December 14th, 2023

Decarbonizing Heavy-duty Vehicles beyond 2030 and toward 2050

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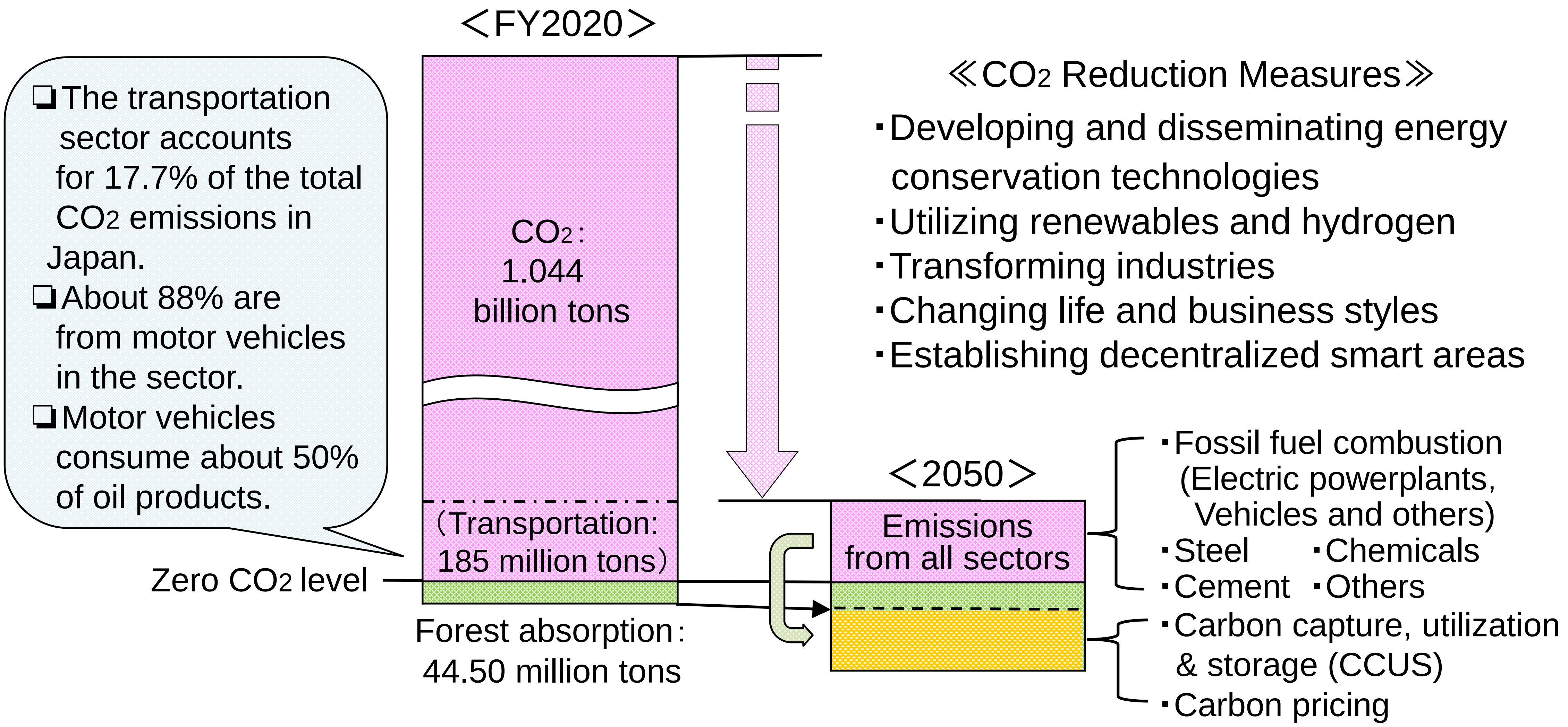
Carbon Neutrality Target in 2050 (Japan)



❑The transportation sector accounts for 17.7% of the total CO_2 emissions in Japan.
❑About 88% are from motor vehicles in the sector.
❑Motor vehicles consume about 50% of oil products.

≪CO_2 Reduction Measures≫

- Developing and disseminating energy conservation technologies
- Utilizing renewables and hydrogen
- Transforming industries
- Changing life and business styles
- Establishing decentralized smart areas

- Fossil fuel combustion (Electric powerplants, Vehicles and others)
- Steel
- Chemicals
- Cement
- Others

- Carbon capture, utilization & storage (CCUS)
- Carbon pricing

❑It is significantly difficult to achieve carbon neutrality in the transportation sector.
❑Negative CO_2 emissions in other sectors are indispensable to achieve the neutrality.

Japan’s GHG Emissions Reduction Targets by FY2030

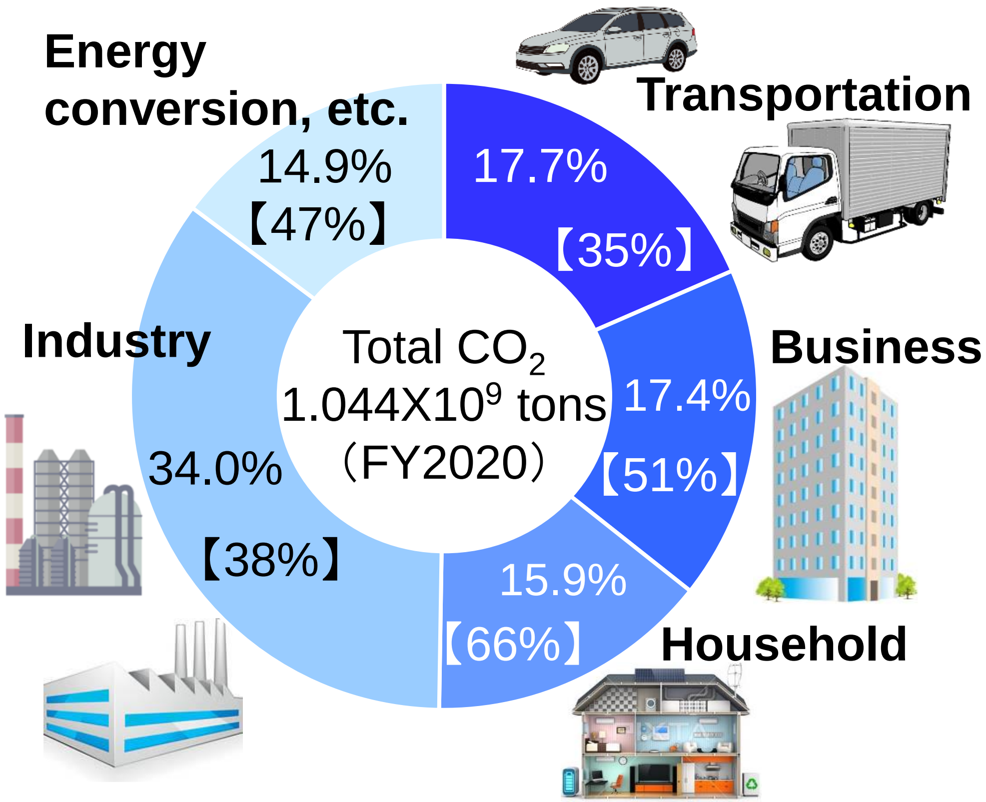
[Unit: Million tons-CO_2], （ ）: % relative level in FY2013

Emission sources		FY2013 Baseline	Results in FY2020		Target emissions in FY2030
			Emission	%	
Energy related CO_2		1,235	967（▲21.7）	92.6	677（▲45）
Sector	Industry	464	356（▲23.3）	34.0	289（▲38）
	Business, etc	237	182（▲23.2）	17.4	116（▲51）
	Household	208	166（▲19.8）	15.9	70（▲66）
	Transportation	224	185（▲17.6）	17.7	146（▲35）
	Energy conversion	103	78.4（▲23.8）	7.5	56（▲47）
Non-energy related CO_2		82.5	76.8（▲6.9）	7.4	70（▲15）
(Subtotal CO_2 emission)		1,318	1,044（▲29.8）	100	747（▲43）
CH_4		30.1	28.4（▲5.6）		26.7（▲11）
N_2O		22.0	20.0（▲9.4）		17.8（▲17）
CFC alternatives		39.1	57.7（+47.6）		21.8（▲44）
Forest absorption		▲54.3	▲44.5（+18.0）		▲47.7（+12.2）
Joint crediting mechanism (JCM)		(100 million accumulated CO2 tons reduced in collaboration with G and I)			
Total net CO_2 emissions		1,355	1,106（▲21.4）		760（▲46）

Source: “GHG Emissions in Japan in FY2020,” MOE, Japan, April, 2022

CO2 Emission in the Transportation Sector, Japan, FY2020

CO2 emission in each sector



Transportation		$\times 10^4$ tons	percent %
Motor vehicles		16,184	87.6
	Private passenger cars	8,440	45.7
	Private trucks	3,210	17.4
	Commercial trucks	4,039	21.9
	Buses	294	1.6
	Taxis	126	0.7
	Motor cycles	75	0.4
Domestic aviation		524	2.8
Costal shipping		986	5.3
Railway		784	4.2
Total		18,478	100.0

【 】: CO_2 percent reduction targets in FY2030 compared to the levels in FY2030

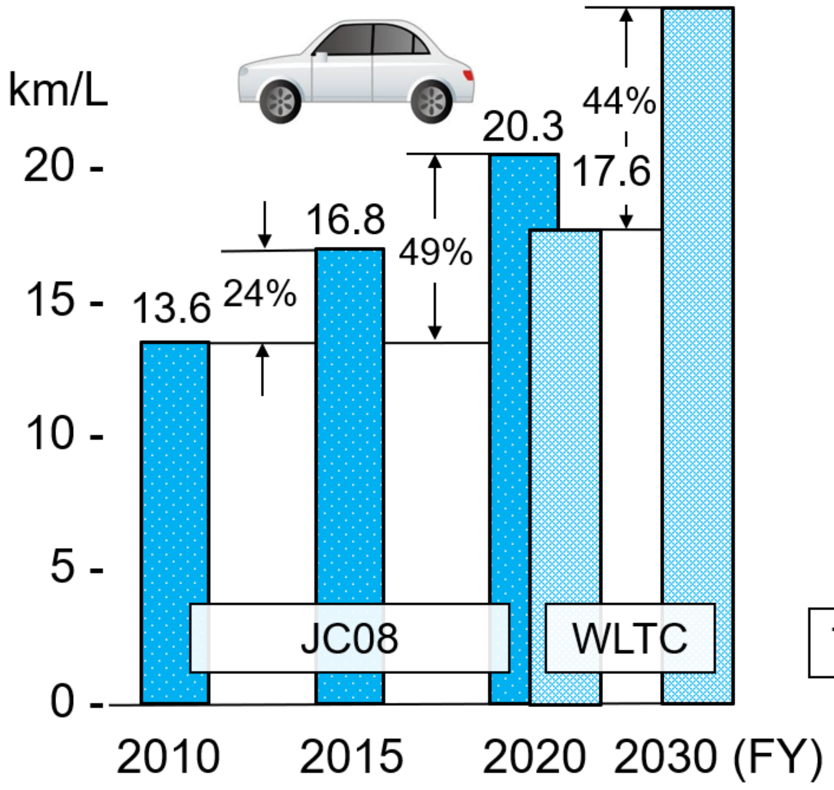
HP, MLIT, 2022

❑CO_2 emission from the vehicles account for 16.0% of the total CO_2 emissions in Japan in FY2020.

