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Perspectives on Disseminating Next Generation Vehicles for Sustainable Mobility beyond 2030 and towards 2050

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Research Council

Waseda University

Serious Issues associated with mobility

< Environment >

Air pollution

Global warming

< Energy >

Oil dependence

Renewables

< Traffic Congestion >

< Traffic Accidents >

< Natural Disasters>

Three important measures to resolve or mitigate vehicle-related environmental and energy issues

1. Reducing exhaust gas emissions and improving fuel economy in conventional gasoline and diesel vehicles

2. Developing and disseminating alternative power systems, fuels and energy, including hybrids, EVs, plug-in hybrid, FCVs, etc.

3. Changing the way we use the automobile, by means of ITS, ICT, modal shift using mass transit, eco-driving, social and community planning, tax incentives, public awareness, etc.

Greenhouse Gases Reduction by each Country according to the Paris Agreement, Nov., 2015

Country	Reduction		Reference
China	per GDP 60 - 65 %	by 2030	2005
E U	40 %	by 2030	1990
India	per GDP 33 - 35 %	by 2030	2005
Japan	26 %	by 2030	2013
Russia	70 - 75 %	by 2030	1990
USA	26 - 28 %	by 2025	2005

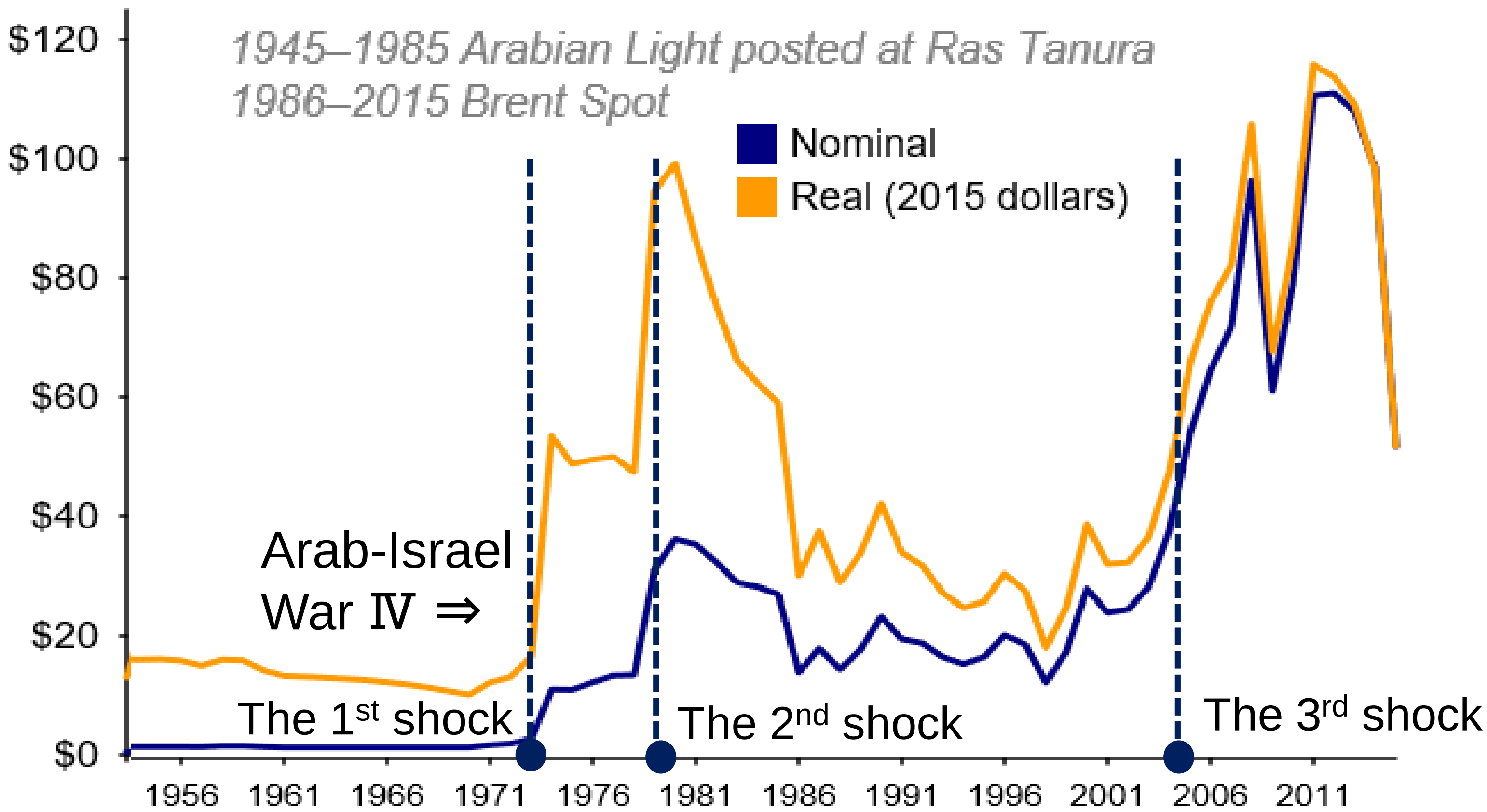
☆President Trump announced that the United States would withdraw from the Paris climate accord on June 1st, 2017

Energy Related CO_2 Emission Reductions in 2030 for the Paris Agreement, Japan

[Unit: Million t-CO_2]

Sector	2013 （2005）	2030 ／ Reduction % 2013（2005）
Industry	429 (457)	401 ／ ▲6.5 (▲12.3)
Business, etc.	279 (239)	168 ／ ▲39.8 (▲29.7)
Household	201 (180)	122 ／ ▲39.3 (▲32.2)
Transportation	225 (240)	163 ／ ▲27.6 (▲32.1)
Energy Conversion	101 (104)	73 ／ ▲27.7 (▲29.8)
Total	1,235 (1,219)	927 ／ ▲24.9 (▲24.0)

Crude Oil Price Significantly Changed. (US EIA, 2015)



☆Such oil shocks must be avoided or overcome by improving vehicle efficiency, disseminating lower carbon energy vehicles and making mobility smarter.

Comparison of LDV Fuel Economy Standards based on NEDC, ICCT 2015

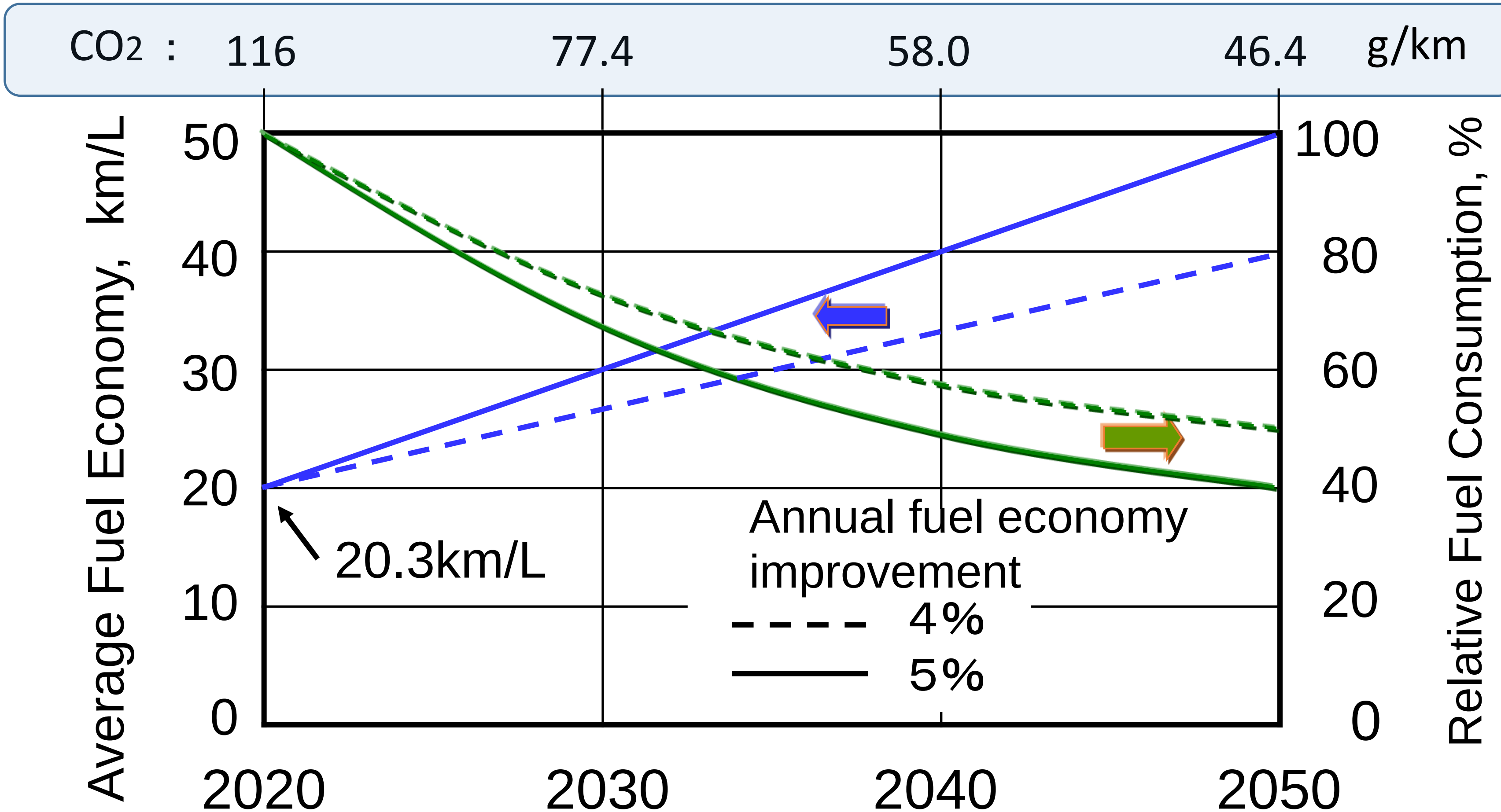
Country	Year	km/L	L/100 km	CO_2 g/km
Japan	2020	22.1	4.52	105
E U	2021 (2030)	24.4 (31.7)	4.10 (3.1)	95 (73)
USA	2025	22.5	4.44	103
China	2020 (2025)	19.8 (25.0)	5.05 (4.00)	117 (93)
India	2021	20.5	4.88	113

