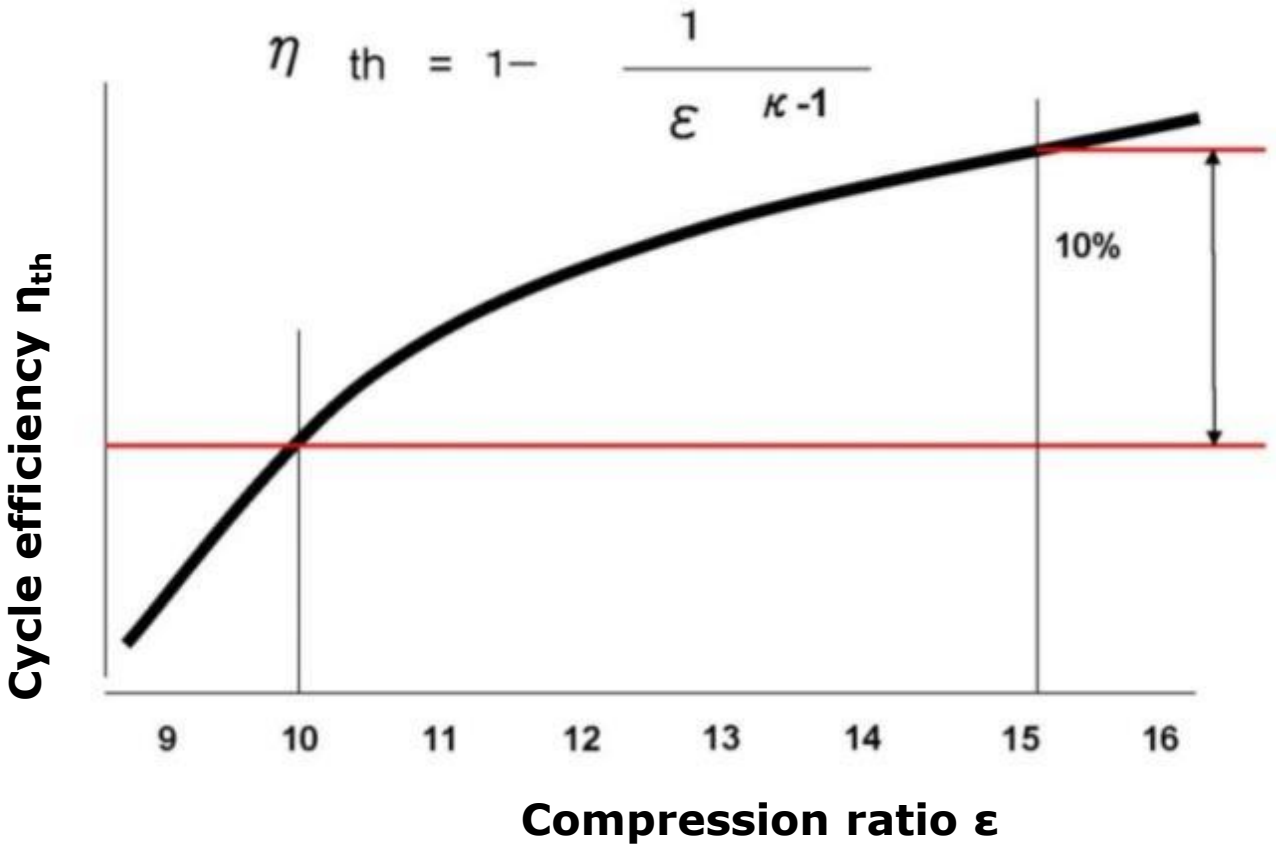
Energy Efficiency of Gasoline Engine

- Maximum efficiency of gasoline engine is 30 - 36%.
- Average efficiency under actual driving is around 20% because of low torque driving.



Cycle efficiency improvement

Theoretical efficiency η_{th} of internal combustion engine is improved with increasing of the compression ratio ε and the specific heat ratio.

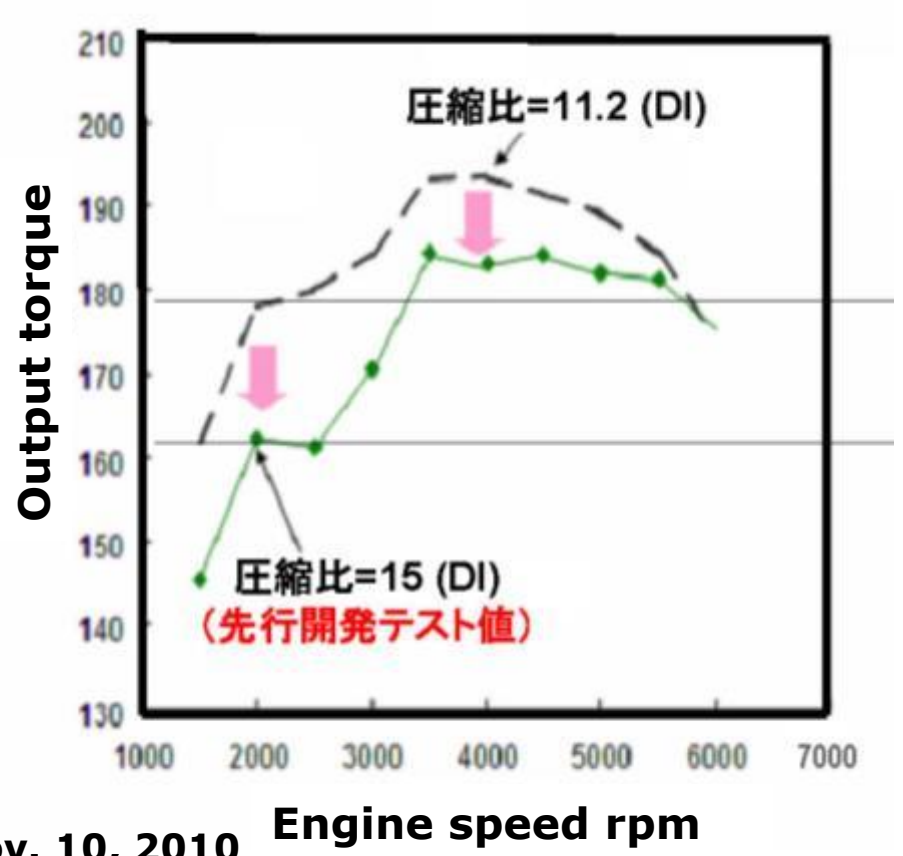


Source: Symposium on ICE technologies, Nov. 10, 2010

Toshio Hirota, Environmental Research Institute, Waseda University, Japan

High compression gasoline engine: Mazda Sky active

- Increase the compression ratio causes reduce the output torque because of knocking.
- Modifications of the combustion chamber and fuel injection system realize high compression ratio without knocking.