❑Annual demand for automotive fuels (crude oil ratio) in FY2020: accounting for about 50% of the total demand
Gasoline = 4552.4×10^4 kL（31.2%）, Gas oil = 3202.7×10^4 kL（23.5%） （METI, 2022）

Fuel Economy Standard Trends in Japan（MLIT, METI 2019）

- ❑32.4% improvement in FY 2030 compared to FY2016 level
- ❑FY2030 standards consider WTW CO_2 of BEVs and HEVs.

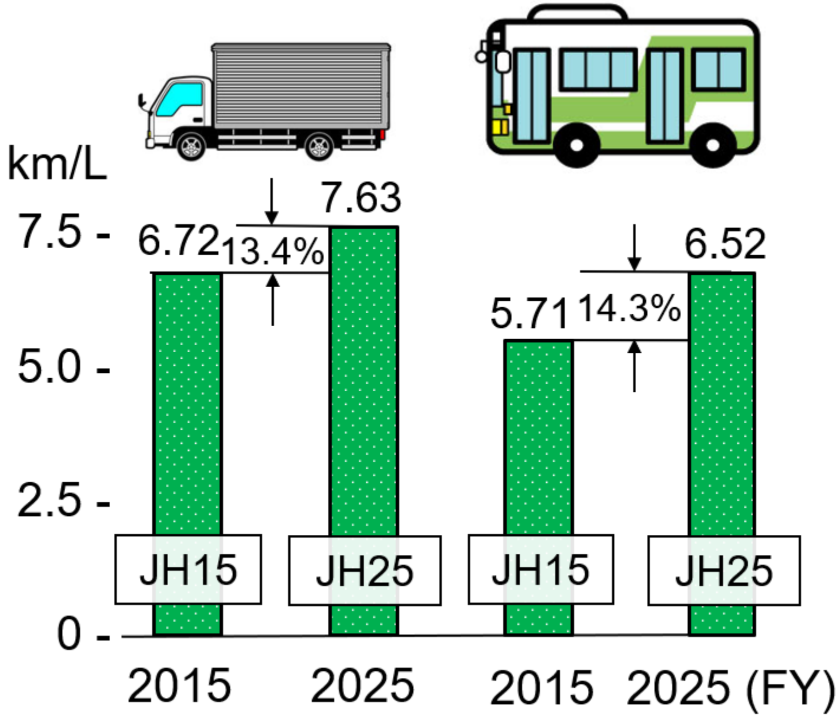


[Corporate average fuel economy]

《Passenger Cars》

Test mode

- ❑FY2015 standards are the world-first with 12% improvement compared to FY2002 level.
- ❑BEVs, PHEVs and FCVs are not included.
- ☆Drastic fuel economy improvement is difficult in heavy duty vehicles.

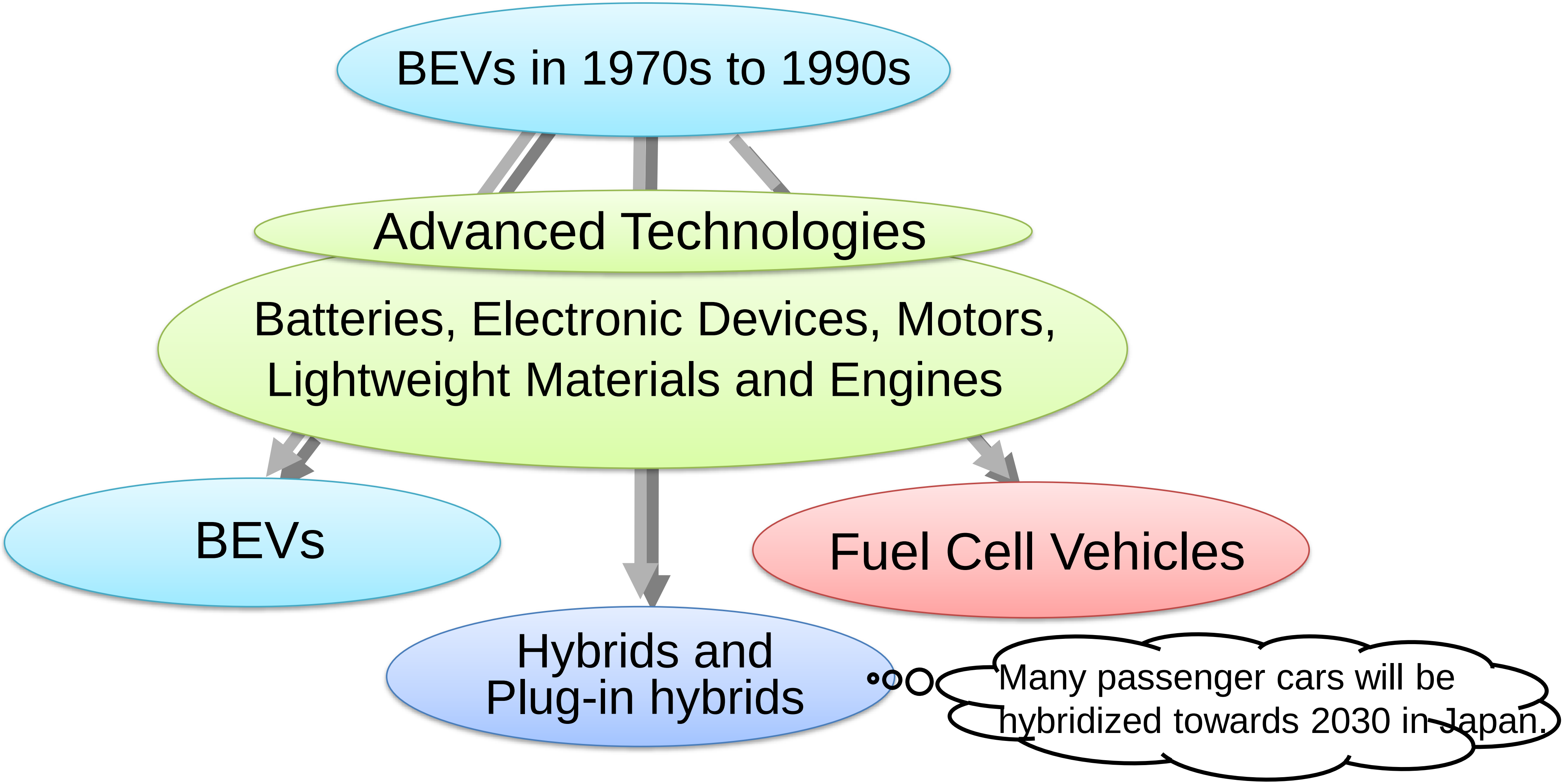


＜Trucks＞ ＜Buses＞

《Heavy-Duty Vehicles》

★Beyond 2030, even stricter fuel economy standards must be imposed on both passenger cars and heavy-duty vehicles along with almost zero pollutants requirements.

Variations of Electrified Vehicles



BEVs in 1970s to 1990s

Advanced Technologies

Batteries, Electronic Devices, Motors, Lightweight Materials and Engines

BEVs

Fuel Cell Vehicles

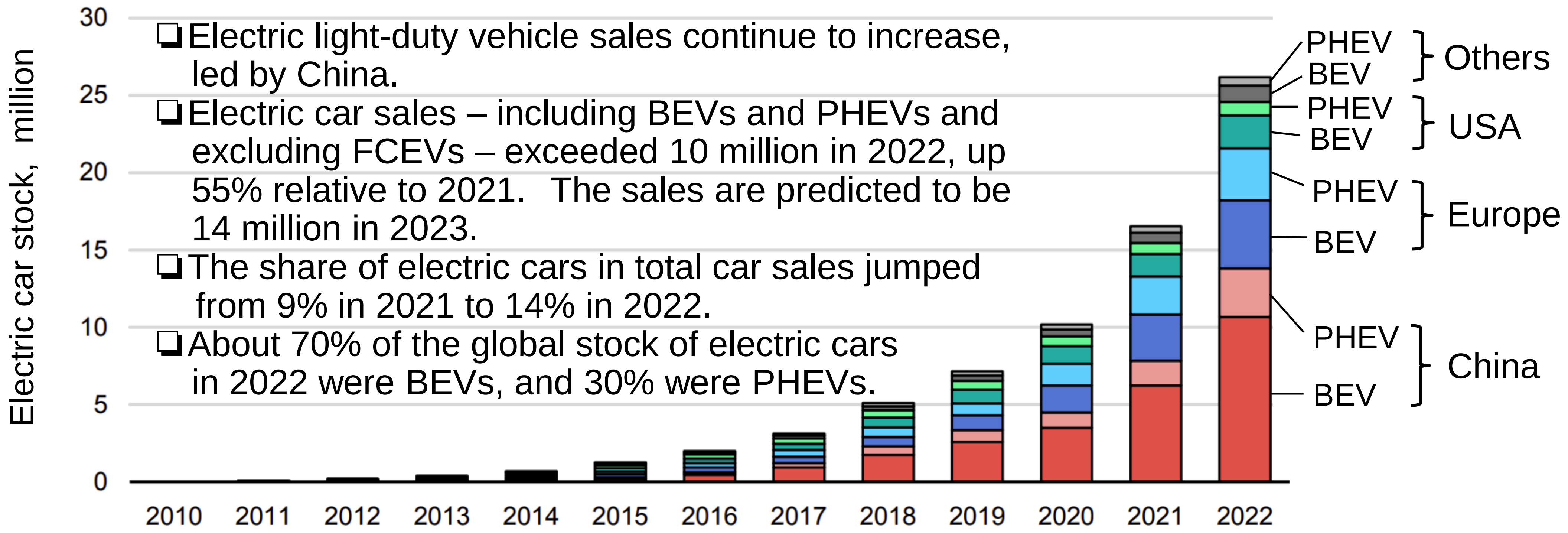
Hybrids and Plug-in hybrids

Many passenger cars will be hybridized towards 2030 in Japan.

Electrifying the vehicle is indispensable in response to the demand for fuel efficiency improvement and CO_2 reduction, which will be increasingly tightened in the future.