( ): Proposed

NEDC: New European Driving Cycle

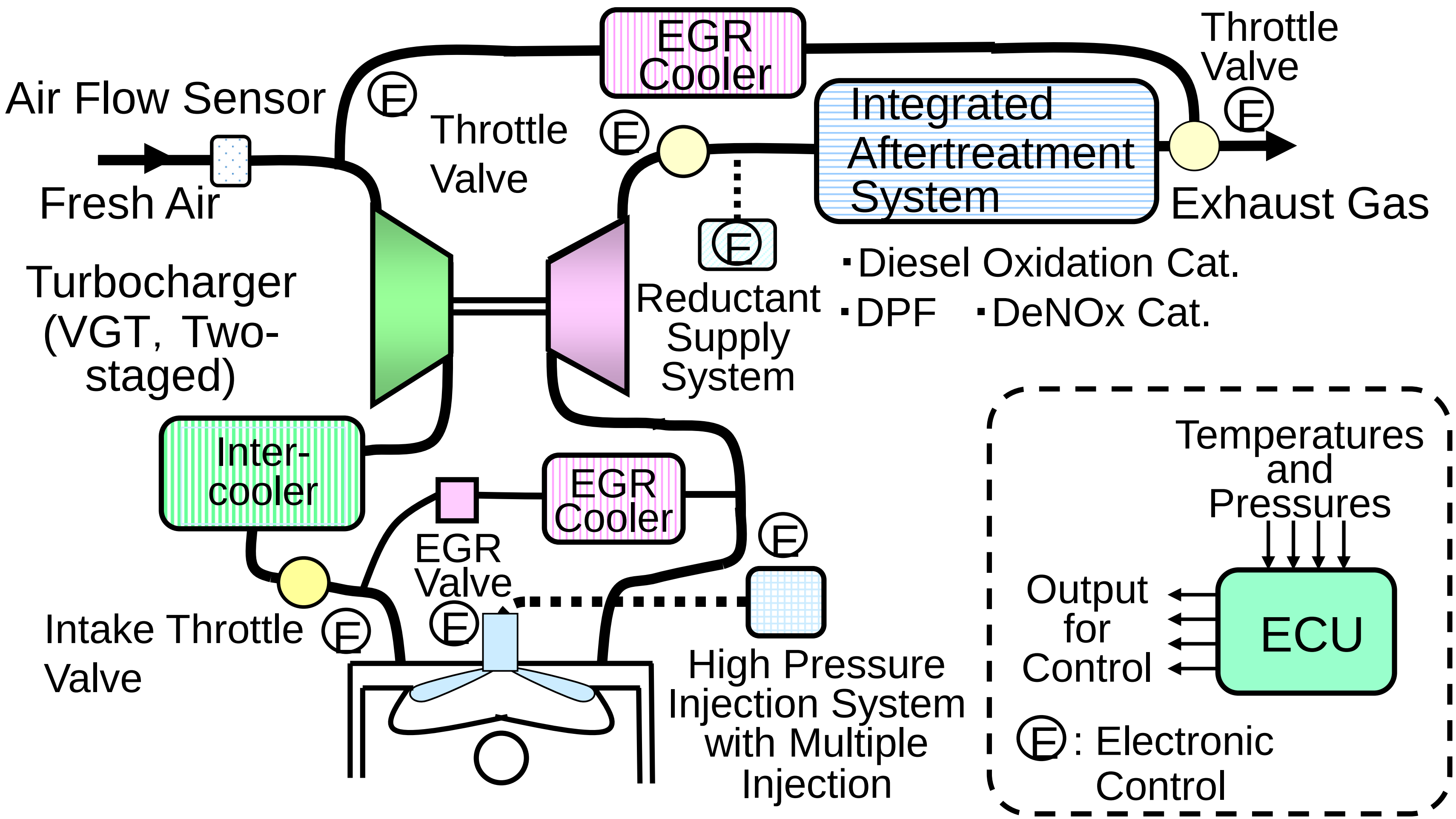
ICCT: The International Council on Clean Transportation

Future Passenger Car Fuel Economy Targets



By Y. Daisho

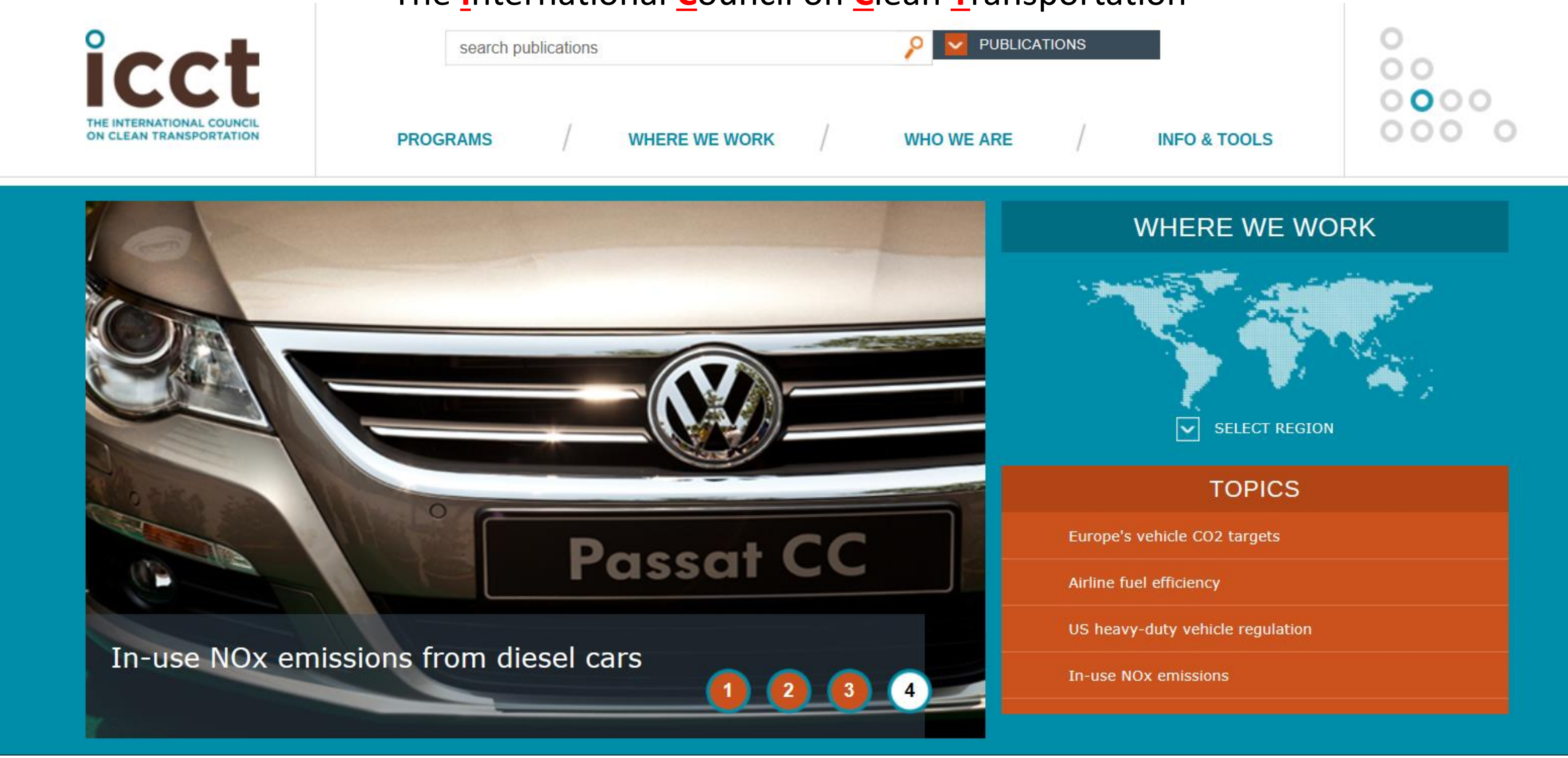
A Typical Advanced Diesel Emission Control System



Ensuring efficiency, durability and cost reduction are essential to comply with more stringent diesel emission regulations to be in effect in Japan, the EU and the USA in 2010s to 2020s.

The Volkswagen emissions scandal called "dieselgate" started on 18 September 2015.

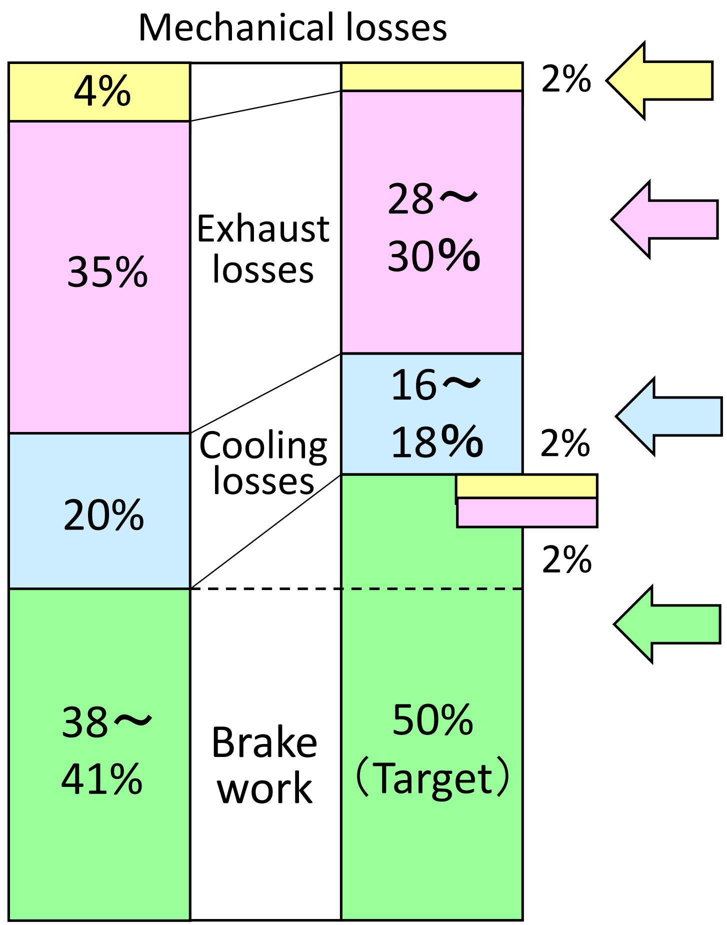
The International Council on Clean Transportation



VW decided to shift from diesel to EVs. Some large cities in Europe have prohibited drivers from driving in a diesel passenger car. In 2017, France and the UK announced that selling diesel passenger cars will be prohibited after 2040.