Source: Symposium on ICE technologies, Nov. 10, 2010
Toshio Hirota, Environmental Research Institute, Waseda University, Japan

Best fuel economy K-car in Japan

Suzuki Alto Eco
Dec. 18, 2013

- Fuel economy 35.0 km/L (JC08 mode)
- Ene-charge (Regeneration system)
- Idling stop
- Eco-cool
- Light weight vehicle

Daihatsu Mira e:S
July 9, 2014

- Fuel economy 35.2 km/L (JC08 mode)
- High compression ratio, Atkinson cycle
- Dual injector fuel injection system
- Adv. regeneration system

Source: Suzuki Website, Dec. 18, 2013, http://www.suzuki.co.jp/car/alto_eco/
Daihatsu Website, July 9, 2014, http://www.daihatsu.co.jp/wn/2014/0709-1/20140709-1.pdf

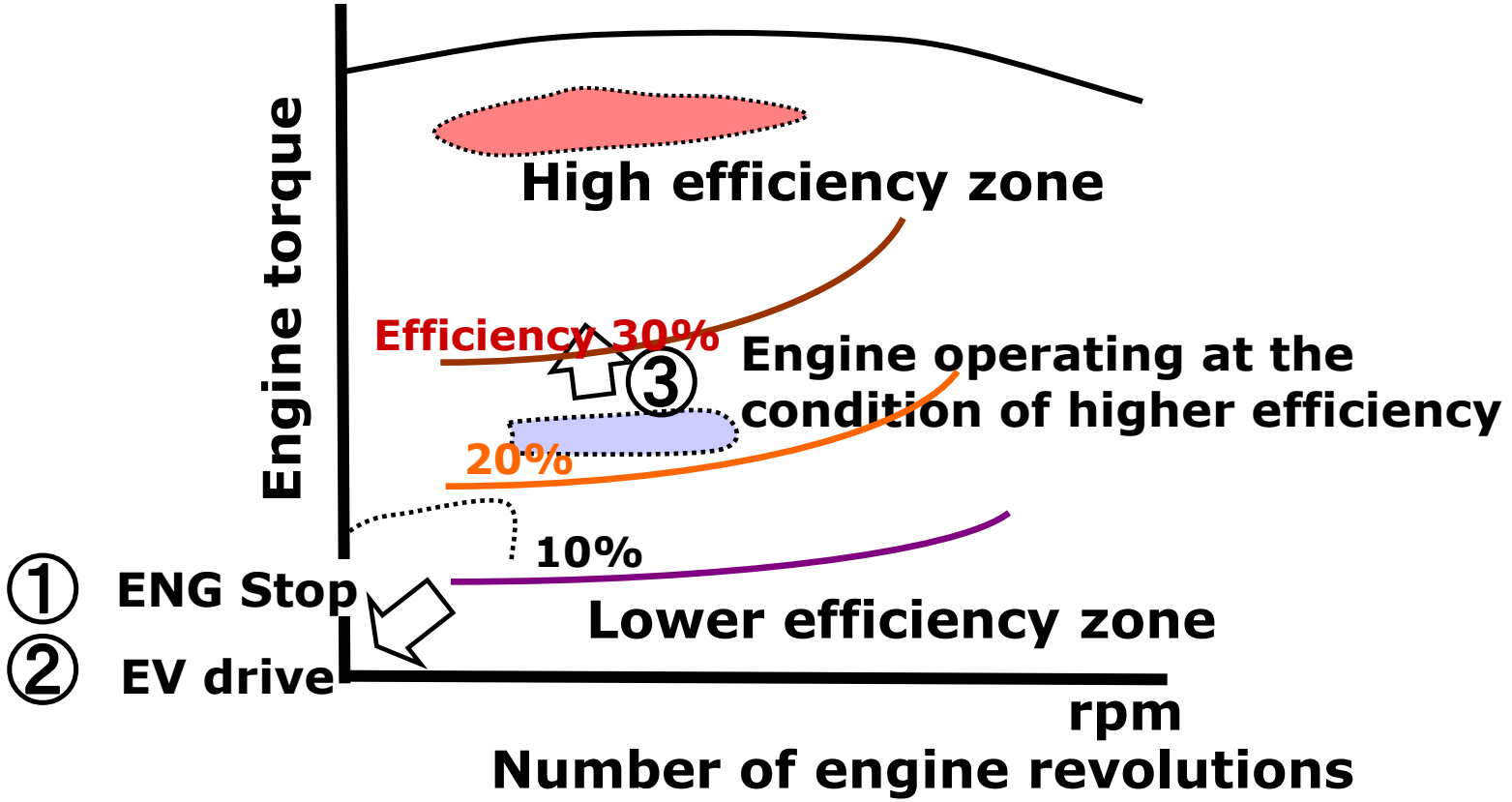
Efficiency Improvement by Hybrid System

① Engine stop mode（Low revolution･Idle range）

② EV driving mode（Starting･Low speed range）

③ Shifting engine driving range to high efficiency range (Charge the battery with surplus torque）

④ Cooperation recovery of brake energy （Deceleration）



Toyota Hybrid Aqua

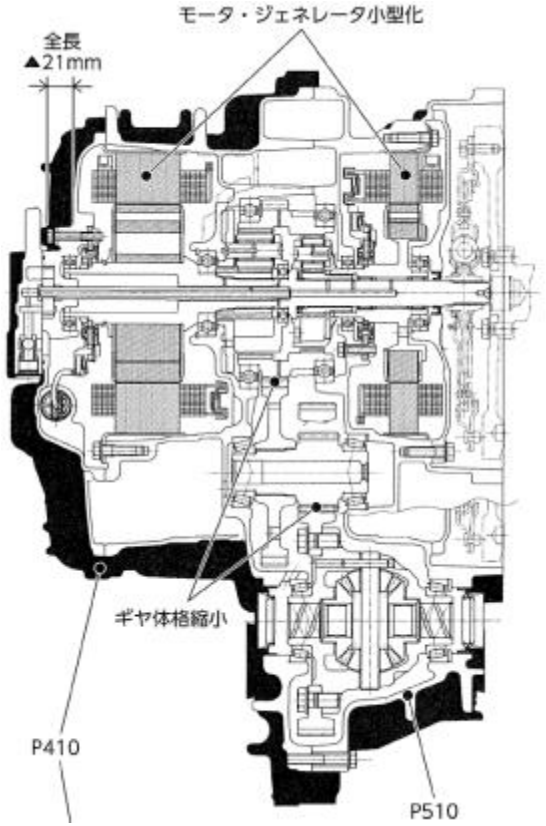
- Compact size passenger car
- Start of sale: Dec. 2011
- Hybrid system: THS-Ⅱ
- Fuel economy: 37.0 km/L (JC08 mode)
- Price: 1,748 k-yen
- Top sales model in Japan, 260,000 in 2013

Size	3,995 x 1,695 x 1445 mm
Seating capacity	5
Curb weight	1050kg
F.E	37.0 km/L (JC08 mode)
Engine	1.5L Atkinson cycle 54kW/4,800rpm
Motor	PMAC synchronous motor 45kW, 169N•m
Battery	Ni-H 6.5Ah

Source: Toyota Website, http://toyota.jp/aqua/

Aqua hybrid system

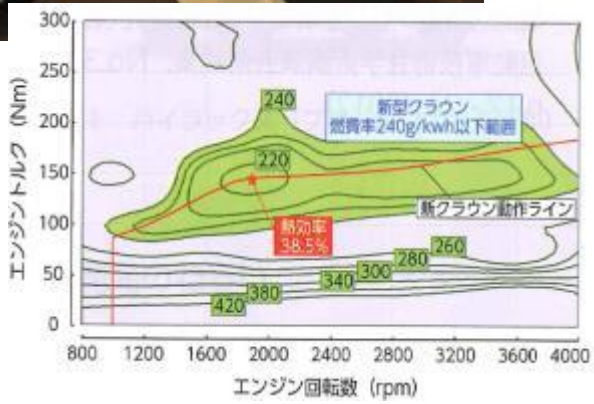
- Hybrid system is basically same as Prius system.
- A lot of efforts are made to install the complex system in the compact engine compartment.
- Engine length is 51 mm shorter and the transmission with 2 motors is 21 mm shorter than previous system.