Global Electric Car Stock in Selected Regions, 2010-2022

Source: Global EV Outlook 2023, IEA



- Electric light-duty vehicle sales continue to increase, led by China.
- Electric car sales – including BEVs and PHEVs and excluding FCEVs – exceeded 10 million in 2022, up 55% relative to 2021. The sales are predicted to be 14 million in 2023.
- The share of electric cars in total car sales jumped from 9% in 2021 to 14% in 2022.
- About 70% of the global stock of electric cars in 2022 were BEVs, and 30% were PHEVs.

- The recent rapid growth of EV demand causes the increased costs of related materials including Li, Co and Ni used for the battery, resulting in increasing the vehicle prices. Establishing the supply chain for them are becoming a very important challenge.
- EV sales will be enhanced by the major countries’ deployment policies.
- The market share of electric trucks and buses are still very small.

“New eCanter” Launched by Mitsubishi Fuso Truck and Bus, 2023

eCanter’s Battery Type	S	M	L
Battery module number	1	2	3
Battery capacity, kWh	41	82	124
Maximum motor power, kW	110	110, 129	129
JE05 mode, drive range, km	80	140	200
Electricity milage, km/kWh	1.95	1.71	1.61
Speed: 60 km/h, drive range, km	116	236	324
Electricity milage, km/kWh	2.83	2.88	2.61
Wheelbase, m	2.5-3.4	3.4-3.85	4.75
Gross vehicle weight, t-class	5-6	5-7.5	8
Loading capacity, t-class	2-3	2-3.5	-3.5

Diesel Canter for comparison	Standard body（S, M）
Maximum engine power, kW	110
Fuel Economy, km/L	11.4～10.6
Wheelbase, m	2.5～3.4
Gross vehicle weight, t-class	4.87～5.95
Loading capacity, t-class	2～3

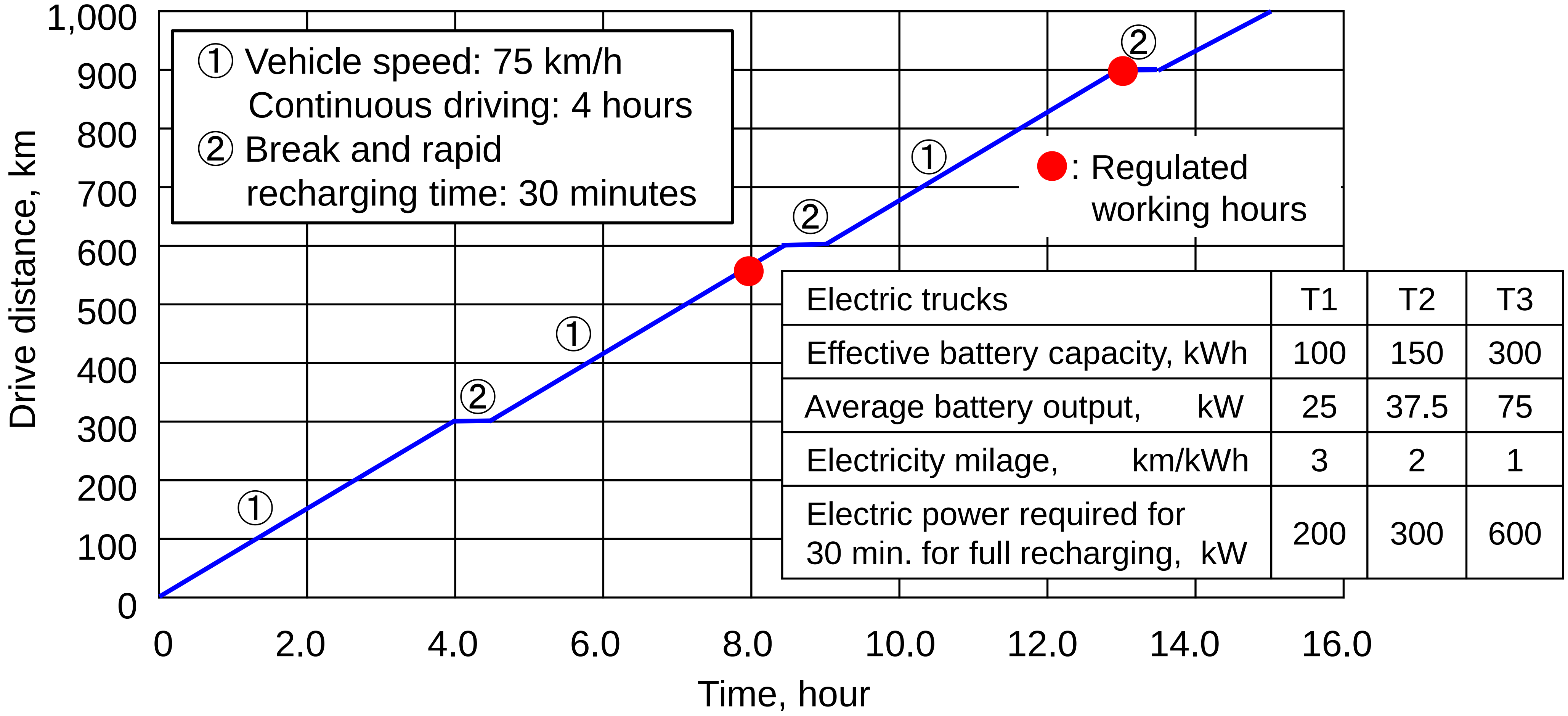
❑ Battery modules (LFP) are provided by CATL, China.

❑ E-Axle has been developed by MFTB.

❑ Vehicle Price:
eCanter = ¥13.70-20.05 million
Canter = ¥4.50 - 5.50 million

Source: HP, MFTB, 2023

Rapid Recharging Power Required for Long-distance Electric Trucks

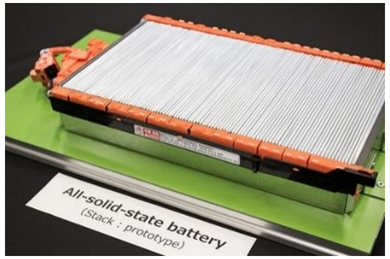


Electric trucks	T1	T2	T3
Effective battery capacity, kWh	100	150	300
Average battery output, kW	25	37.5	75
Electricity milage, km/kWh	3	2	1
Electric power required for 30 min. for full recharging, kW	200	300	600

Since drivers are required by law to take a 30-minute break every 4 hours of continuous driving, it is assumed that after driving 300 km in 4 hours at 75 km/h within the speed limit of 80 km/h on a motorway, a rapid recharge of 200, 300 and 600 kW shall be performed in 30 minutes during the break time for electric trucks T3, T2 and T1, respectively.

Solutions for the Problems with HD Electric Trucks

- ❑ Advanced battery systems with a higher energy density
  - ▪ Improved Lithium-ion battery (250-280 Wh/kg)
  - ▪ All solid-state Lithium-ion battery (300-400 Wh/kg) *
  - ▪ Innovative battery (>500 Wh/kg)



Toyota, Oct. 2023 *

- ❑ Rapid charging systems
  - ▪ High-power recharging up to 400-800 kW is necessary for long-distance HD EVs.
  - ▪ The present power ranges from 20 to 180 kW in Japan.
- ❑ Battery swapping systems **
  - ▪ Swapping time can be much shorter than recharging time.

Isuzu, Oct. 2023 **

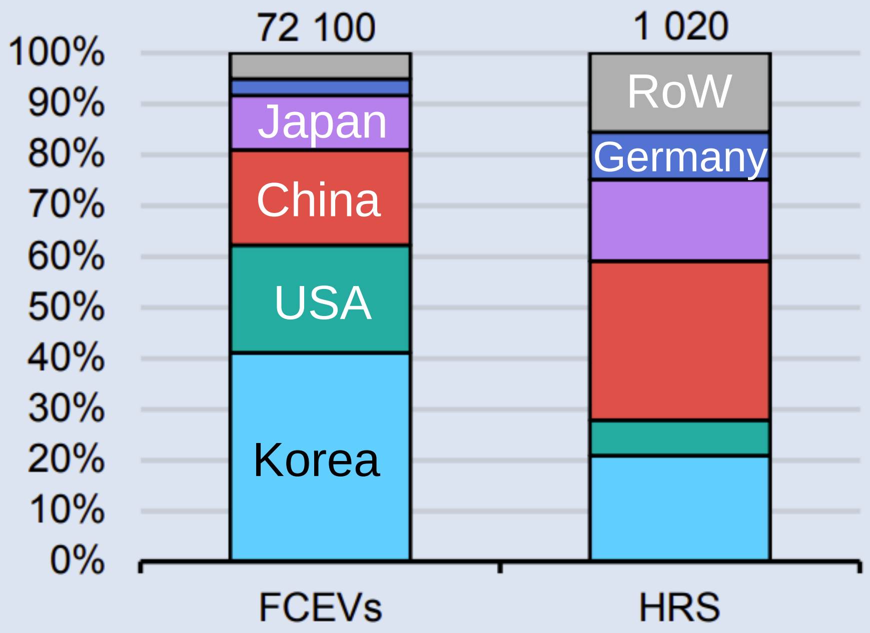
- ❑ Electric road systems (ERS)
  - ▪ Conductive overhead catenary systems ***
  - ▪ Conductive rail systems ****
  - ▪ Wireless inductive systems being developed for HD vehicle applications
- ❑ Low-carbon electricity should be utilized, taking into account sufficient system durability and the overall cost-effectiveness.

Siemens, 2018 ***

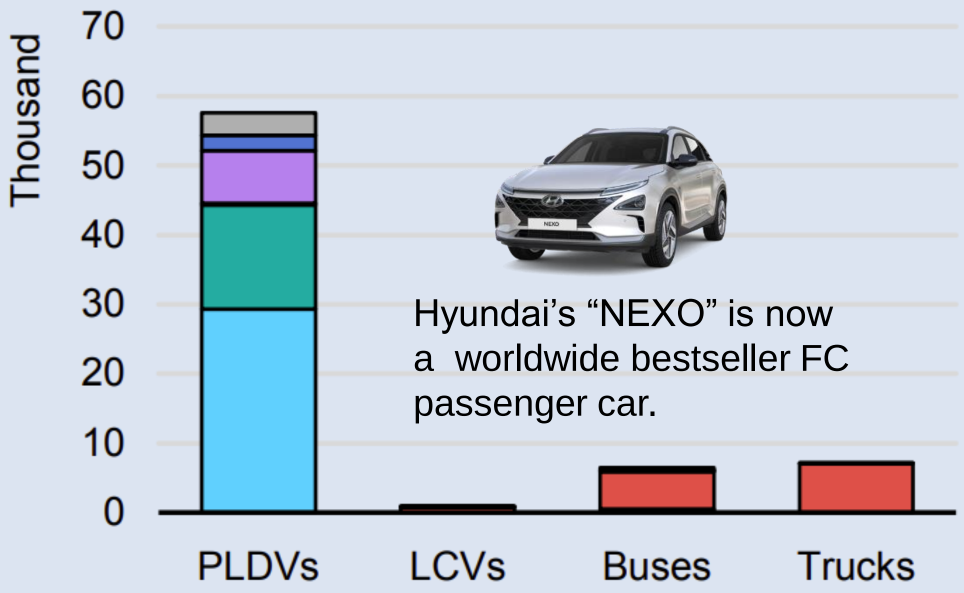
Elways, Sweden, 2020 ****

FCEV and Hydrogen Refueling Station Stock by Region, 2022

Share of FCEV and HRS stock by region



FCEV stock by region and mode



Hyundai’s “NEXO” is now
a worldwide bestseller FC
passenger car.