Solutions to Achieve a 50% Brake Thermal Efficiency in ICEs

"Innovative Combustion Technologies"
by the Strategic Innovation Program (SIP), JST, FY2014-18



≪Energy Balance≫

- ✓Reducing mechanical losses by 50%

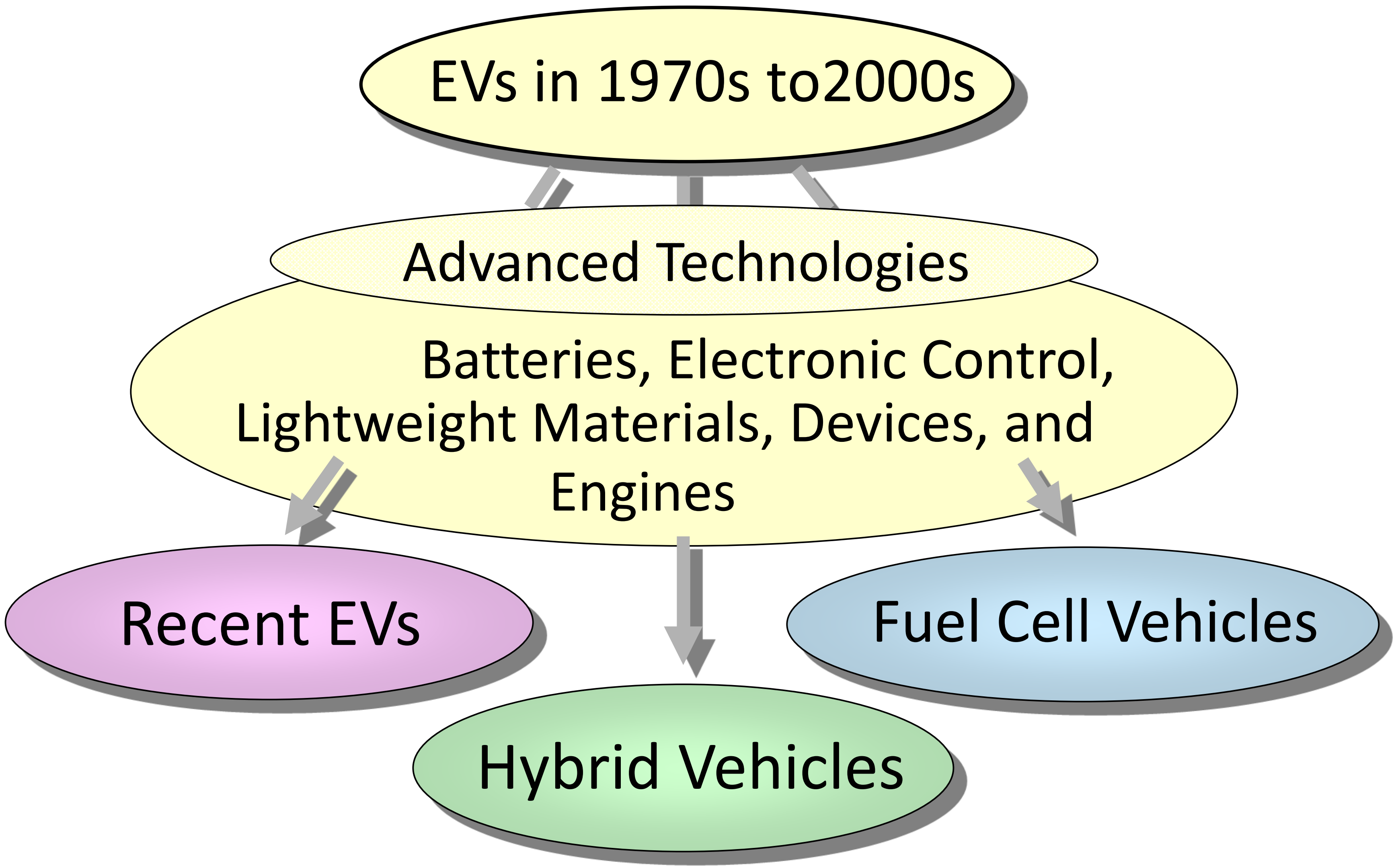
- ✓Utilizing exhaust gas energy
  - ･Increasing turbocharging efficiency
  - ･Using a thermoelectric device
- ✓Reducing heat losses by improving combustion

- ✓Enhancing indicated work by improving combustion in both engines

★ Brake Thermal Efficiency Baseline:
Gasoline engines ⇒ 38%
Diesel engines ⇒ 41%

☆The high efficiency engine is essential for increasing hybrids' fuel economy.

Variations of Electrified Vehicles

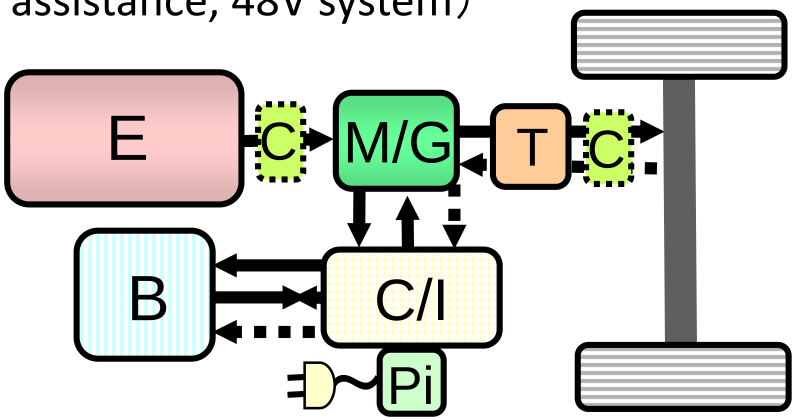


Three Hybrid Systems

<Hybrid type>
【Improved fuel economy, %】

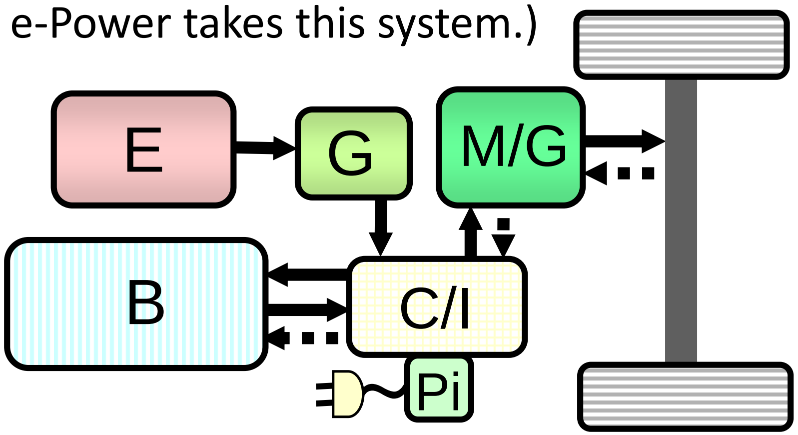
M: Motor G: Generator
C/I: Controller / Inverter
B: Battery unit
T: Transmission C：Clutch
Ps: Power splitter
Pi: Plug-in
⟶ : Drive / Power generation
◂■■■■: Regeneration

（Integrated starter and generator, Power assistance, 48V system）

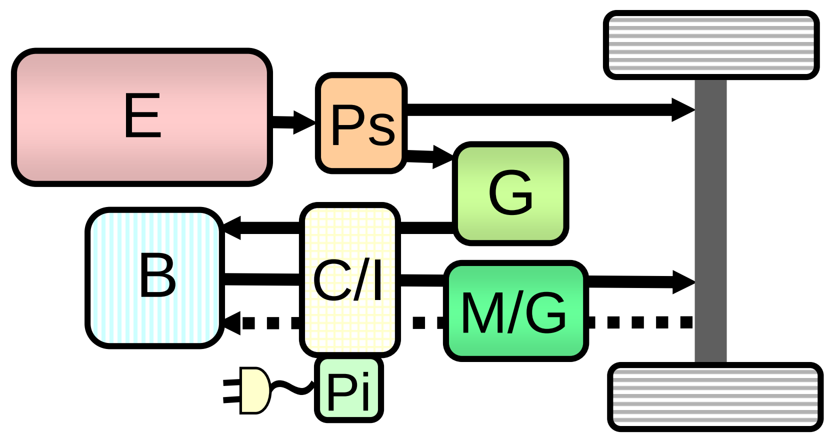


<Parallel (Mild)>【20-50%】

（FCVs adopts the similar system. Nissan’s Note e-Power takes this system.)