Source: Toyota Website, http://toyota.jp/aqua/

High thermal efficiency engines

- Toyota Crown hybrid
- Sept. 2012
- Thermal efficiency: 38.5%
- Atkinson cycle, Cooled EGR



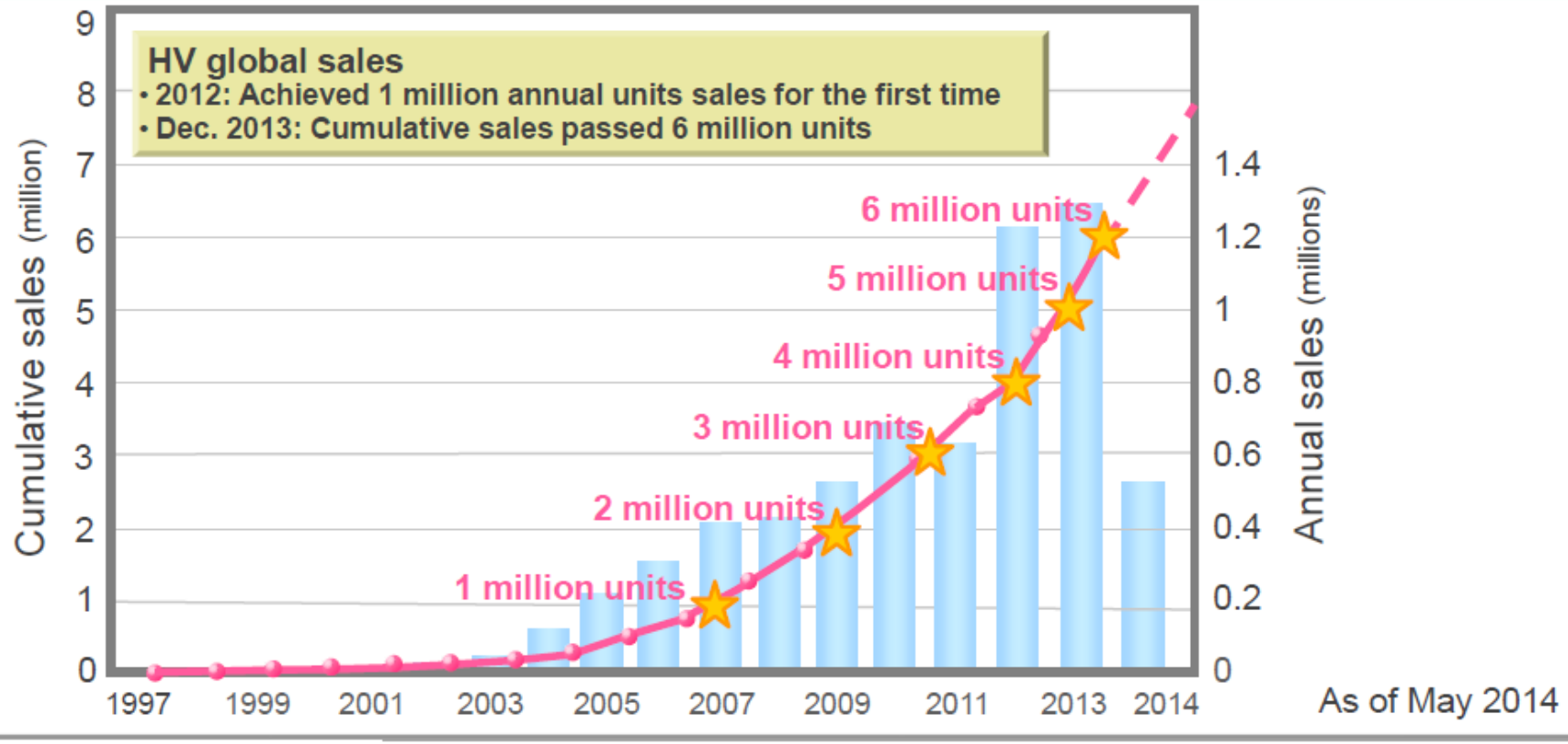
- Honda Accord hybrid
  June. 2013
- Thermal efficiency: 38.9%
- Atkinson cycle DOHC i-VTEC

Source: Toyota Website, Honda Website

Toyota Hybrid Vehicle sales

June 25, 2014

Hybrid vehicle sales



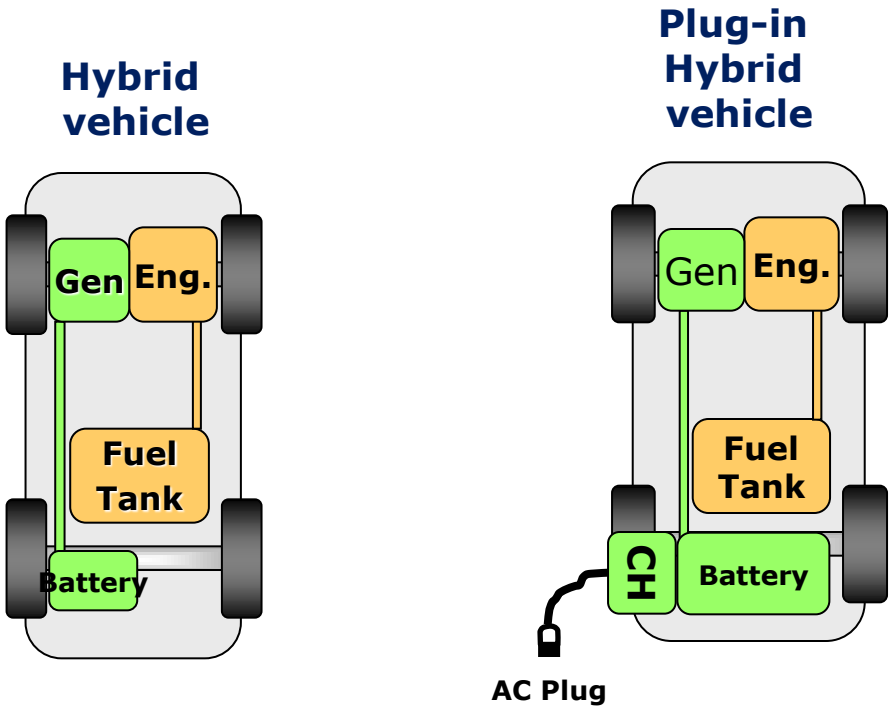
Rewarded with a smile

TOYOTA

Source: Toyota Presentation Material on FCV, June 25, 2014
Toshio Hirota, Environmental Research Institute, Waseda University, Japan

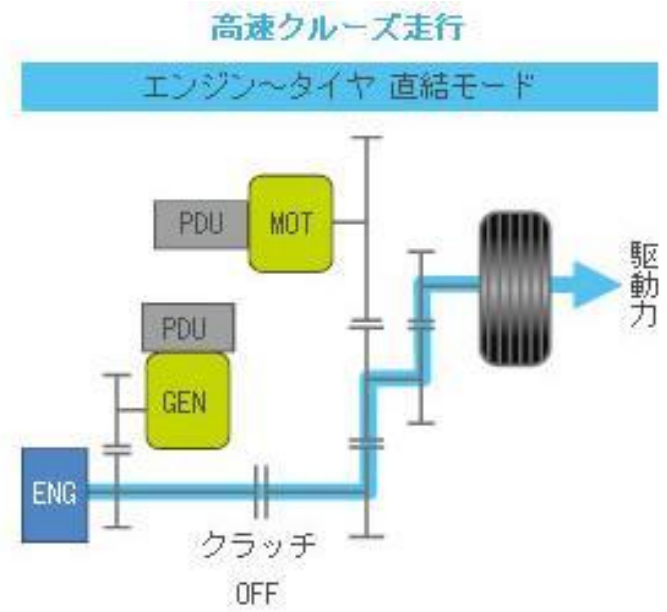
Plug-in hybrid vehicle

- Equipped a large capacity battery and a charger by grid power
- Driven by a motor with battery at short distance driving and driven by a hybrid system with engine and motor at long distance driving.



Honda Accord Plug-in Hybrid, Jan. 2013

- Honda developed a series hybrid system for passenger car.
- The system is consist of 2 motors, 100kW generator and120kW motor, a clutch, and a lithium-ion battery.
- An engine drives wheels through electric transmission.
- Under high speed driving condition, an engine drives wheels mechanically through a clutch and reduction gears.
- AER, all electric driving range, is 13 miles with 6 kWh battery.