Notes: FCEVs = fuel cell electric vehicles; HRS = hydrogen refuelling station; PLDVs = passenger light-duty vehicles; LCVs = light commercial vehicles; RoW = rest of the world.
Source: IEA analysis based on the data submission of the Advanced Fuel Cells Technology Collaboration Program.

- ❏FCEV and HRS stock is still much smaller than BEV and recharging station stock.
- ❏China is trying to actively disseminate FC electric buses and trucks.

Source: Global EV Outlook 2023, IEA

Toyota's Strategy for Disseminating a Variety of FCEVs

"Mirai" remodeled in Dec. 2020.
Five passengers, Rear drive,
Drive range: about 850 km

FC refrigerator truck provided to "Seven Eleven" in 2019.
Drive range: about 200 km

FC forklift introduced in Motomachi Plant in 2017

FC bus, "Sora" launched in Tokyo, in 2017, Feb., using two Mirai's FC stacks,
Drive range: about 200 km

HD FC truck based on Hino XL series for the US market, using Mirai's stacks.
The road test was conducted in 2021.

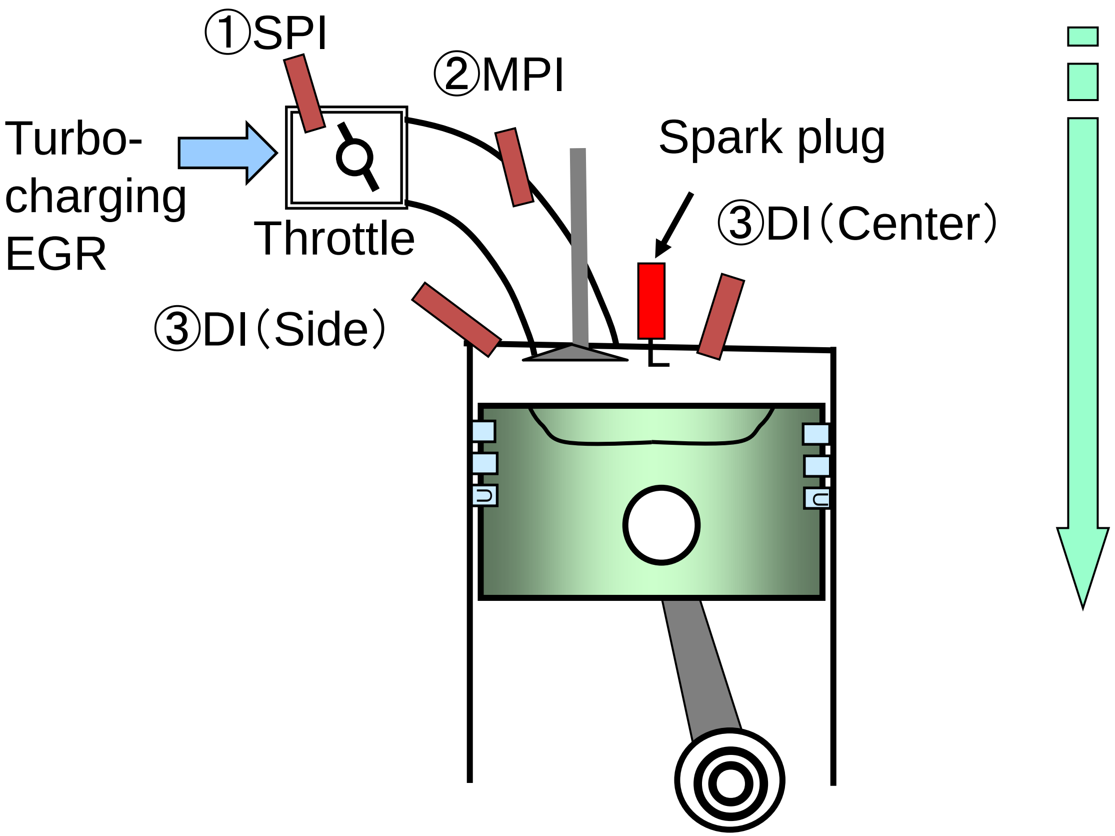
- ❑ Major FC components are communized for a variety of FCEVs for HD applications.
- ❑ Other automakers are expected to launch their own FCEVs or to collaborate with the FCEV forerunning company.

Hydrogen and Fuel Cell Strategy 2020 (METI, Japan)

- Cost reduction and procurement of hydrogen for power plants
  - Present: ¥100/Nm^3, ¥30/Nm^3 in 2030, ¥20/Nm^3 in 2050, (ultimately ¥13.3/Nm^3) （Power generation costs: ¥17/kWh, ¥12/kWh, ¥8.7/kWh, respectively)
  - The supply target is 3.0 million tons/year by 2030, 12 million tons/year by 2040 and 20 million tons/year (equivalent to gasoline of 69 million kL) by 2050.
- Innovative hydrogen-related technologies should be developed by 2050.
  - High efficiency electrolysis, artificial photosynthesis and permeable membrane
  - High efficiency hydrogen liquification
  - Low cost and efficient energy carriers
  - Advanced FC systems
  - Advanced synthesis of chemicals using H_2 and CO_2
- A variety of FCEVs should be introduced by several automakers.
- Targets of hydrogen stations and FCEVs are as shown below.
  - FC trucks will be part of 3.20 million commercial trucks.
- Station cost should drastically be reduced. (¥320 (2019) ⇒ ¥200 million (2025))
- Station business should be profitable in late 2020s.

Stations and vehicles	2021, May	～2025	～2030	～2050
Hydrogen station	162	320	1,000	≪
FC passenger cars	5,268	200,000	800,000	≪
FC buses	104	-	1,200	≪
FC forklifts	330	-	10,000	≪

Hydrogen Engine Combustion Systems



≪Common issues≫

- ・Air-H_2 mixture formation and compression ratio should be optimized to avoid preignition and excessively rapid combustion or knock.
- ・Turbocharging is necessary to ensure high power.
- ・A deNOx catalyst is necessary.

① SPI（Single-point injection）

〇Simple system

△Difficulty with precise air-fuel ratio control

② MPI（Multi-point injection）or PFI

〇Controlling precise air-fuel ratios

〇Reducing cylinder to cylinder fueling variations

△Turbocharging is necessary to improve volumetric efficiency and to enhance power.

③ DI (Direct-injection)

◎Improving volumetric efficiency

◎Avoiding backfire, preignition and knock

◎Enhancing ultra lean burn

Note: Early injection at lower pressures is preferrable to have sufficient air-H_2 mixing time and durability of the injector.

❑The combustion concepts may be applicable to e-methanol and e-methane engines.

Estimated Costs for Producing Synthetic Liquid Fuels

(Source: The Research Committee on Synthetic Fuels, METI, April, 2021)

Measure to produce fuel	Production Cost ￥/ℓ-Fuel			
	H_2	CO_2	Fuel	Total ($/gallon)
A. Producing H_2 and the fuel in Japan (present)	634	32	33	700 (20.4)
B. Producing H_2 overseas at ¥32.9/Nm³ and transporting it to Japan at ¥14.65/Nm³	301			350 (10.2)
C. Producing H_2 at ¥32.9/Nm³ and the fuel overseas	209			300 (8.7)
D. Producing H_2 at ¥20/Nm³ and the fuel overseas around 2040 or later	127			200 (5.8)

【Cost comparison】

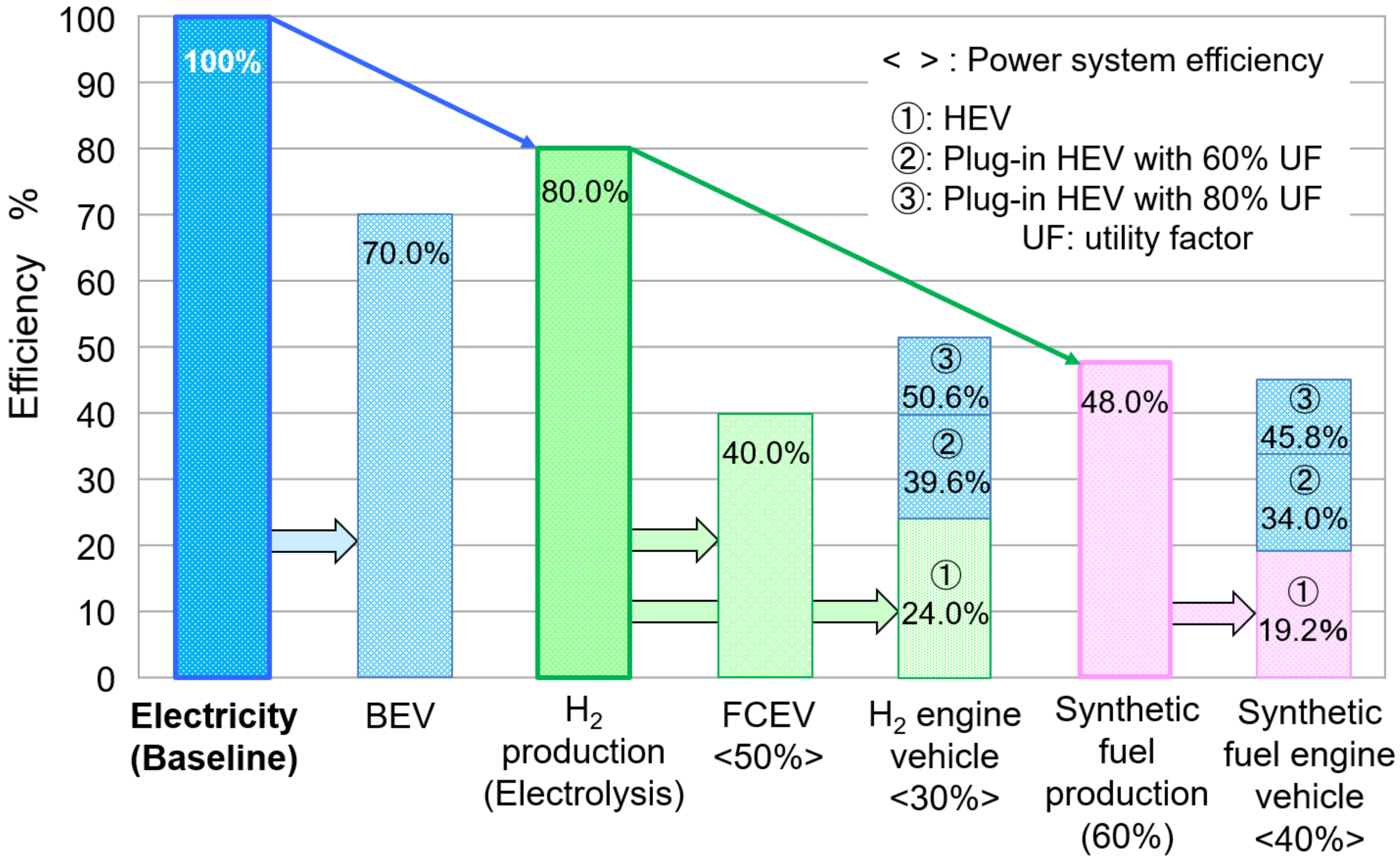
- Synthetic fuel: **¥6.06/MJ**
- H_2: **¥1.85/MJ**