<Series（Full）>【50-100%】



<Series/Parallel (Full)>【50-100%】

Various HVEs Sold Recently in Japan

Prius, Toyota

Plug-in Prius, Toyota

Plug-in Outlander, Mitsubishi

Solio, Mild hybrid (ISG) Suzuki

Note, e-Power, Series Hybrid, Nissan

Fit Hybrid, Dual Clutch Transmission Honda

Diesel Parallel Hybrid Truck, Isuzu

Diesel Parallel Hybrid Bus, Hino

A Variety of Electric Vehicles in 2017-2019

Chevrolet Bolt, GM

i3, BMW

E-Golf, VW

Leaf, Nissan

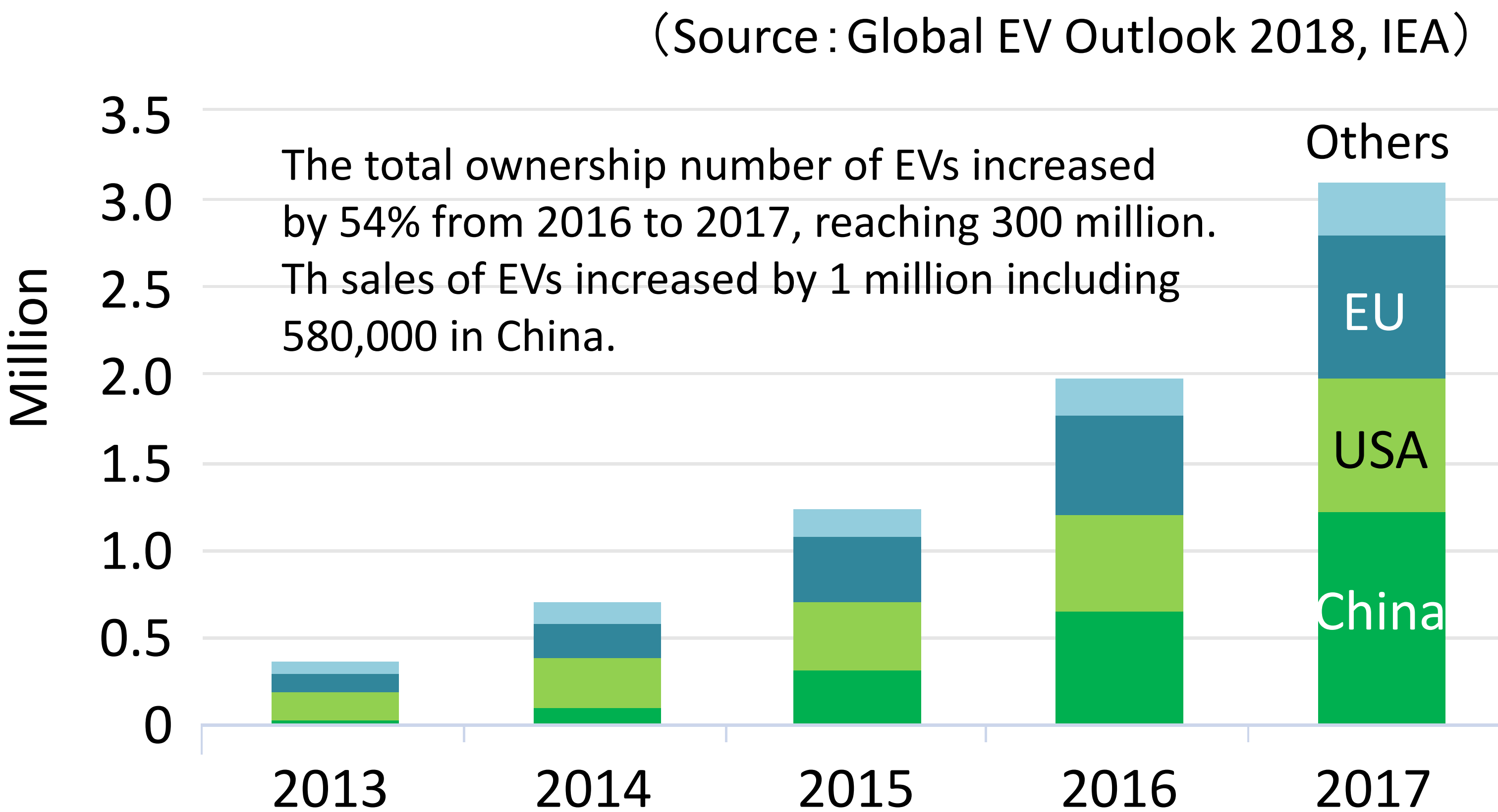
Model 3, Tesla

Honda Urban EV Concept

E-Canter, Mitsubishi

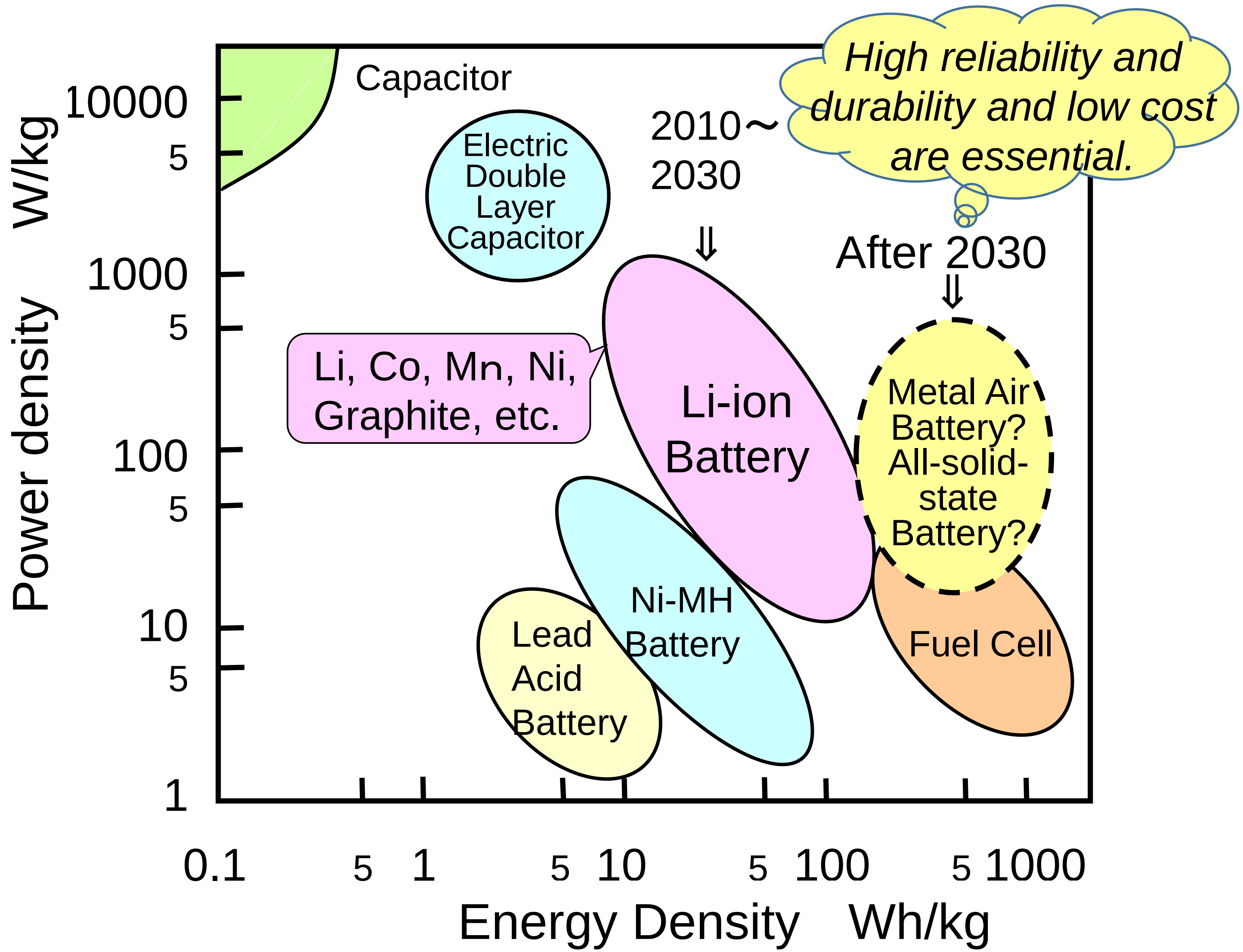
Semi in 2019?, Tesla

Number of EVs in Circulation



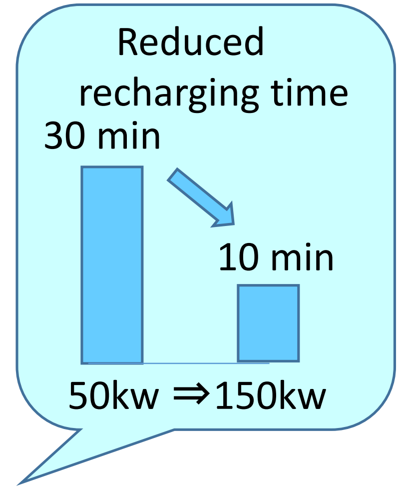
- ❑ The number of EVs will increase by 24% annually based on BAU policies of each country, reaching 4 million in 2020 and 21.5 million in 2030. The number EVs in circulation will reach 13 million and 125 million in 2030, counting for 10% in the light duty vehicle categories.
- ❑ Enhanced policies will make the global EV stock number 220 million in 2030.

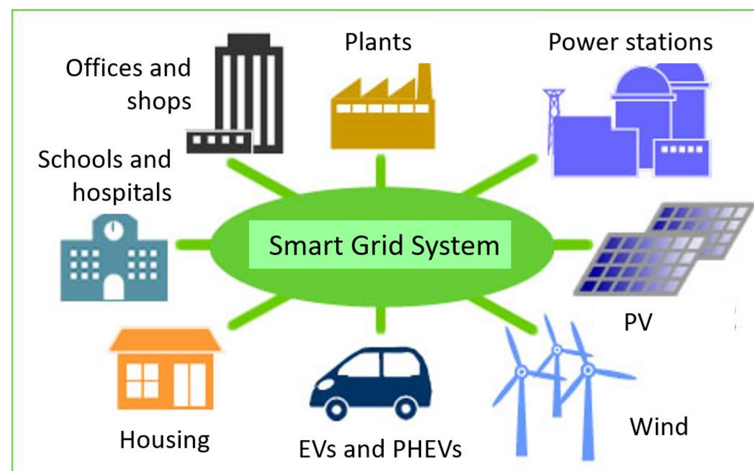
Devices for Storing Electricity



Issues on Rapid Recharging Systems for EVs and PHEVs in Japan

- ❑ The effect of stopping all nuclear power stations in March 2011 on increased CO_2 emissions in Japan
  - ･340g/kWh in 2010
  - ･610g/kWh（1.8 times） in 2014 (average)
- ❑ Revised CHADEMO standards for rapid EV recharging, announced in March 2017
  - ･Increasing power capacity for Evs and reducing recharging: 50 kW ⇒ 150kW (2017) ⇒ 350kW (2020)
  - ･Issues on how to manage electricity supply and demand for transportation, business and household sectors
    - ✓ Smart grid and demand response systems are necessary.
    - ✓ Power management systems are also necessary to store and generate electricity





ZEV and NEV policies will lead the global EV market.

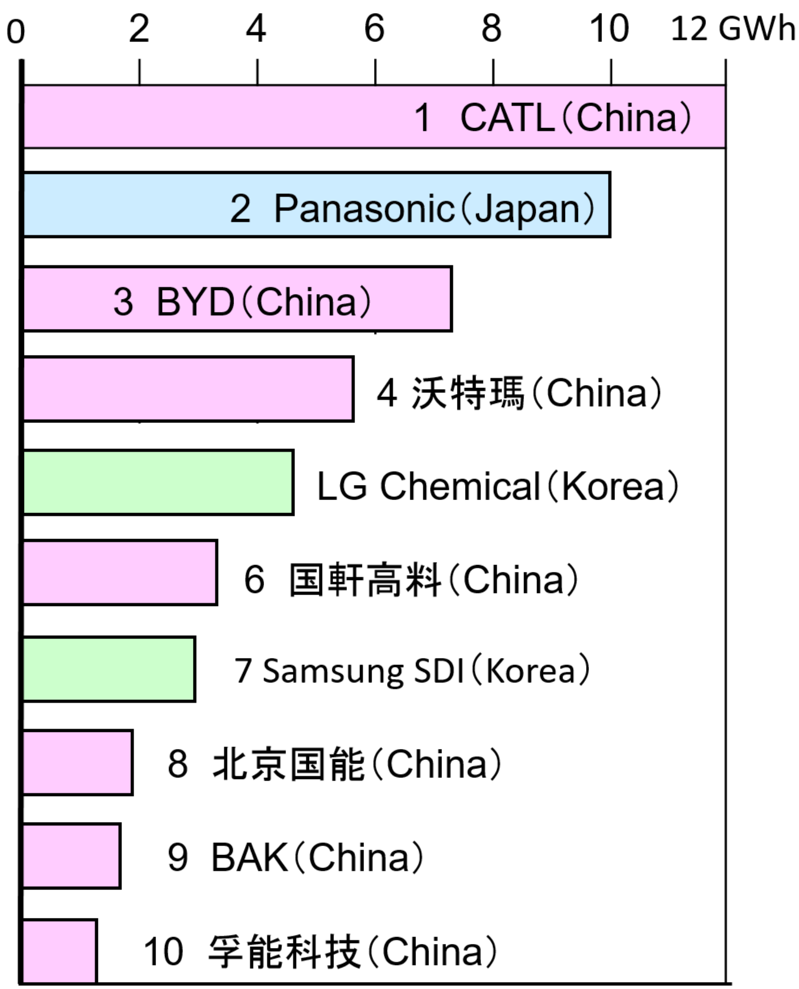
❑ZEV regulations is tightened in California.