Source: Response, Jan. 17, 2013
http://response.jp/article/img/2013/01/17/189002/517835.html

Improvement of plug-in hybrid vehicles

VW 1 liter car "XL1"

- Prototype model for advanced technology
- 2 seat plug-in hybrid vehicle
- Fuel consumption: 0.9L/100km (111km/L)
- CO2 emission:24g/km
- EV drive range:35km

- Power unit
  Max torque 140N·m
- 2 cylinder diesel engine
  800cc, 48PS
- Motor:20kW
- Max speed:160km/h
- Acceleration:11.9 seconds
  (0-100km/h)

Source:http://car.watch.impress.co.jp/docs/news/impression/20110506_439383.html (2011/5/6)

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Fuel cell vehicle

Advantages

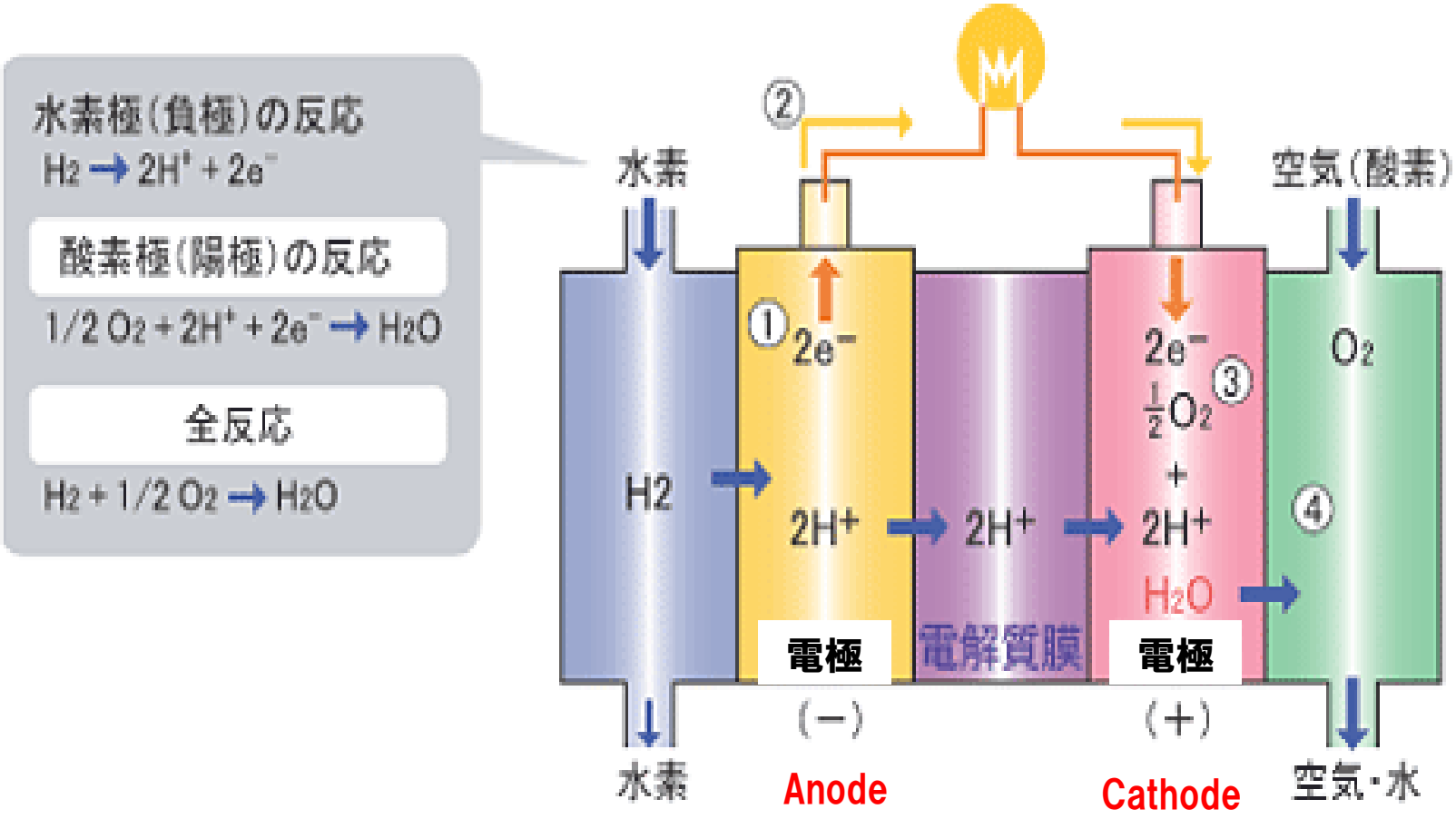
- Zero CO2 emission
- High energy efficiency
- Quiet and smooth driving

Need to improve

- Cost reduction of FC and hydrogen storage tank
- Hydrogen infrastructure

PEMFC: Proton exchange membrane fuel cell

- Hydrogen resolves into protons and electrons at an anode electrode
- Proton moves to cathode side through a membrane
- Proton and oxygen react at cathode side to generate water



Source：JHFC website
http://www.jhfc.jp/fc_fcv/about_fc/index.html

Toyota Reveals Exterior, Japan Price of Fuel Cell Sedan

News release, June 25th, 2014

- Toyota will introduce FCV in Japan before April 2015.
- The price of the FC sedan is approximately 7 million yen.
- The FCV features performance similar to a gasoline engine vehicle, with a cruising range of 700 km (JC08) and a refueling time of 3 minutes.
- FCVs contribute to the diversification of automobile fuels, emit no CO2 or harmful substances during operation.

Fuel Cell System
Output: 100kW
Placed under seat

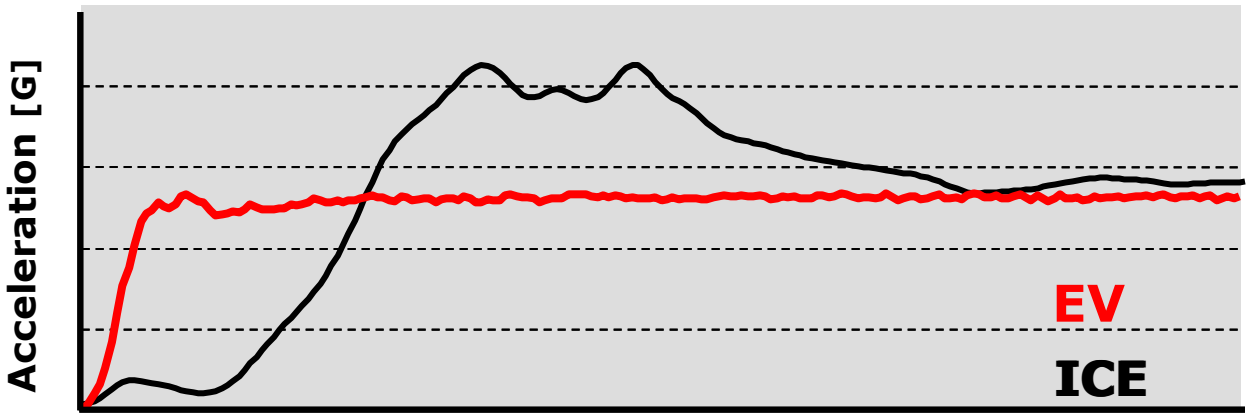
Hydrogen Tanks
70MPa
5.7wt%

Source: Toyota Website, http://newsroom.toyota.co.jp/en/detail/3286486/

Electric Vehicle LEAF

Acceleration of electric vehicle

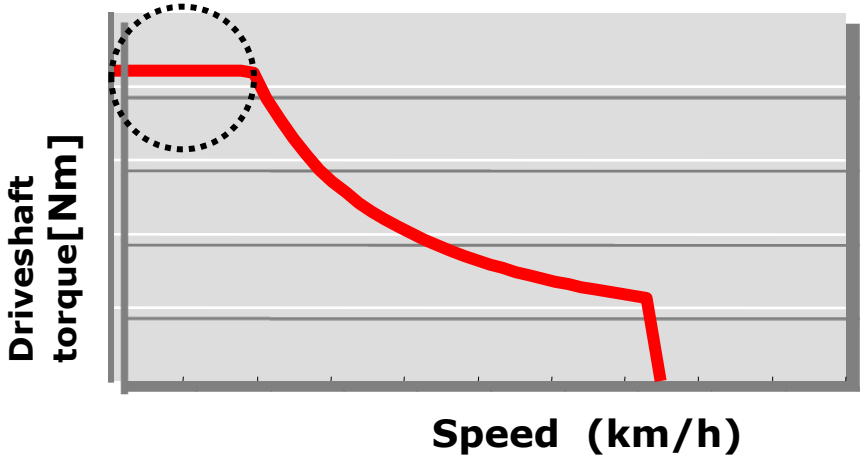
- **Significant improvement in acceleration**