＜Assumptions＞

(1) Present domestic electricity costs ¥20/kWh. (2) Electricity overseas will cost ¥1-2/kWh.
(3) Transportation from overseas to Japan and other related costs must be included.
(4) One litter of a synthetic fuel requires 6.34 Nm³ (0.570 kg) of H_2 and 5.47 kg of CO_2.
(5) The total costs don't include associated profits or taxes.

＜Issues＞ A significant reduction in H_2 cost even lower than ¥20/Nm³ must be achieved to commercialize synthetic fuels around 2040 by procuring massive amounts of H_2 and CO_2 from overseas. Synthetic fuels could mitigate the sharp demand for recharging BEVs.

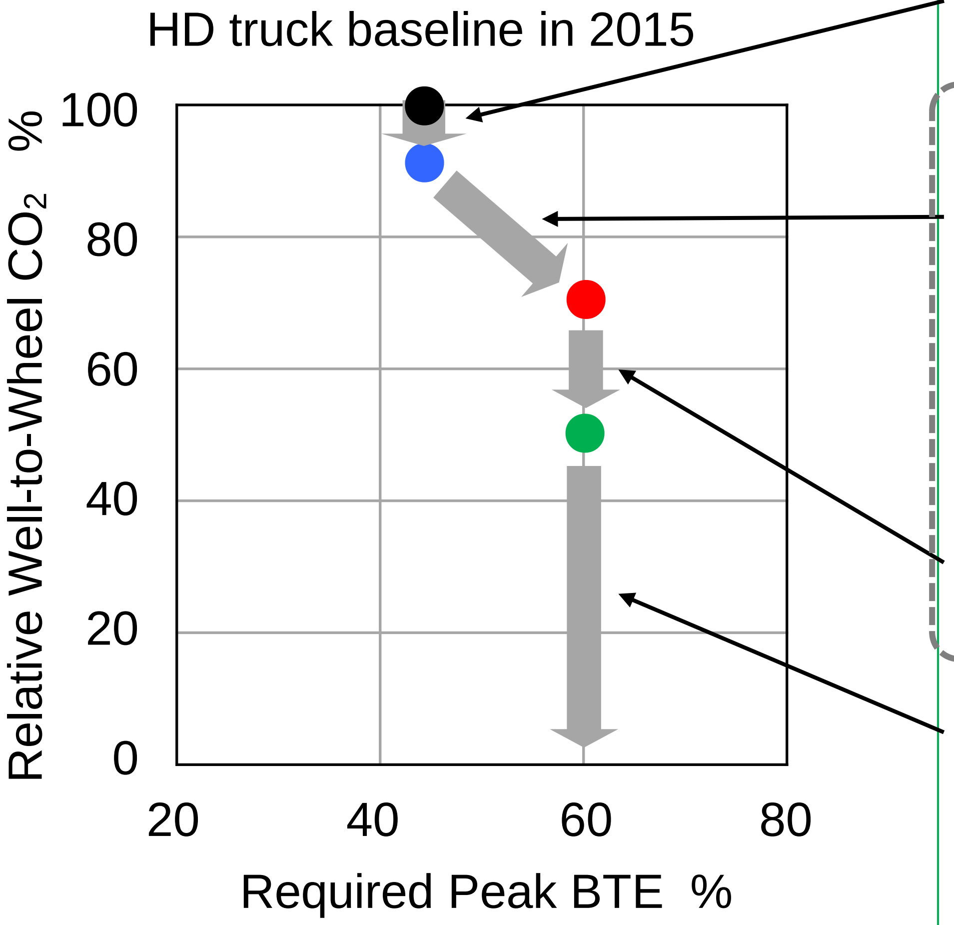
Fuel Production and Vehicle Efficiencies of a Variety of Vehicle Types Relative to Electric Energy



（Reference: Concawe Review, Vol. 28, No. 1, October 2019, revised by Y. Daisho)

A GI Fund Project for Developing High-efficiency Commercial Trucks

Green **I**nnovation Fund Project "Developing Technologies for Efficient Utilization of Synthetic Fuels for passenger cars and HD vehicles" ･Budget: ¥4.5 billion ･Period: FY2022-27 ･Secretariat: AICE



【 】: CO_2 Reduction

① Average thermal efficiency improvements【>8%】
- ☐ Hybridization 【6%】
- ☐ Steady operation at best fuel economy points
- ☐ Exploration of measures except for electrification

}【>2%】

② Engine efficiency improvements【>25%】
- ☐ Down-speeding/High turbocharging/ High expansion ratio combustion
- ☐ Reducing friction losses ☐ Reducing heat losses
- ☐ Advanced aftertreatment systems
- ☐ High efficiency waste heat recovery system

③ Vehicle efficiency improvements【>18.5%】
- ☐ High efficiency powertrain control using telematics【3.5%】
- ☐ Lightweighting the body and reducing rolling resistance

④ Technologies for removing CO_2【>48.5%】
- ☐ Defining CN-dedicated vehicles using e-fuels
- ☐ Preparing CO_2 capture measures in cooperation with other sectors

Themes covered by the project

Source: NEDO, AICE, 2023

Advanced HD Diesel Engine Concepts

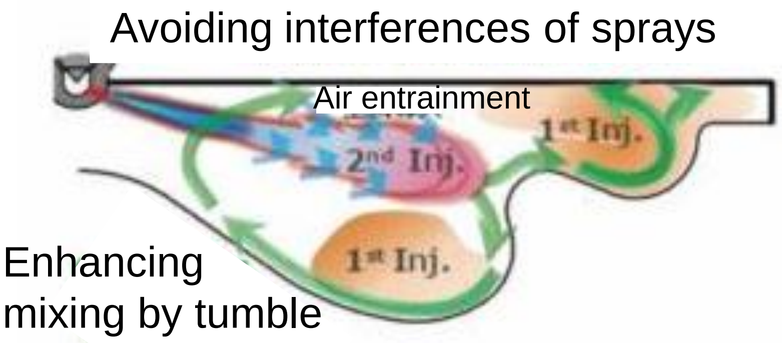
❏Utilizing the results on achieving 50% brake thermal efficiency in passenger car diesel engines in JST's SIP "Innovative Combustion Technology," FY2014-18

≪Highly Dispersive Diesel Spray Combustion≫

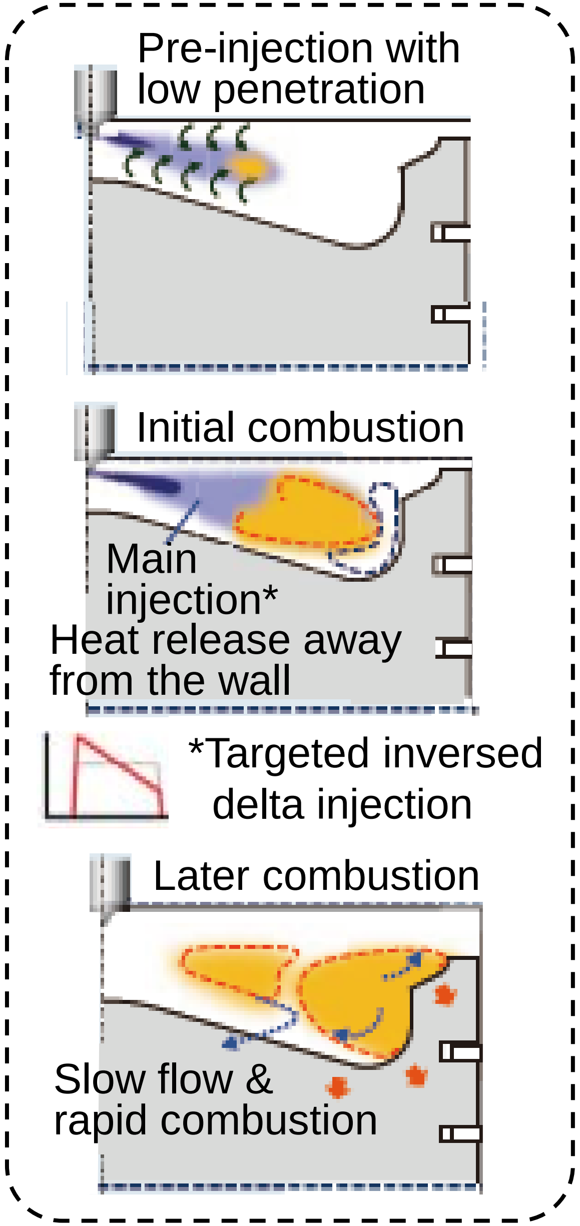
- High pressure multiple injection with increased nozzle holes
- Low swirl to reduce heat losses
- Shallow combustion chamber with a wide diameter
- High efficiency turbocharging ･Reduced mechanical friction losses
- Waste heat recovery using a thermoelectric device

☛

❏To improve brake thermal efficiency of HD engines toward 55%, based on the above results, it is important to avoid interference between fuel sprays and reduce the wall impingement of the sprays.
Specifically, optimizing a combination of the combustion chamber geometry and fuel injection strategies is essential.



Distribution-**C**ontrolled Partially **P**remixed **C**ompression **I**gnition for a 3.3 L, 6-cylinder DI diesel engine by Mazda in 2022



Model-Based Development of HD Vehicles

Japan **A**utomotive **M**odel-**B**ased **E**ngineering Center established in July, 2021.