- ZEV sales: 4.5% in 2018, stepwisely 22% in 2015
- GM, Ford, FCA, Toyota, Honda, Nissan, VW, BMW, Daimler, Hyundai/Kia and Mazda have to comply.
- ZEVs include BEVs, FCVs, TZEVs (Transitional ZEV, PHV) excluding hybrids.
- Nine statess follow California.

❑NEV（New Energy Vehicle）policy starts in China.

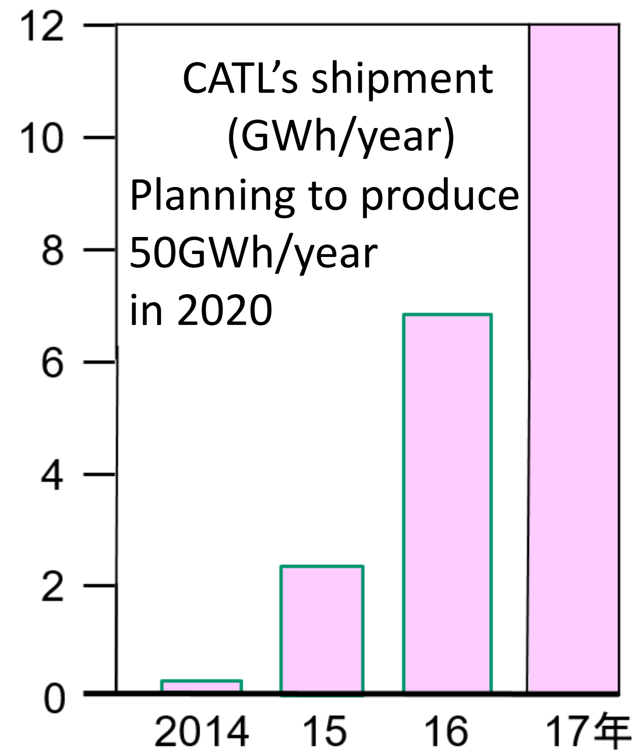
- ZEVs sales: 10% in 2019, 12% in 2020
- Hybrids are excluded.
- PHEVs having more than 50 km EV range are included.
- EV and battery technologies are expected to advance.
- Will EV sales decrease after EV's purchase incentives are expired in 2020?
- China will become the mightiest EV nation, producing 7 million EVs out of 35 million vehicle production along with "Made in China 2025."
- Disseminating EV will not have any significant effect on reducing CO_2 or improving air pollution in all megacities in China.

Chinese Li-ion Battery Makers dominate the market.



Automotive Li-ion battery shipment ranking in 2017（高工産業研究院, China／Nikkei, May, 2018）

BYD plans to produce 60 GWh/year no later than 2000（July, 2018）



- 10 GWh for 250,000 EVs（40 kWh）
- Will mass production reduce the costs?
- Reduced EV sales will cause over-production of battery units.

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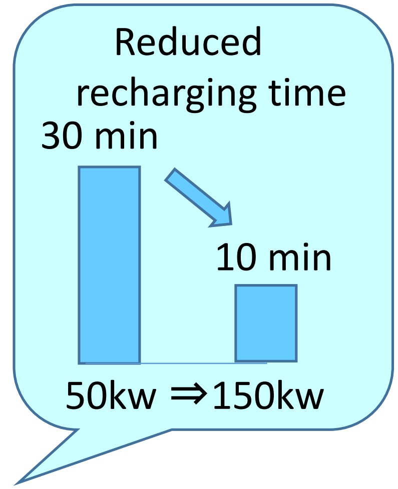

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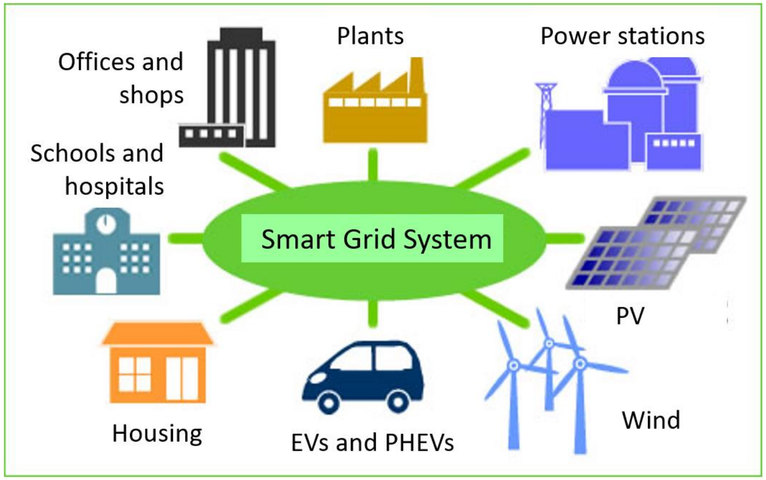


SHIZUKI ELECTRIC CO.

Advanced Electric Micro-Buses with an Wireless Power Supply System for Community Transportation (Sponsored by NEDO and MOE, 2004-2016)

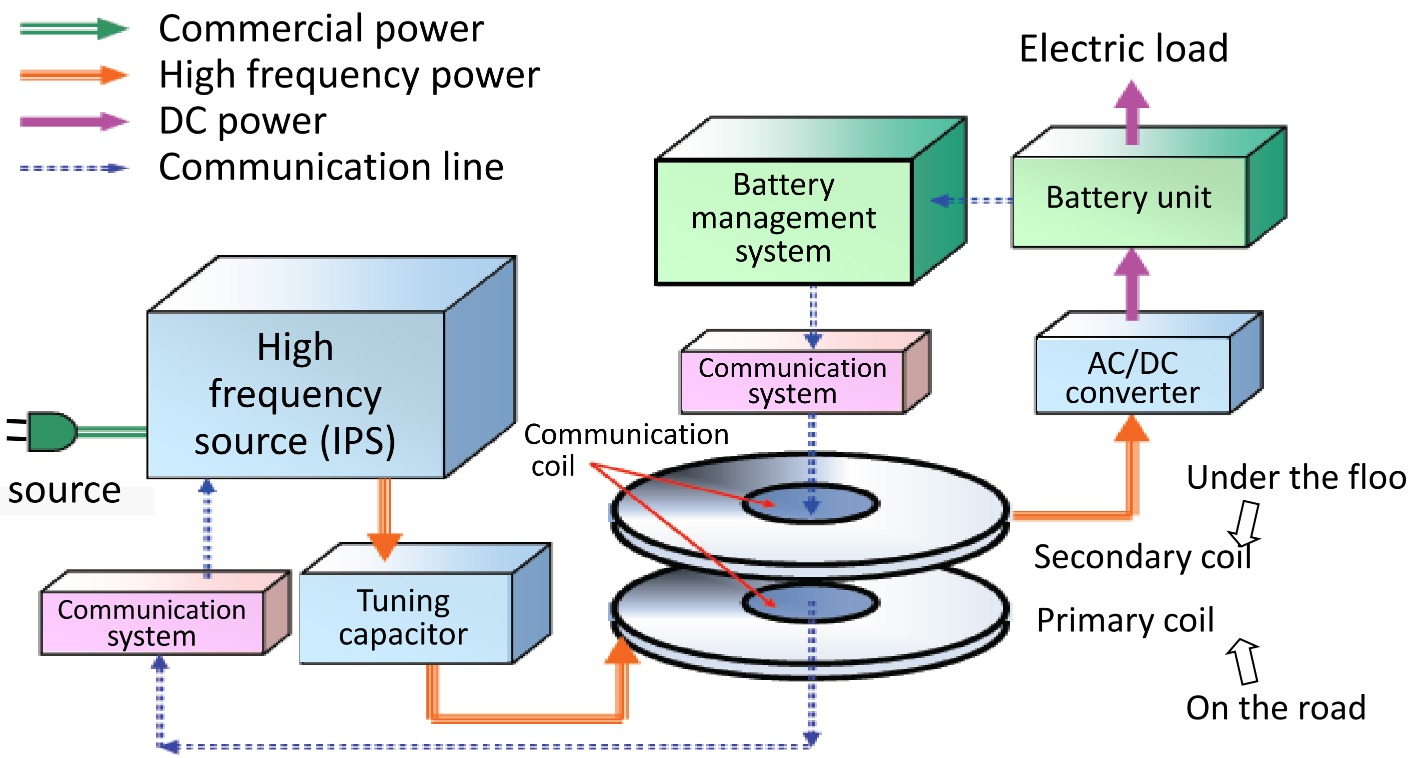
＜Specifications＞

- Base: Hino Motors' Poncho
- Length: 6.29 m, Width: 2.08 m
  Height: 3.10 m
- Occupancy: 20-30 passengers
- Drive range: 45 km
  (fully charged)

By Waseda University, Hino Motors and Showa Aircraft

- An advanced rapid inductive charging system is developed to reduce the capacity of batteries.
- Zero emissions, high efficiency and low CO_2 emission characteristics
- A demand system is possible for regional transportation.
- Low noise, smooth acceleration and comfortable ride for elderly and handicapped passengers