Situation: First- in-line at green light

- **High Torque Motor**
- **Motor Control Technology**

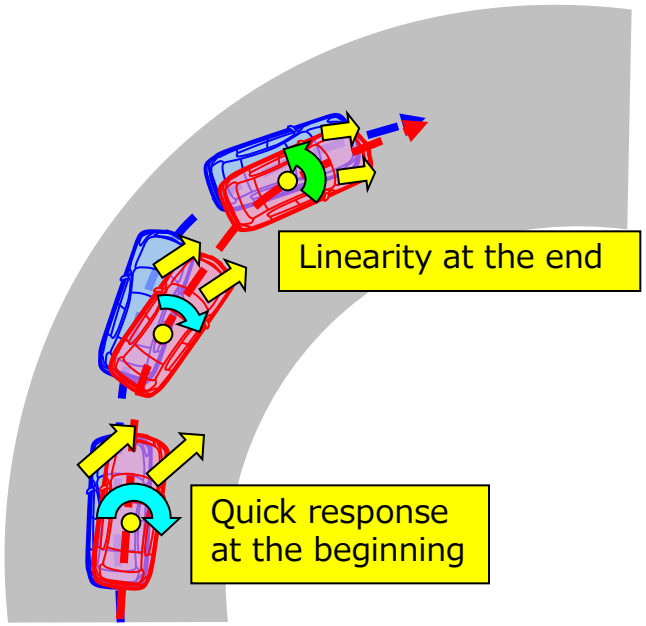
Motor

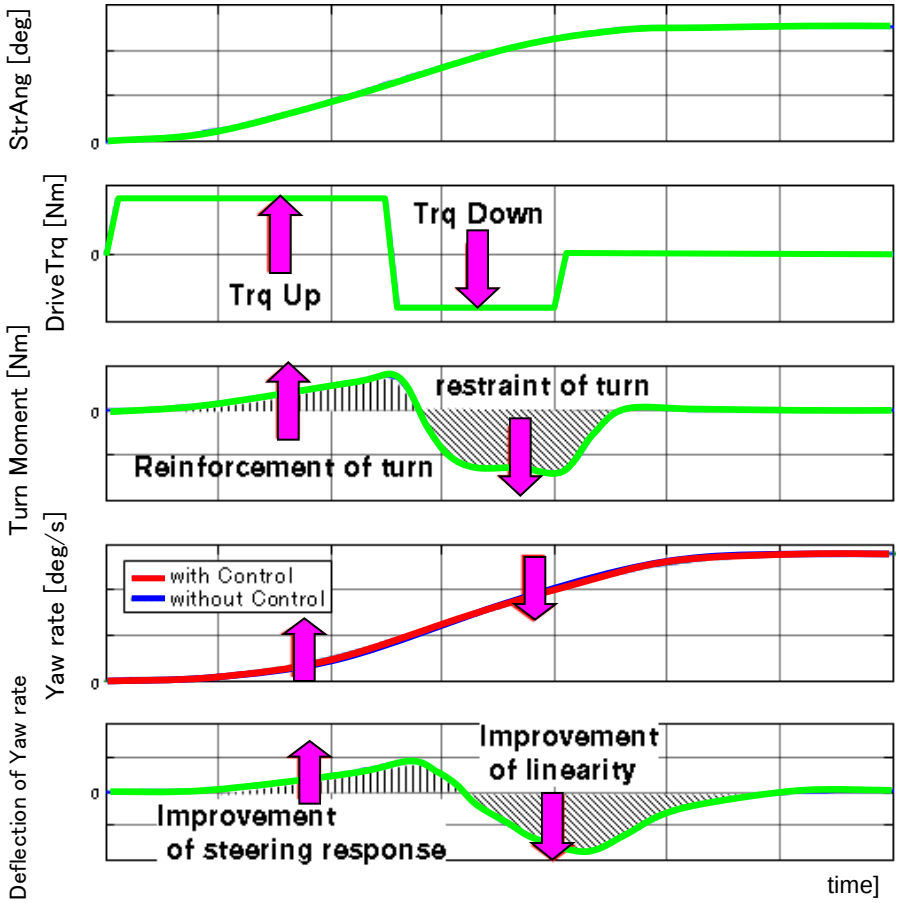


Source: Takaaki Karikomi, JSAE paper, May 2011

Improvement of Handling Performance

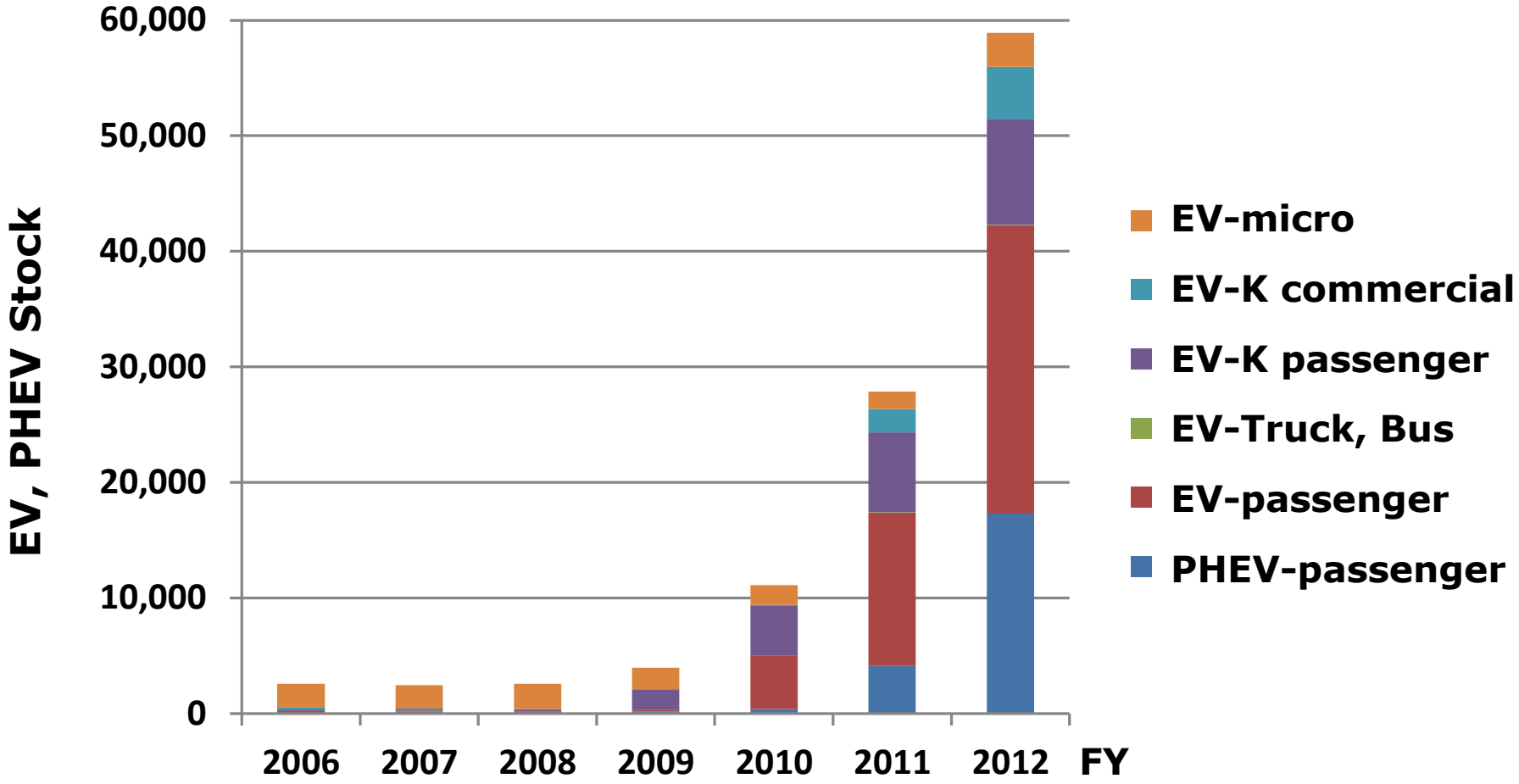
- Quick and linear response to driver's steering operation with motor torque control
- Torque up at the beginning and torque down at the end of turn