The purpose of the center is to promote the spread of the MBD technology and to establish a mechanism for sharing its models among companies and academia to improve the efficiency of the overall automobile development. < https://www.jambe.jp >

- Vehicle Performance
- Fuel/Energy Efficiency
- Emissions

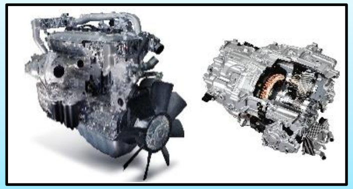
- Numerical Models
- Design & Test Data

- Combustion
- Heat Transfer
- Control
- Materials
- Mechanics
- Fluid dynamics
- Chemistry
- Aftertreatment
- Electrical Eng.
- Electrodynamics
- Electronics, etc.

Vehicles

⟷

Power Systems



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Parts

Automobile Manufacturers (OEMs)

Supply Chain

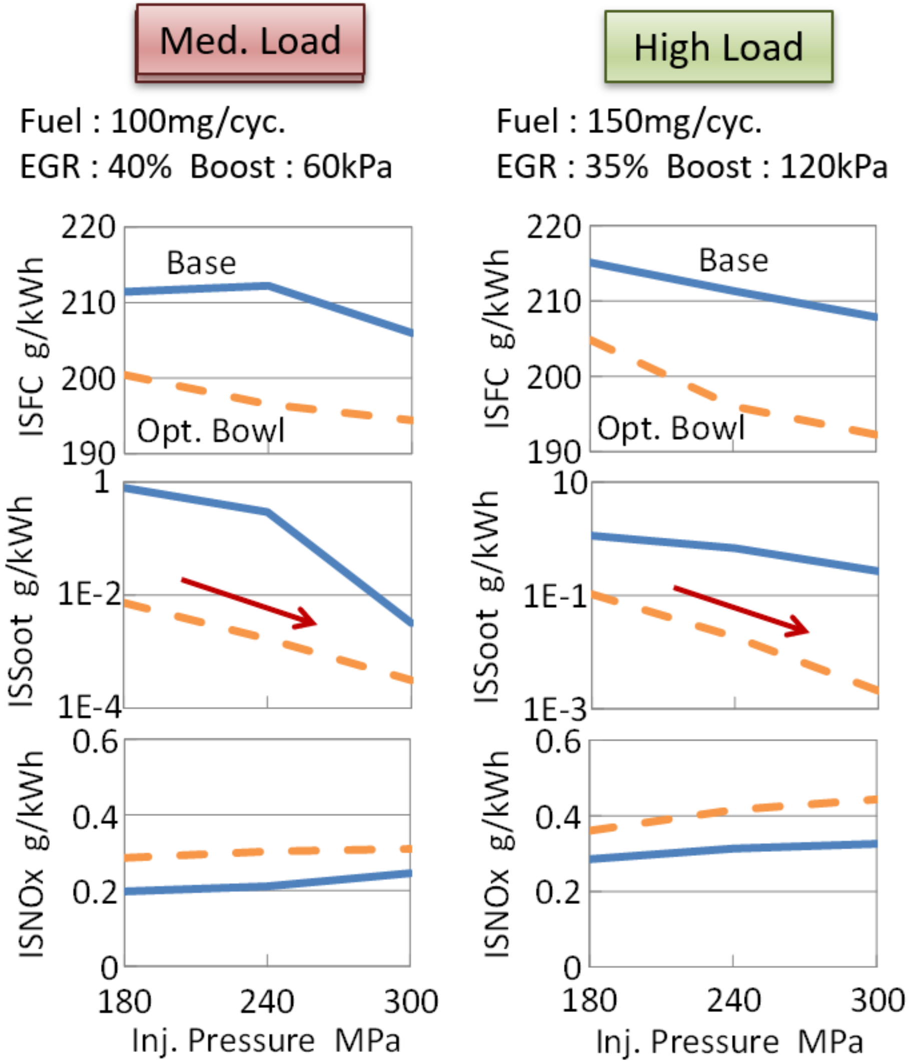
Parts Suppliers (Tiers 1, 2 …)

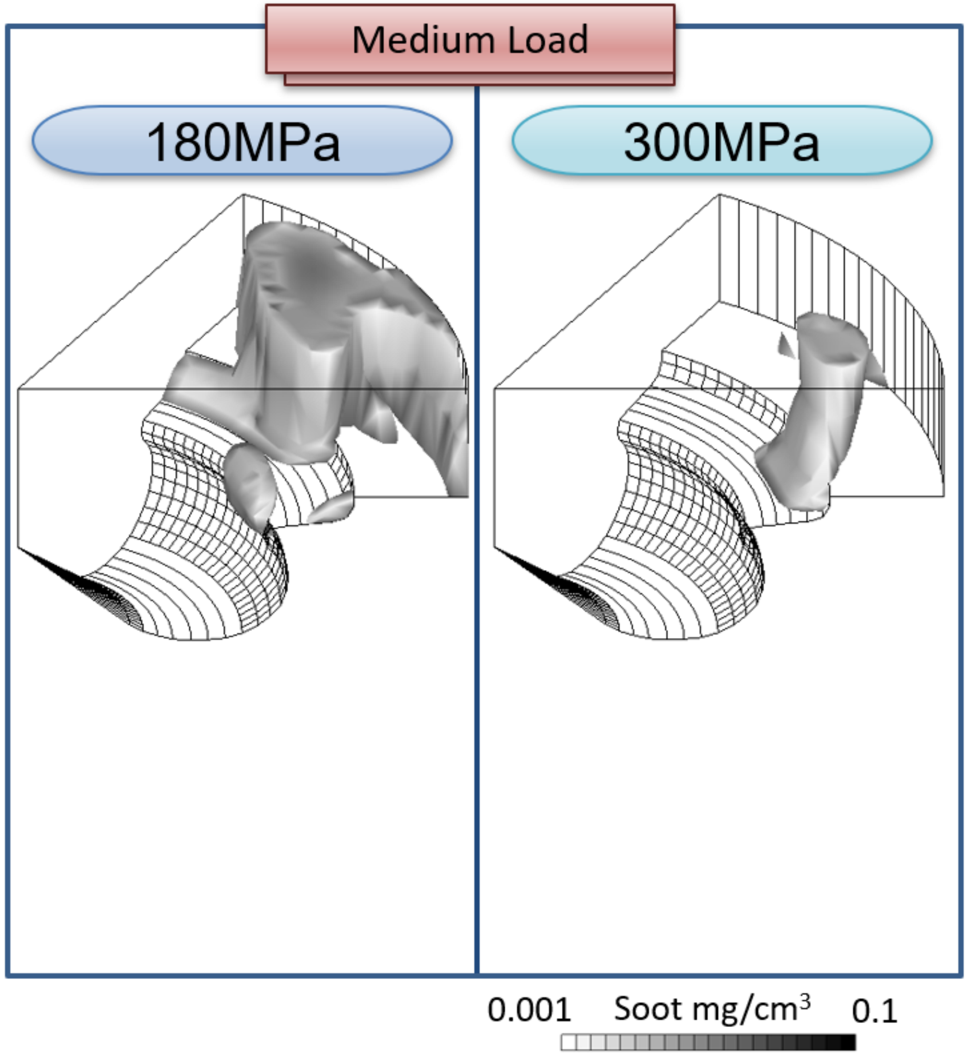
- 1-D models are shared and used among OEMs, parts suppliers and academia.
- 3-D models are tools for developing and designing engines, motors, related parts, etc.
- **L**arge **E**ddy **S**imulation model:
- **D**irect **N**umerical **S**imulation model:

} Elucidating combustion phenomena

- **G**enetic **A**lgorithm and **AI** models for calibrating and optimizing the power system

Optimizing Combustion Chamber Geometry and High Pressure Injection in a HD Diesel Engine by a Genetic Algorithm

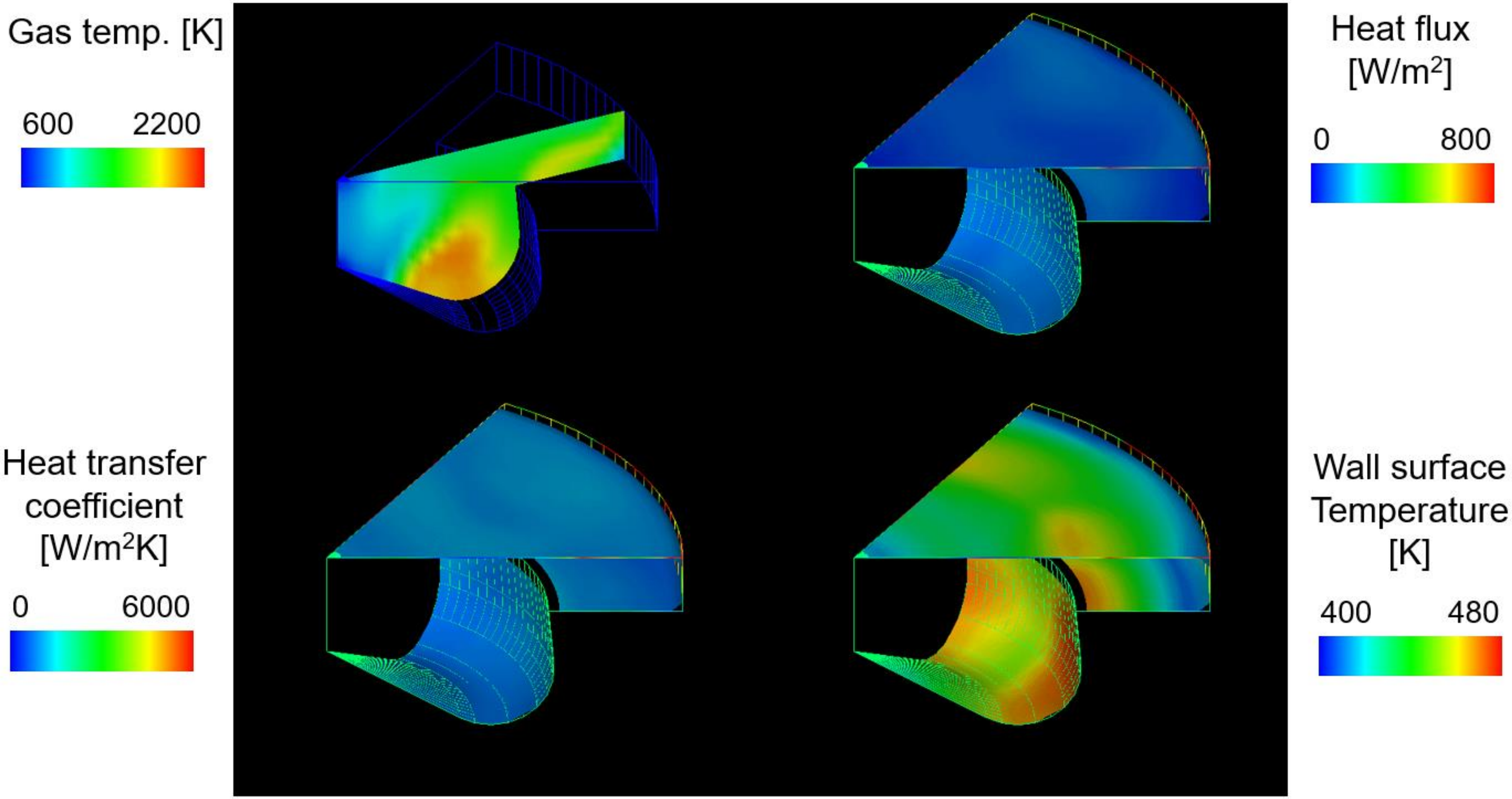




Significant Reductions in PM by optimizing the combustion chamber geometry and ultra-high pressure injection