An Inductive Power Supply System for Rapid Recharging EV's Batteries

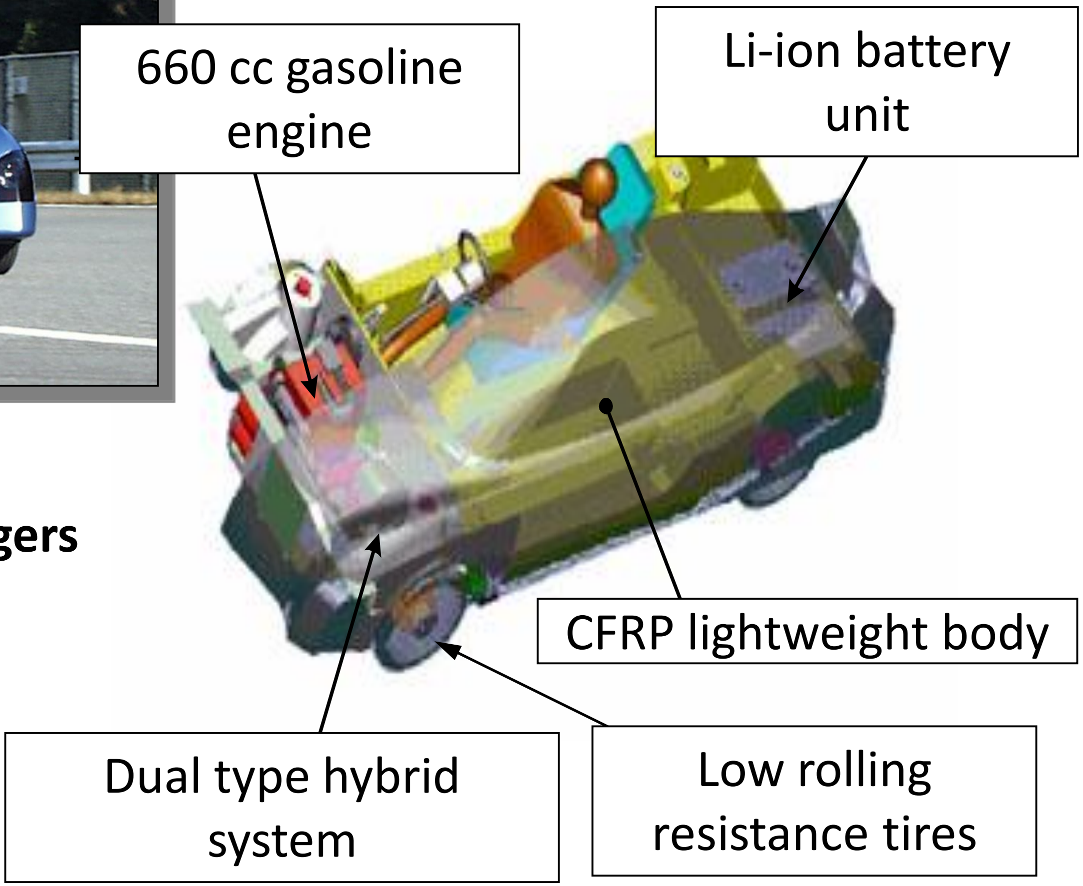


Maximum power: 50 kW

Waseda University
Showa Aircraft Industry Co., Ltd.

"Waseda's Future Vehicle" (2000-2014)

☆ **The vehicle has been converted to a fuel cell vehicle**



- **Occupancy: two passengers**
- **Weight: 750 kg**
- **Fuel economy: 35 km/L (10-15 mode)**

Small Electrified Vehicles for Personal Mobility

Y. Daisho and Y. Kamiya, Waseda University

FCV for elderly passengers (2009-)

FC bike

(MOE, -2007)

FC carrier for market place

(NEDO, 2007-）

Two-seater EV

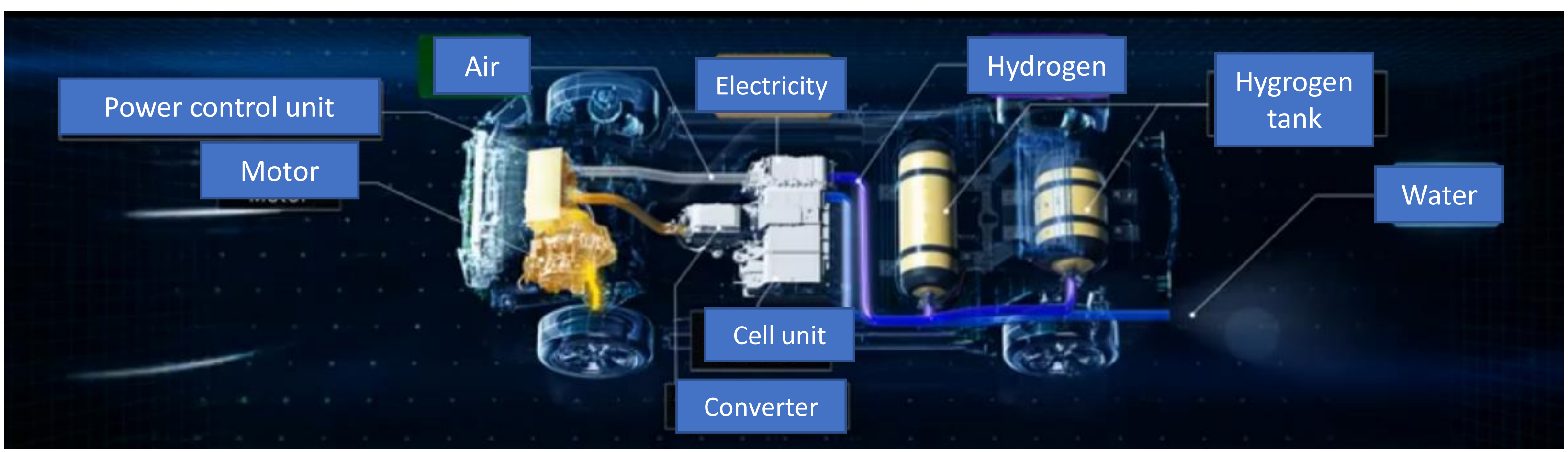
7 kW IPS (2008-）

Plug-in hybrid

(2008-）

Toyota launched FCV "Mirai" in Nov., 2014

- ❑"Mirai" is the world-first mass production fuel cell passenger car sold worldwidely.
- ❑Specifications
  - ・70MPa（2 tanks）　・Range：700 km　・Max. speed：170 km/h
  - ・Power density: 3 kW/L (100 kW)　・Cold startability：-30℃
  - ・Vehicle efficiency：65%
- ❑Almost all related patents will be opened.
- ❑Price. 7.23 Million yen（Tax incentive: 2 million yen）
- ❑Annual production schedule: 700-1,000 in 2014-15, 2,000 in 2016 and 3,000 in 2017



A Variety of Toyota's FCVs, 2014-2017

"Mirai" December, 2014

FC Forklift, January, 2017

FC Bus with two Mirai's FC systems sold to the Tokyo Metropolitan Government, February, 2017

FC Truck , in U.S. California bay areas April, 2017

The truck has two "Mirai`s FC systems, 12kWh battery unit and 500kW power motor unit with 1,800N・m torque. The gross vehicle weight is 36 tons.

Other automakers are expected to follow or collaborate with Toyota.

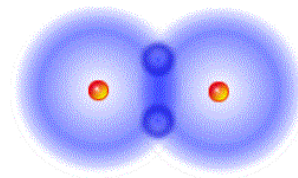
A Roadmap for Disseminating Hydrogen Fuel Cell Vehicles in Japan (METI, 2016-2017）

❑Number of registered FCVs:

・**40,000 by 2020** ・**200,000 by 2025** ・**800,000 by 2030**

(・3-6 million in 2040 ・8-16 million in 2050)

❑FCVs should include not only passenger cars but also forklifts, trucks, buses, vessels, etc.



❑Number of hydrogen stations:

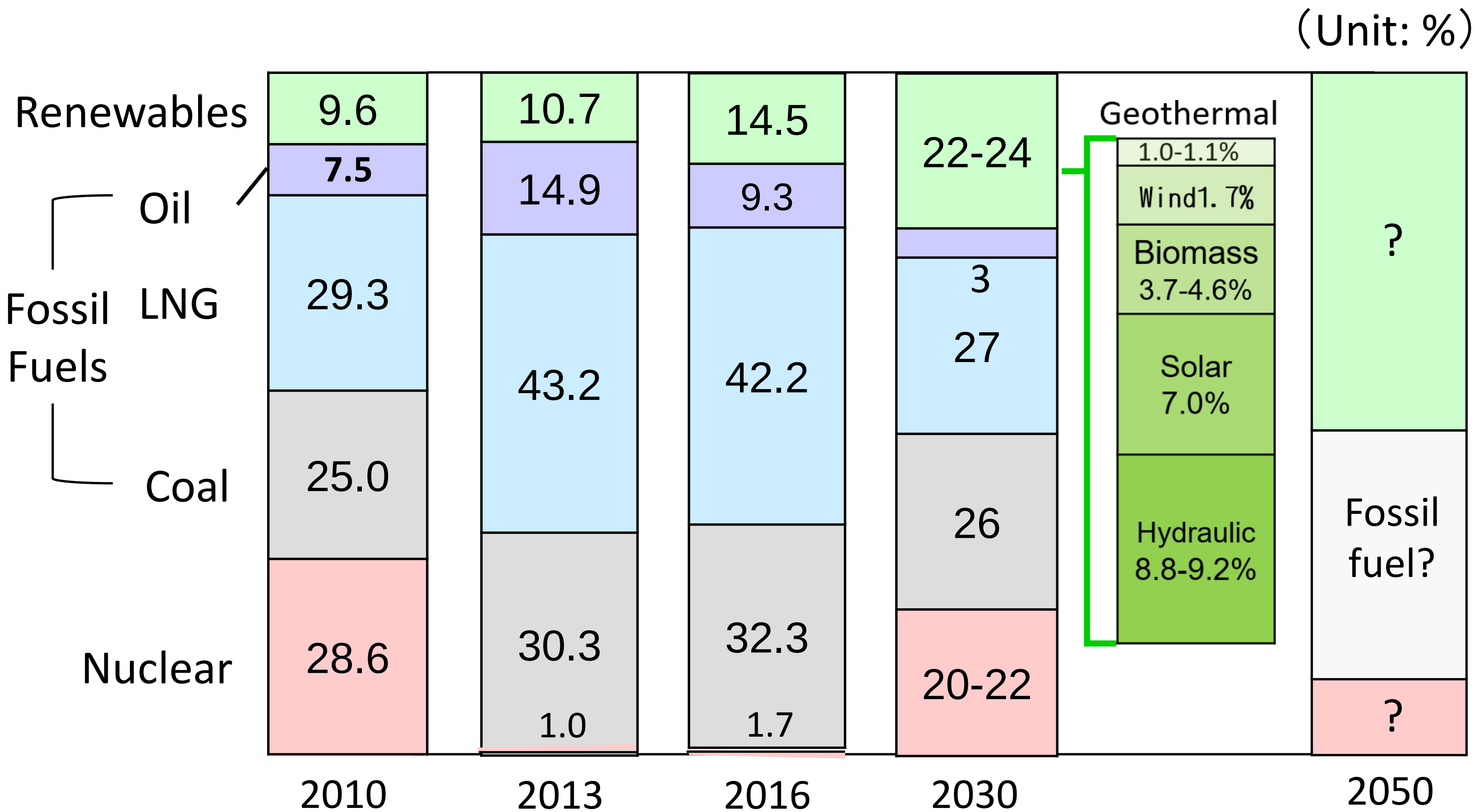
・**160 by 2020** ・**320 by 2025** (・720 in 2030)

❑Hydrogen should be CO_2 free in terms of production, transportation, storage and usage by 2040.