Source: Yuuki Shiozawa, JSAE, May 2011

EV, PHEV Market introduction in Japan



Source: Next generation vehicle PC: EV, PHEV stock data
http://www.cev-pc.or.jp/NGVPC/data/index.html

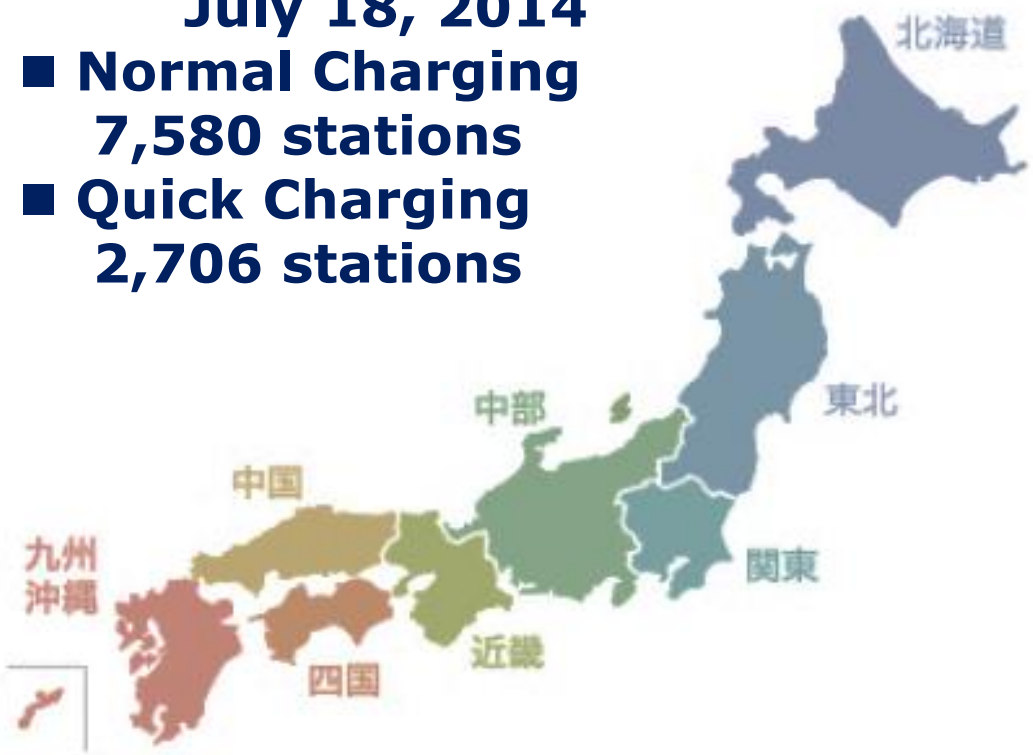
EV Charging infrastructure in Japan

- **Increasing number of EV charging stations**

GoGoEV

July 18, 2014

- **Normal Charging 7,580 stations**
- **Quick Charging 2,706 stations**



Kamakura city area
Kanagawa prefecture

Source: GoGoEV, July 18, 2014, http://ev.gogo.gs/

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Power-train efficiency

- **We should evaluate not only the power-train technologies but also energy for automotive application.**

	Gasoline Diesel Oil	Natural Gas NG	Bio-fuel	Hydrogen H2	Electricity	Power-train efficiency
ICE				Renewable Energy Carbon Free		20 ⇒ 30 %
HV		NG-ICE/M	Bio-ICE/M			30 ⇒ 40 %
PHV		NG-ICE /M/BAT	Bio-ICE /M/BAT	H2-FCV /BAT		Depend on bat. capacity
FCV		NG-FCV				40 ⇒ 60%
Bat-EV						70 ⇒ 80 %

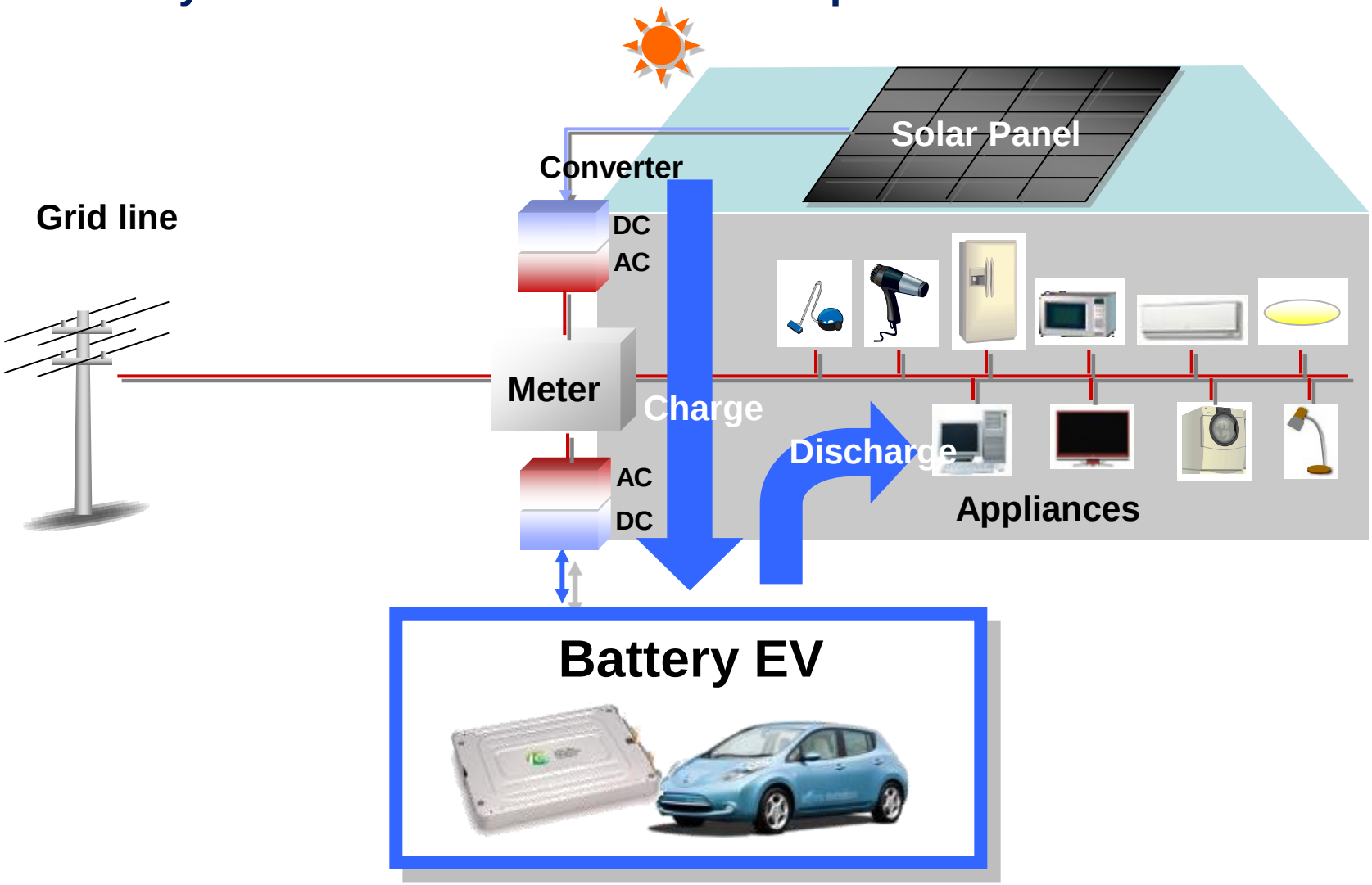
ICE: Internal Combustion Engine
HV: Hybrid Vehicle
PHV: Plug-in Hybrid Vehicle
FCV: Fuel Cell Vehicle
Bat-EV: Battery Electric-drive Vehicle