B. Zhou, Y. Daisho and J. Kusaka, Waseda University

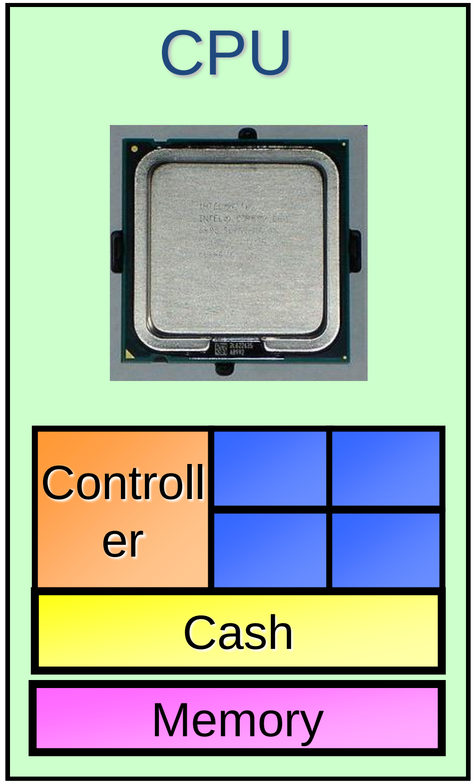
Heat Transfer and Combustion Wall Temperatures Simulated by 3-D CFD Combined with Detailed Kinetics



JSAE/SAE 2015, PF&L
A. Kikusato, J. Kusaka and Y. Daisho, Waseda University

High Speed Parallel Processing Combustion Simulation by using a GPGPU

GPGPU, General Purpose computing on Graphics Processing Unit can be utilized for 3-D combustion simulation with chemical kinetics..

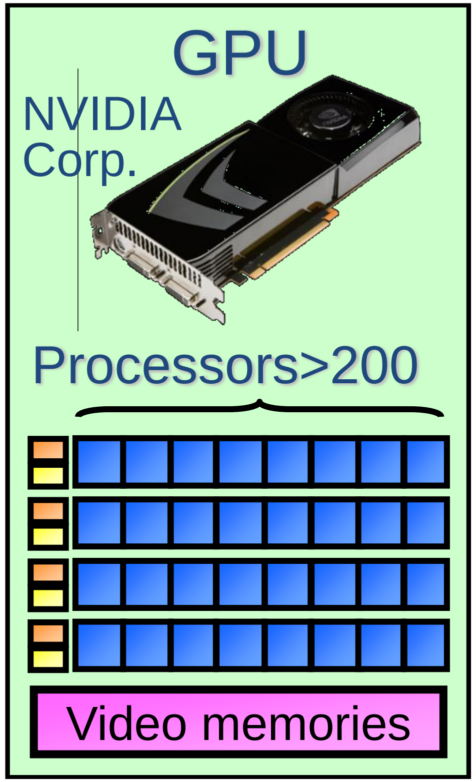


CPU

Controller

Cash

Memory

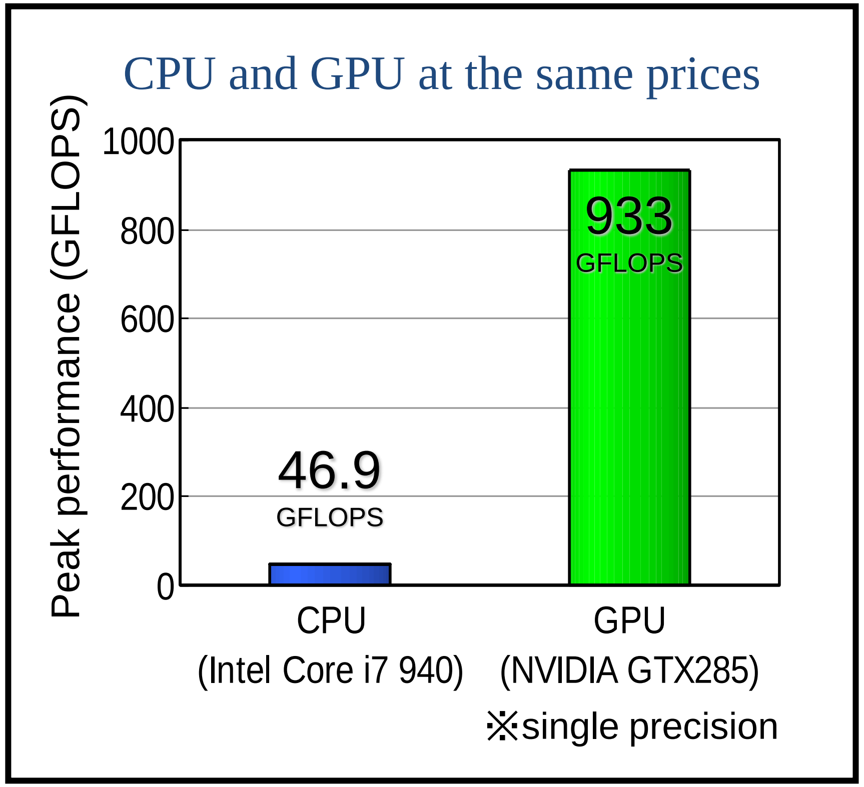


GPU

NVIDIA Corp.

Processors>200

Video memories



CPU and GPU at the same prices

※single precision

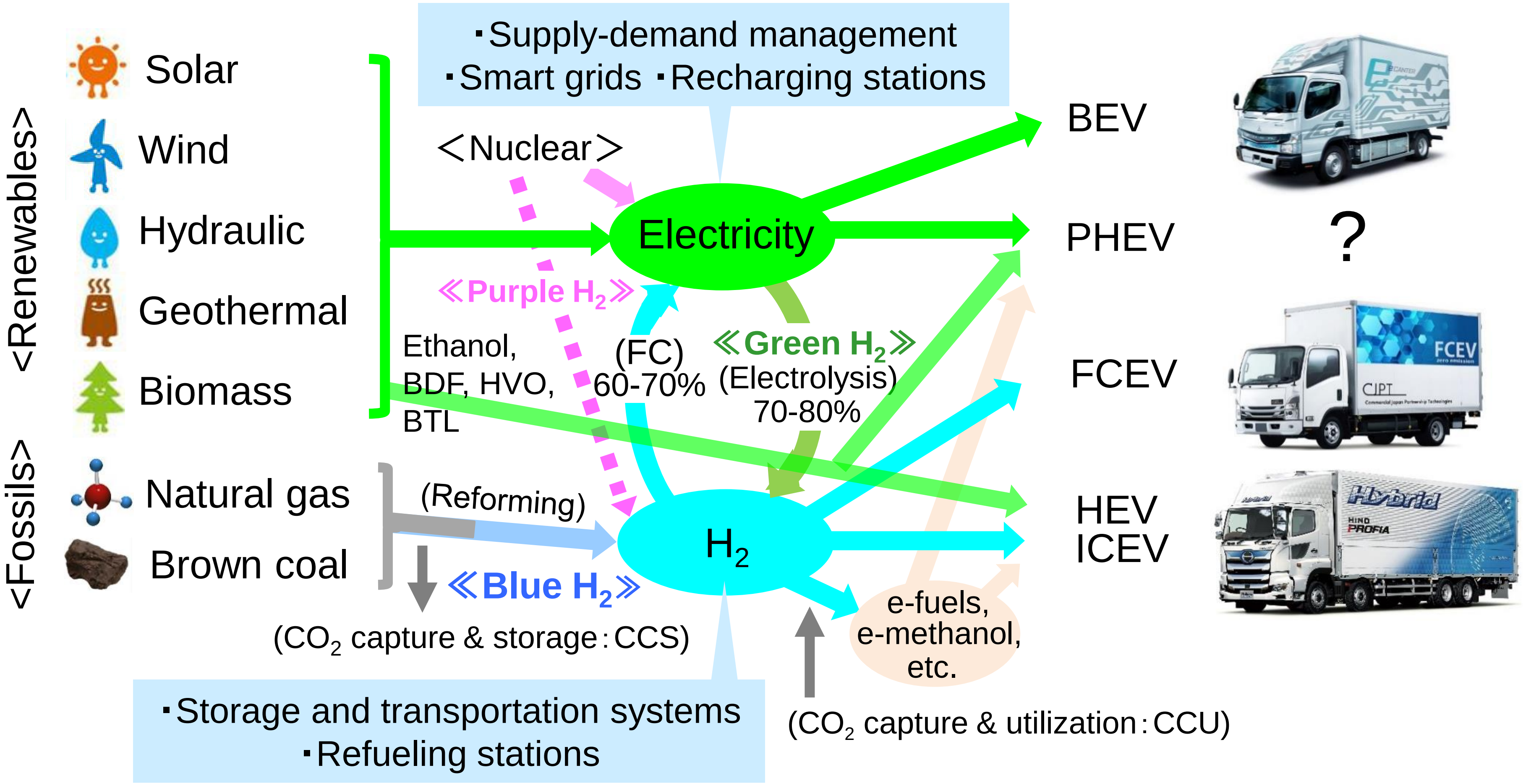
Y. Matsumoto, Y. Daisho and J. Kusaka, Waseda University

Electrifying Trucks and Related Issues

Type Range	HEV	BEV	FCEV
Short（LD） <100-200km	○ ･Improved by 10-20% ･Limited low emissions	○ ･Zero emissions ･Expected by freight industry	○ ･Zero emissions ･Electricity provision
Medium（MD） <300km	□ ･Fuel economy depends on the way of vehicle use	□ ･Limited payload and drive range ･High battery costs	□ ･High vehicle and H_2 costs
Long（HD） >300km	□ ･Limited fuel economy improvement	△ ･Limited payload, drive range and battery performance	△～□ ･Limited durability of FC stacks at high load
Common issues	･Reduce vehicle cost ･Improve engine efficiency（BTE：55%） ･Adopt strong and/or plug-in systems ･Reduce emissions ･Use a synthetic fuel?	･Reduce battery cost ･Ensure battery durability ･Extend drive range ･Mitigate increased mass and reduced volume ･Shorten charging time ･Increase charging spots ･Utilize renewables	･Reduce vehicle and H_2 costs ･Improve FC stack performance and durability ･Increase H_2 stations ･Increase vehicle types ･Commonize FC parts ･Decarbonize H_2 ･Secure H_2 supply chain

Note: ○: Superior ❑: Comparable △: Inferior relative to diesel trucks

Renewable Electricity and Hydrogen for HD Vehicles



❑Large scale CO_2 free hydrogen is supposed to be introduced toward 2050.