❑Hydrogen carriers including organic hydride, ammonia and liquefaction are the most promising measures to store and transport hydrogen. (SIP)

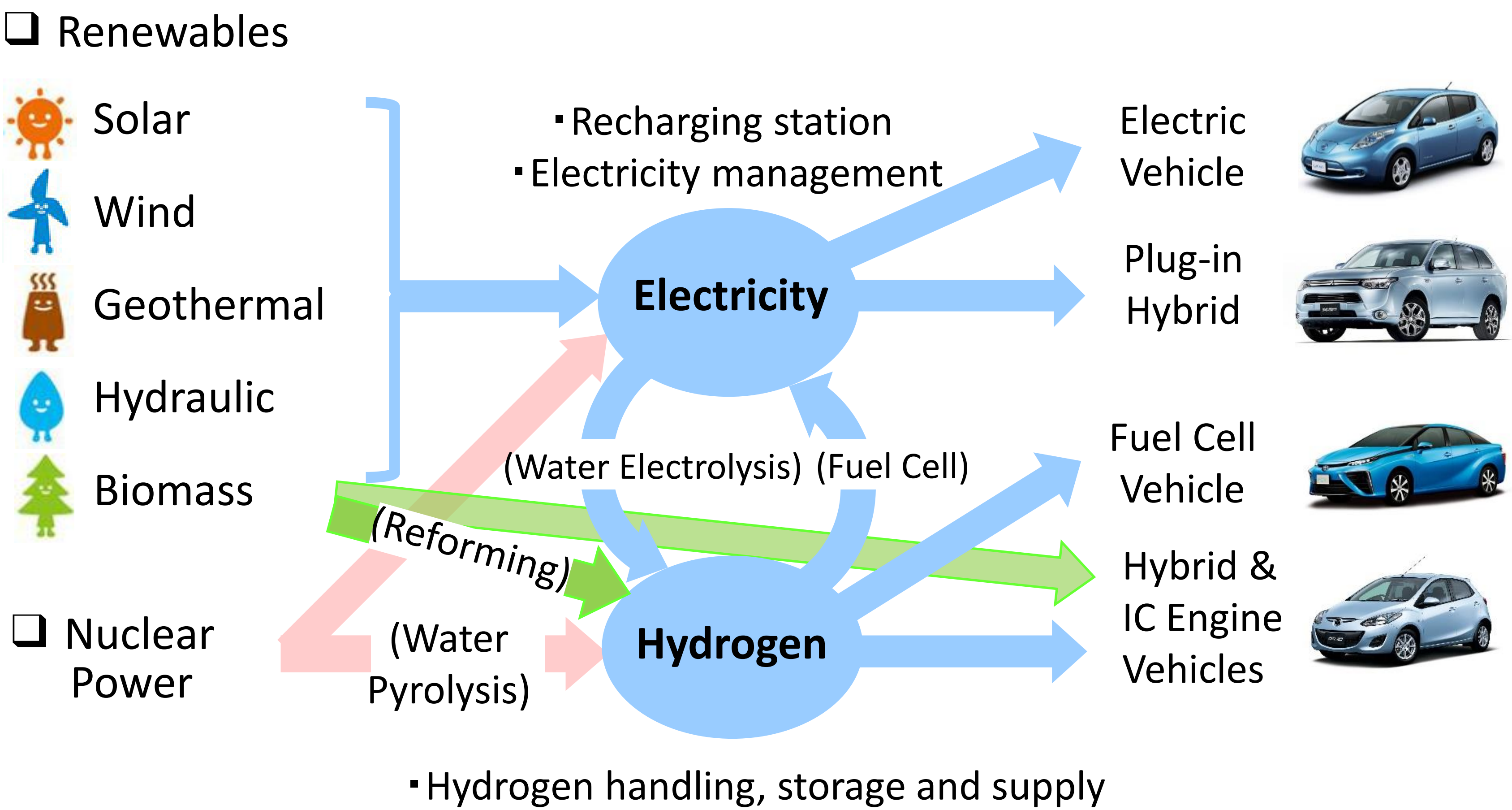
❑Technological and economical issues should be discussed and overcome to introduce renewable hydrogen.

Electricity Sources Proposed for the Paris Agreement by METI, Japan, 2018



☆Reducing the consumption of fossil fuels in electric power stations is effective to decrease CO_2 emission from all sectors.

Options for Decarbonizing Electricity and Hydrogen



☆ Hydrogen is produced mainly from fossil fuels such as oil and natural gas.
☆ Carbon-free hydrogen must be realized by 2040 taking into production, transportation, storage and supply processes. (Japan)
☆ Overall LCA and cost evaluation should be made on these fuels and energy.

Comparison of Next Generation Vehicles

Category	Emissions	Low cabon	Drive range	Recharging time	Cost	Potential and issues
Gasoline vehicle	○	△	○	◎	◎	increasing efficiency
Hybrid vehicle	○	◎	◎	◎	□	lowering costs
Electric vehicle	◎	◎	△	▲	△	Lowering costs Decarbonizing electricity
Plug-in hybrid	○	◎	◎	□	△	lowering costs, decarbonizing electricity
Fuel cell vehicle	◎	◎	◎	○	▲	decarbonizing hydrogen locating hygrogen stations
Clean diesel vehicle	□	○	◎	◎	○	reducing emissions hybridization
Natural gas vehicle	○	□	△	○	□	locating NG stations Increasing efficiency

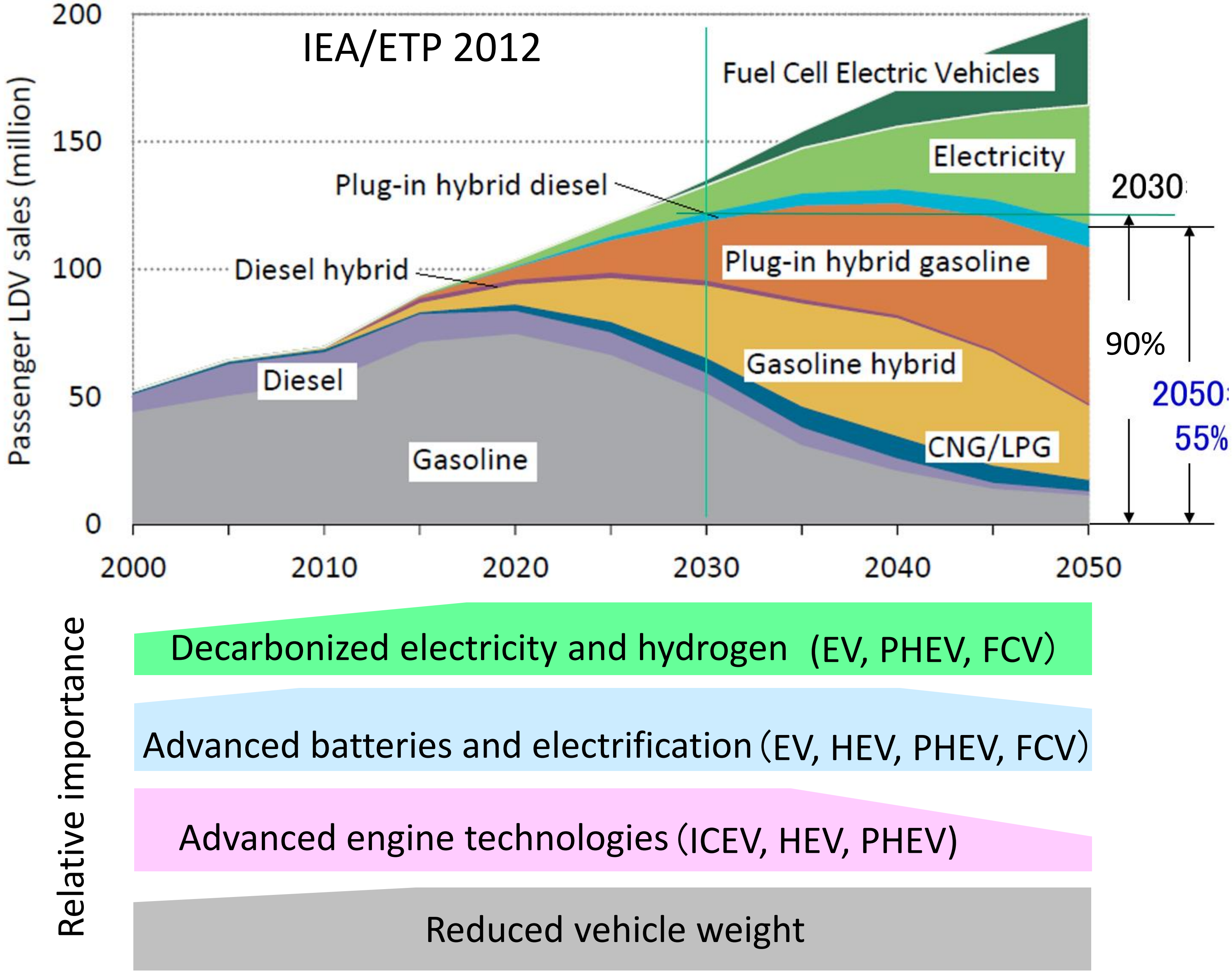
Market Share Targets for Passenger Cars in 2020-2030 proposed by METI

（A Strategic Research Committee for Next Generation Vehicles, METI, 2010, The following Committee, METI, 2018）

Vehicle type		2017（data）	2020	2030
Conventional vehicles		63.97%	50～80%	30～50%
Next generation vehicles		36.02%	20～50%	50～70%
	HEV	31.2%	20～30%	30～40%
	EV / PHEV	0.41 / 0.82%	15～20%	20～30%
	FCV	0.02%	～1%	～3%
	Clean diesel	3.52%	～5%	5 ～10%

- ❑ 4.386 million passenger cars were sold in Japan, in 2017.
- ❑ Percent market share of passenger cars is lower than 5% in the other major countries in 2017 as follows. ・USA： 4.0% ・Germany: 3.0% ・France: 4.8% ・China: 3.0% ・India： 0.03%

Projected Next Generation Passenger Vehicles' Share Worldwide and Relative Importance for R&D

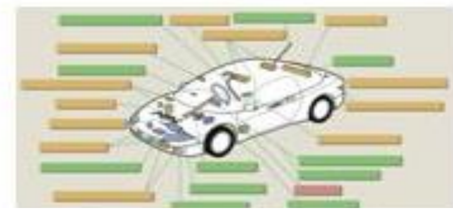


Roles of Intelligent Transport Systems

Drivers, cars and roads are connected using advanced ICTs to achieve safe, eco-friendly and convenient mobility（ITS Japan）