G: Gasoline
D: Diesel fuel
NG: Natural Gas
Bio: Biomass fuel
H2: Hydrogen
M: Motor

Increase energy efficiency and sift energy for 90% reduction of fossil fuel consumption

Smart House

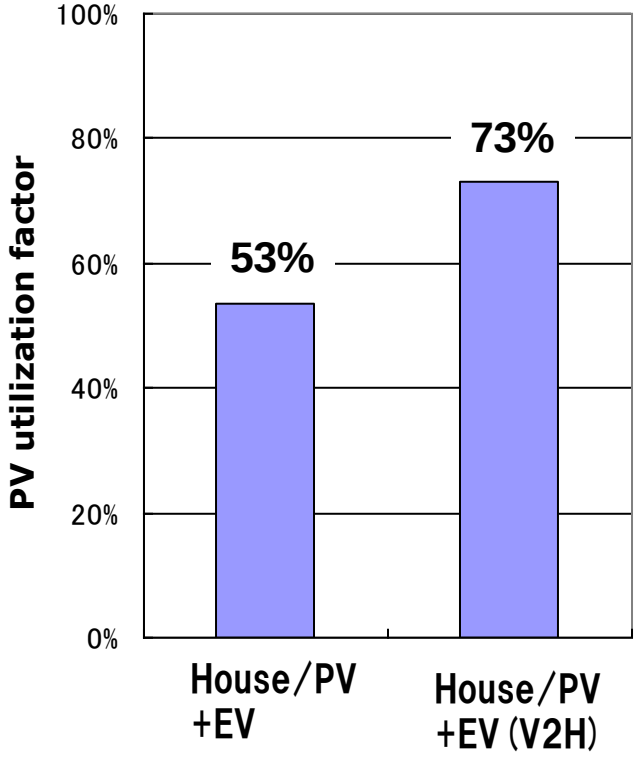
- Solar Energy is utilized for appliances and EV
- EV battery is used for stabilizer of home power line.

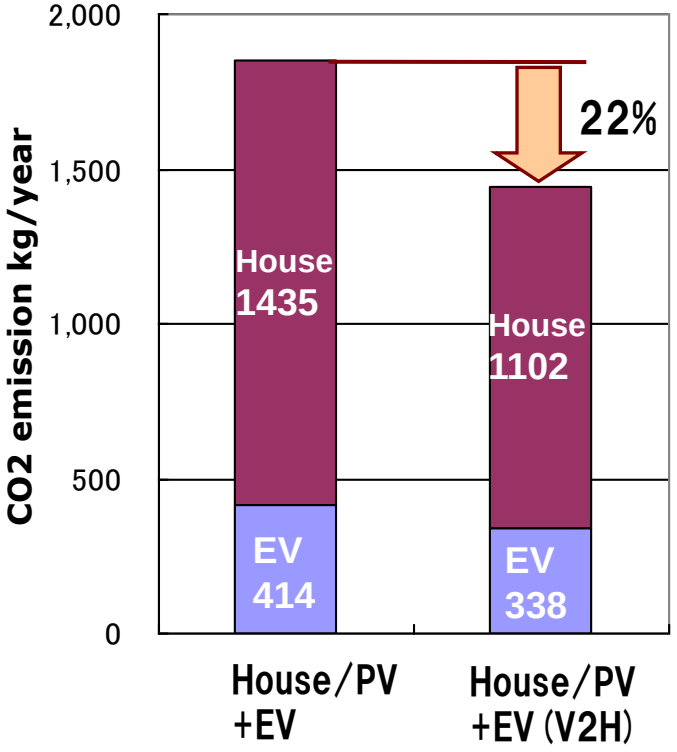


Source: Toshio Hirota, Nissan Technical Review, Vol.69,70, 2012

Improvement of PV utilization with EV

- V2H, Vehicle to Home, system improves PV utilization of a smart house to reduce gap between solar generation and electricity consumption.
- CO2 emissions of house and EV are reduced with lower CO2 intensity.