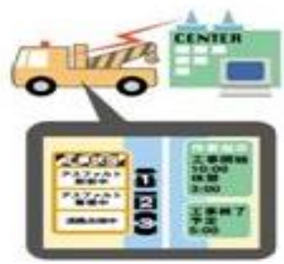
Car Navigation

ETC



Safe Driving Assistance

Traffic Management

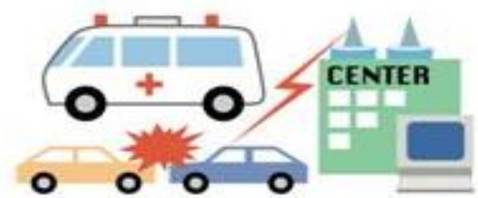


Road Management

Mass Transit Management

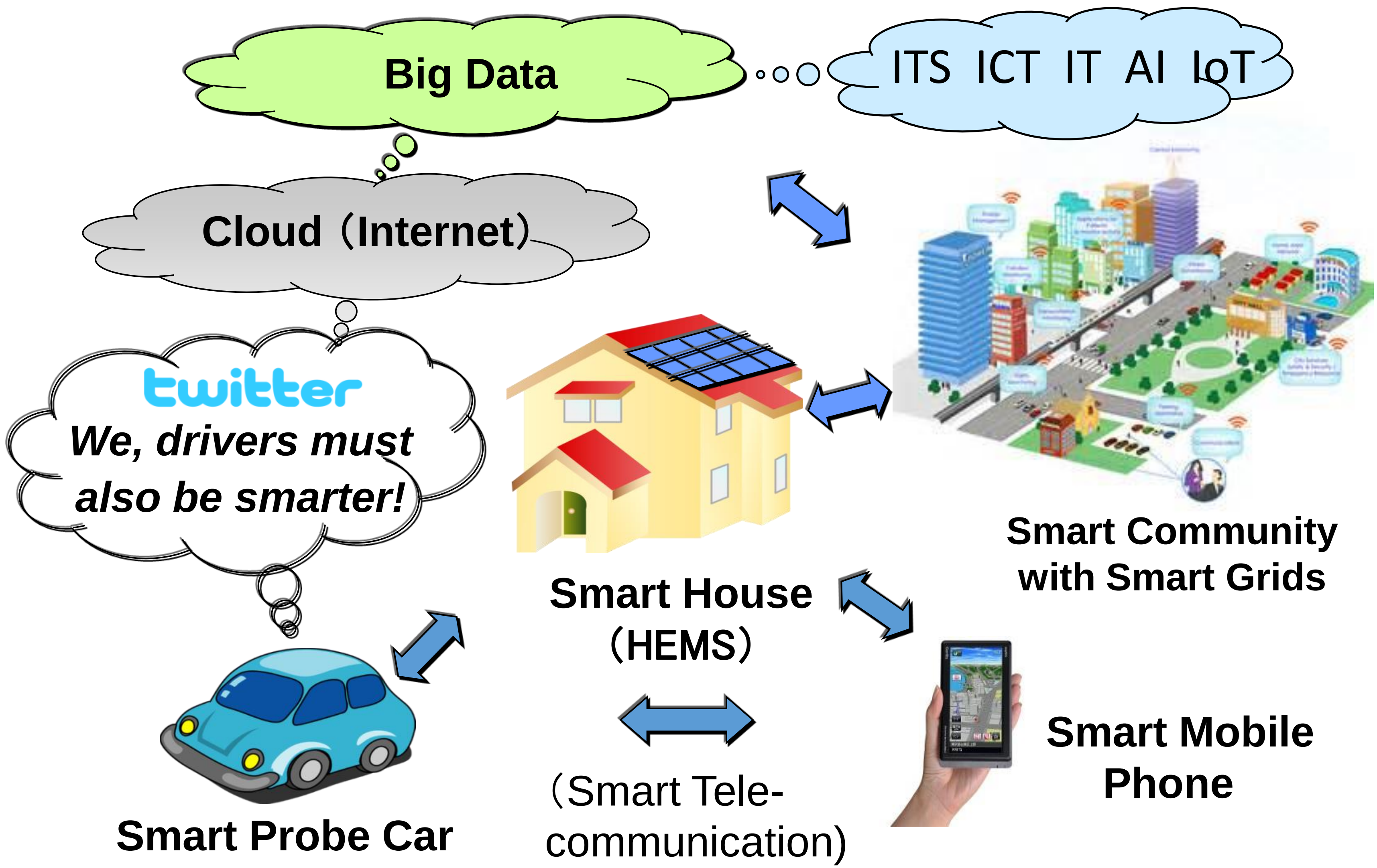
Commercial Vehicle Management

Pedestrian Assistance



Ambulance Vehicle Management

Smart Mobility, Housing and Community



Autonomous Drive and Car Sharing

Google Car

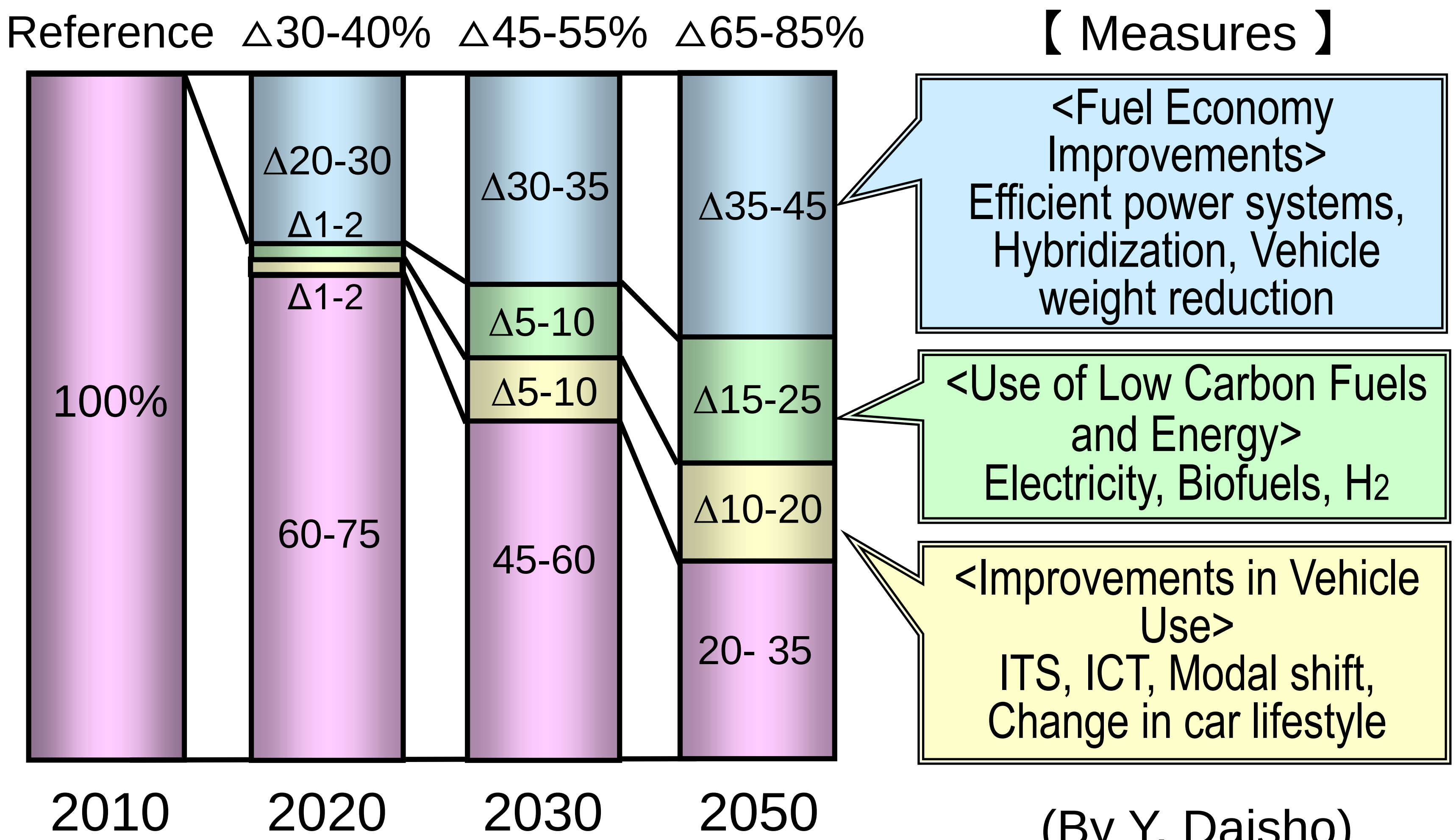
Car Sharing
(Daimler)

Robot Taxi
(DeNA, ZMP, Japan)

Autonomous Ride Sharing
(Uber, Volvo)

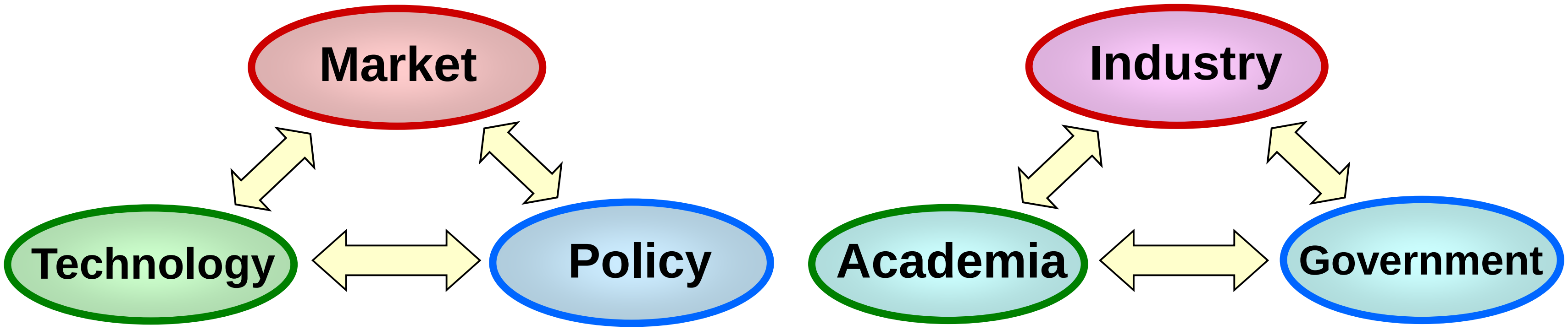
Autonomous Shuttle
Bus "WEpod"
(The Netherlands)

Projected Long-term Reduction in Motor Vehicle CO_2 Emission in Japan



(By Y. Daisho)

Issues for Developing and Disseminating Next Generation Vehicles



- ❑ Social activities for sustainable mobility in terms of environmental protection, energy security, economy, convenience, safety, comfort and resiliency to disasters.
- ❑ Continued governmental support and collaboration between industry, academia and government for developing advanced mobility technologies
- ❑ Strengthening global competitiveness for transportation-related technologies
- ❑ Developing and disseminating technologies related to renewable fuels and energy such as electricity, bio-fuels, hydrogen etc.
- ❑ Creating new environmentally friendly car lifestyles
- ❑ Developing technologies related to ITS, IT and ICT for us to drive conveniently, efficiently and safely.
- ❑ Technological and policy contributions to emerging economies