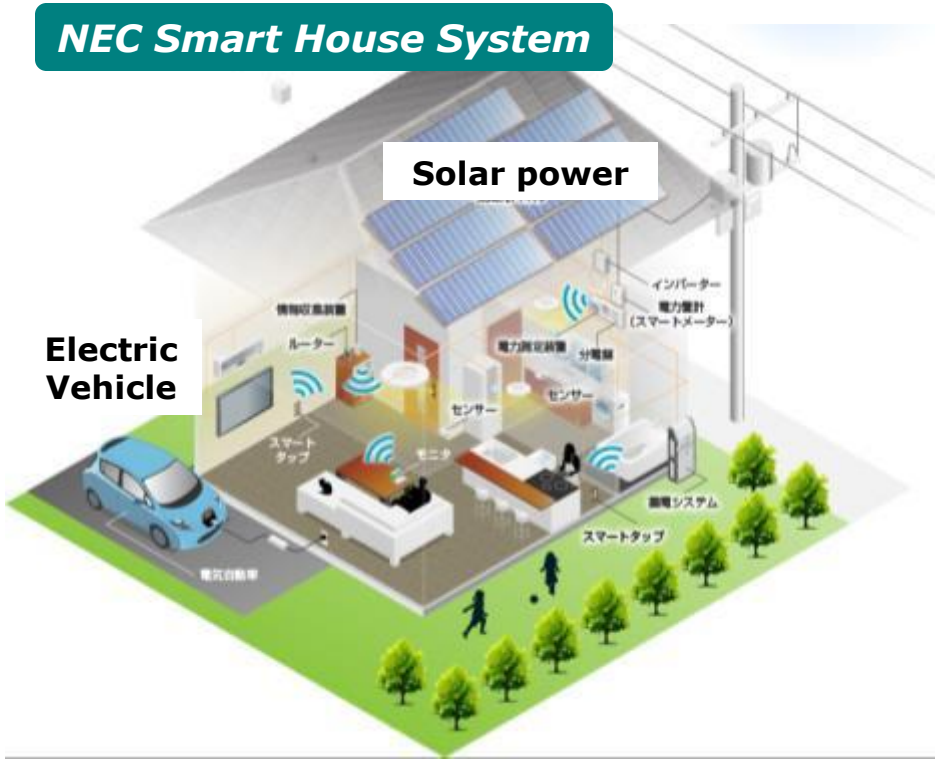


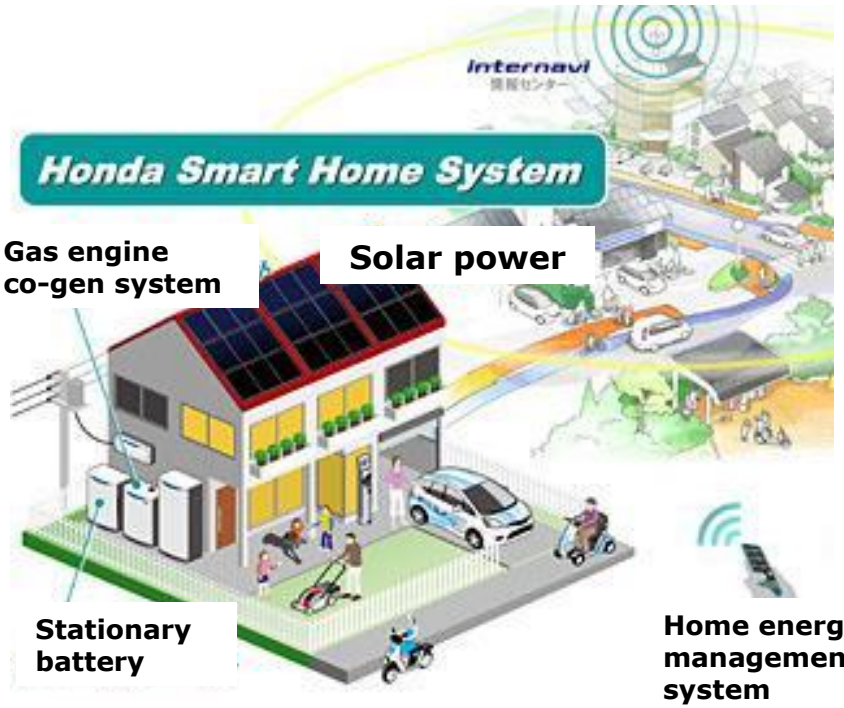


Source: Toshio Hirota, Nissan Technical Review, Vol.69,70, 2012

EV battery for energy storage

- Effective use of renewable energy by storing fluctuated power into the battery of EV
- Reduce energy consumption and shift to renewable energy from fossil fuels for Smart house system





Source: http://www.nec.co.jp/environment/energy/house.html
http://www.honda.co.jp/news/2011/4110523.html

Micro Electric Vehicles

Toyota COMS

Nissan NMC

Honda MC-β

Source: Response, June 28, 2013, http://response.jp/article/2013/06/28/201115.html

Micro mobility sharing in Yokohama city

- Yokohama city and Nissan started a EV sharing feasibility program at Minatomirai and central area of the city Oct. 2013.
- 100 micro EVs and 70 sharing stations for the program
- Easy to access with smart phone and one way rental

- New mobility concept:
  - 1-2 passengers
  - Lithium ion battery
  - Vehicle weight: 500 kg
  - Max. speed: 80 km/h

Source: Choi-mobi, http://www.choi-mobi.com/

Electric Bus for Public Transportation

FY2011-2013 Waseda University

- Field test incl. cold condition in Nagano city for 3 years
- Environmental friendly, low noise and low vibration
- Ready for practical usage as public transportation with government support

- Vehicle weight: 5620kg
- Vehicle size: 6.99×2.08×3.10m
- Number of passenger: 31 persons
- Permanent magnet AC synchronous motor
- Lithium-ion battery: 44 kWh
- Inductive charging system and conductive charging system

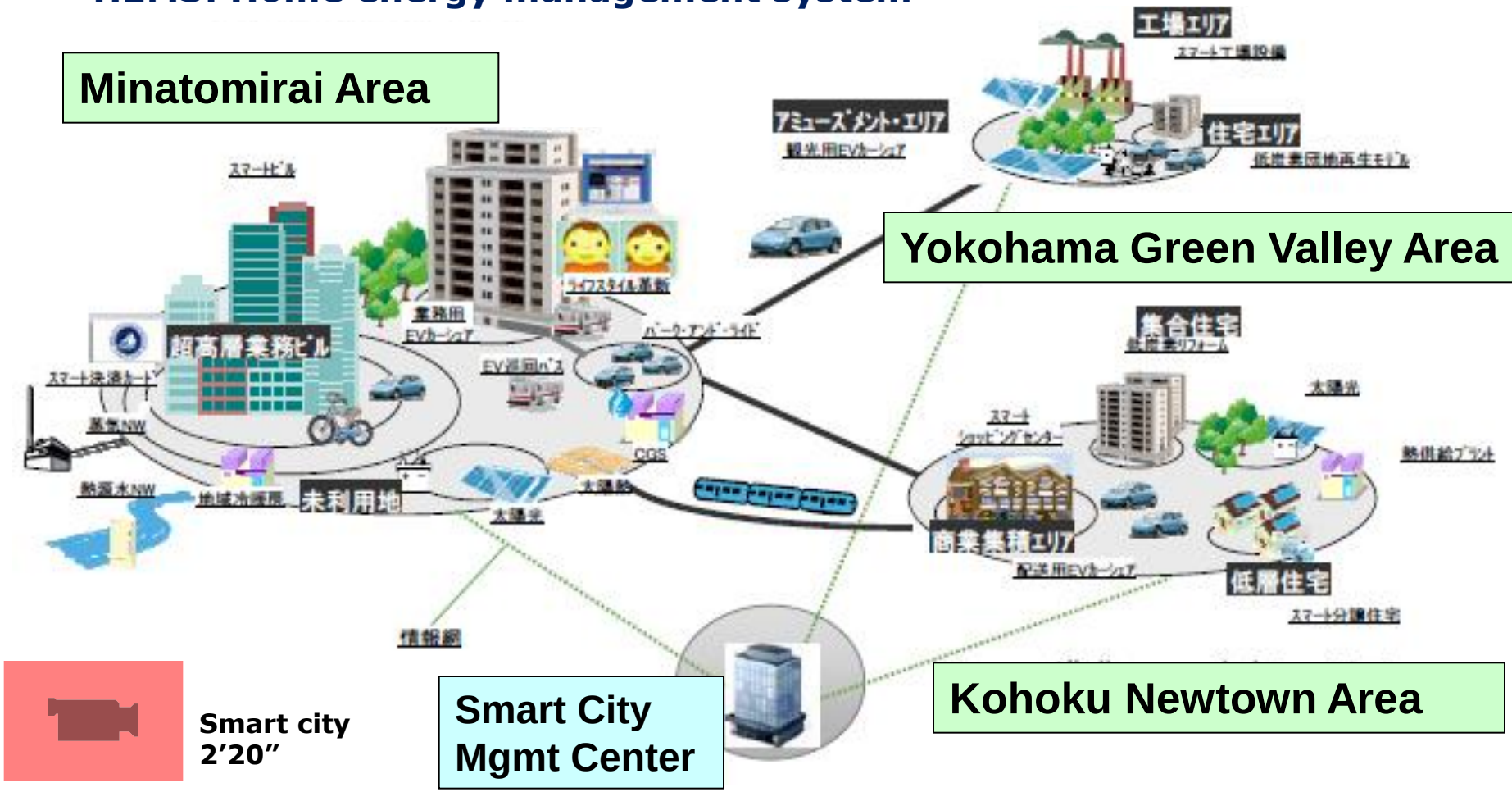
Smart Mobility/Smart Community

Source: METI, EV/PHV Town Concept, 2009

Yokohama Smart City Project

- Field test program in 3 areas, 2010 - 2014
- Target: 64,000 ton-CO2 reduction with 27MW PV, 4,000 HEMS, and 2,000 Electric vehicles

*HEMS: Home energy management system



Source: Yokohama city press release
Toshio Hirota, Environmental Research Institute, Waseda University, Japan

Yakushima CO2 Free Island Project

- Introducing electric vehicles with renewable electricity in Yakushima.
- Local government provides incentives for EVs and charging infrastructure.

*Yakushima island is famous with a natural World Heritage Site.

Low Carbon and Sustainable Mobility

- Technology: Vehicle, Energy and Mobility
- Electrically-Drive Technologies
  Hybrid/Plug-in Hybrid, FCV, Battery EV
- Multiple approaches: Technology, Policy, Behavior Change

1970	1990	2010	2030	2050