❑Total LCA should be conducted on electricity, hydrogen and e-fuels in terms of production, transportation, storage and consumption.

Future Low-Carbon Fuel Candidates for HD Vehicles

Fuel type		Power	CO_2 reduction	Cost vehicle/ fuel	Range	Sustainability	Issues
Biodiesel (B5-B30, B100)		□	○	□/△	□	○	Reducing fuel property deterioration
Hydrogenated BDF (HVO)		□	○	□/△	□	○	Cost reduction, The use of clean H_2
Hydrogen, (Compressed)	Port injection (SI)	△	○	□/△	△	○	Improving efficiency by direct-injection, Locating supply stations
	FCEV	□/△	◎	▲/△	△	○	Cost reduction, Improving durability, Locating supply stations
Methane (Compressed, SI)	Natural gas	△	□	□/□	△	□	Reducing methane slip, Developing liquified natural gas vehicles
	Bio-methane	△	○	□/□	△	○	Capturing methane, Ensuring supplied amount
	Methanation	△	○	□/△	△	○	Ensuring H_2 and CO_2 supply, Improving production efficiency
Bio-ethanol (SI)		△	○	□/△	□	○	Developing cellulosic ethanol
Synthetic fuels including methanol		□	○	□/▲	□	○	Ensuring H_2 and CO_2 supply, Improving production efficiency
Onboard CO_2 capture system		△	○	▲/□	□	△	Developing CO_2 storage systems, Cost reduction

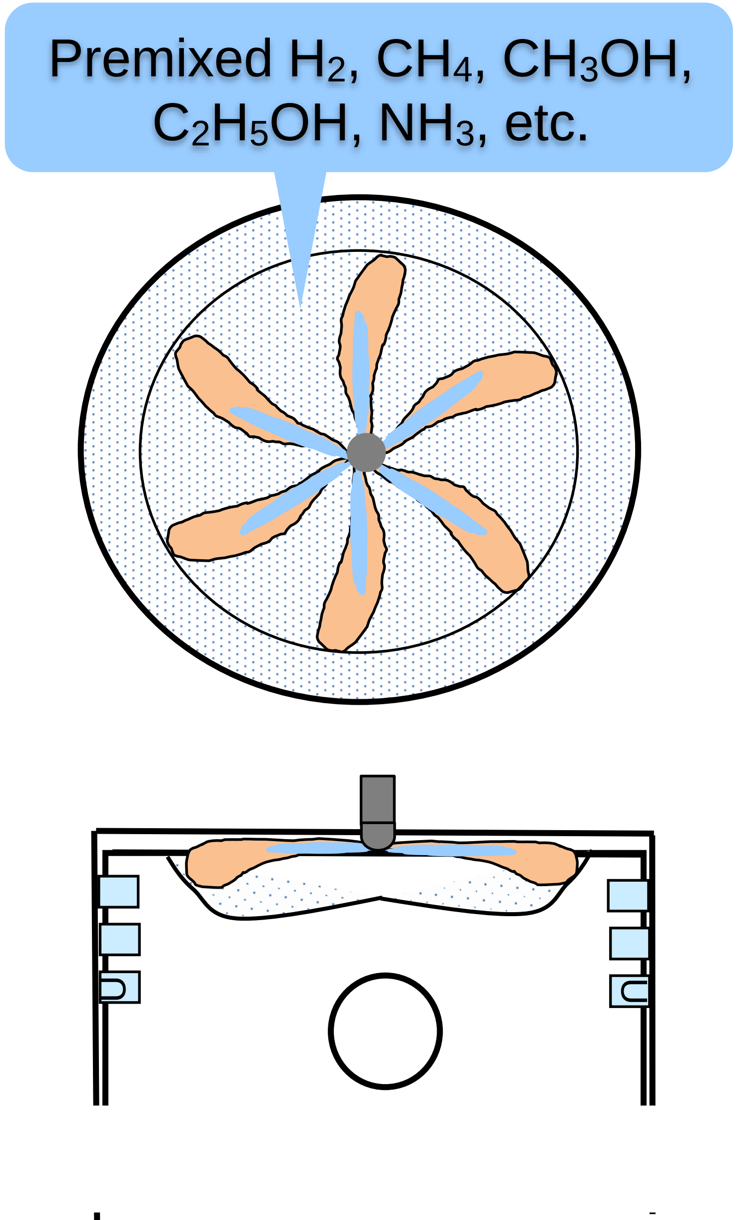
▲: much worse △: worse □: similar ○: Better ◎: much better, compared to conventional diesel fuel

Common issues

- Low-carbon resources should be used to produce energy and fuels based on LCA.
- It is essential to secure a sufficient and stable fuel supply and to provide it at an appropriate price.

Pilot Diesel Sprays to Ignite Low-Carbon Premixed Mixtures

- The gaseous premixed mixtures of low-carbon fuels such as H_2, CH_4, CH_3OH, C_2H_5OH, NH_3, etc. can be ignited and burned at diesel compression ratios by pilot diesel sprays (energy fraction<10%), achieving lean burn, low PM and NOx and almost the same high efficiency as that of conventional HD diesel engines.
- The diesel sprays provide multi-ignition points and turbulence throughout the combustion chamber, thereby preventing knock occurrence and enhancing the flame velocities of the mixtures.
- Some portion of the mixtures may be auto-ignited like HCCI, generating mild pressure rises and improving combustion efficiency.
- Combustion of the premixed mixtures tends to be deteriorated at part load.
- In case of using NH_3 mixtures, N_2O and NOx tend to be formed. They should carefully be reduced by means of combustion control and/or the catalyst.
- These fuels are expected to be decarbonized.

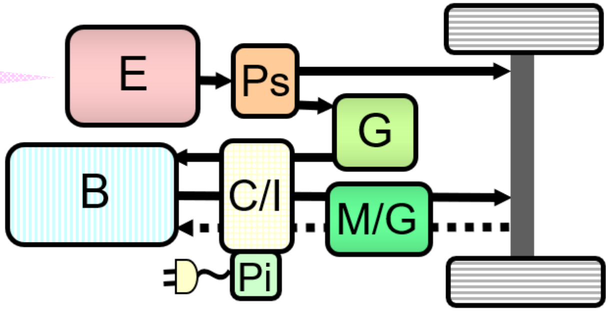


Will HD Vehicles Powered by an Internal Combustion Engine be able to survive?

- Low-carbon fuels are indispensable for engine-powered HD vehicles including hybrids and plug-in hybrids. Improving the engine efficiency is essential for these vehicles.
- Eventually, engine vehicles will have to be hybridized or plug-in hybridized by ultimately high efficiency engines and recharged with low-carbon electricity.
- Plug-in hybrids will be able to co-exist with BEVs and FCEVs, by featuring the following advantages,
  - Battery capacity can be reduced to one forth to one third of that of BEVs, resulting in reducing demands of battery-related materials and their costs.
  - Convenience is provided by avoiding congestion at recharging spots especially for long distance driving. In addition, the increase in recharging load is mitigated.
- Low-carbon fuels must fulfill the following requirements.
  - Total low-carbon characteristics meeting an internationally harmonized LCA criteria.
  - Affordability for customers
  - Long-term stable supply and profitability
  - Convenience in terms of transportation, storage, supply and compatibility to the conventional fuels

≪Low-carbon Fuels≫
Synthetic fuels,
Hydrogen, Biofuels

≪Low-carbon Electricity≫
Renewables, Nuclear



High efficiency PHEV

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

Green Growth Strategy to Achieve Carbon Neutrality in 2050

～Areas in Automobiles and Batteries～（Japanese Government, June, 2021）

＜Passenger Cars＞

❏All new models should be electrified after 2035. The government will extensively support the auto industry. ⇒

＜Commercial Vehicles＞

❏Trucks having gross vehicle weight lower than 8 tons
- New models should be electrified by 20-30% after 2030.
- All new models should be electrified or use e-fuels after 2040.
- The government will provide support for purchasing the vehicle and building recharging stations. ⇒

❏Trucks having gross vehicle weight exceeding 8 tons
- The government will support demonstration projects introducing 5,000 electrified commercial vehicles within 2030.
- Based on experiences with using electrified vehicles and synthetic fuels under development, their dissemination targets after 2040 will be decided by 2030. ⇒

＜Related Policies＞

❏To establish “Advanced Mobility Society with BEVs”, world-leading supply chain systems will be built including battery related industry by 2030.

❏The government will support conversions to BEV and FCEV in motorcycles and commercial vehicles. Support will also be provided to parts suppliers, car dealers, maintenance shops and refueling stations for their shifts to electrified mobility.

❏Domestic battery production capacity should be up to 100 GWh/year along with reducing the battery package costs to lower than ¥10,000/kWh.

Green Innovation Fund Established by METI to Encourage Companies to Take on Ambitious R&D Challenges

❑ "Green Growth Strategy through Achieving Carbon Neutrality in 2050" was announced by the Japanese government in December, 2020.

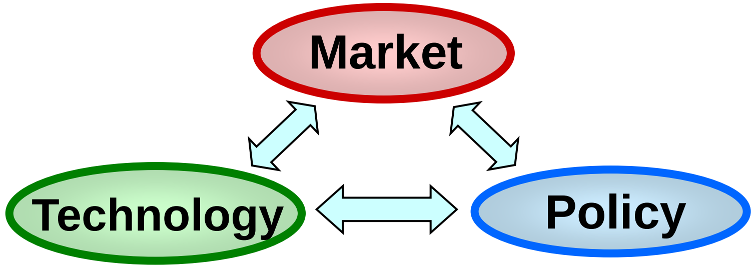
❑ Based on the strategy, the Green Innovation Fund up to 2 trillion yen has been established to encourage Japanese companies to tackle ambitious challenges including the development of advanced technologies for the next ten years to eventually achieve carbon neutrality as shown the table.

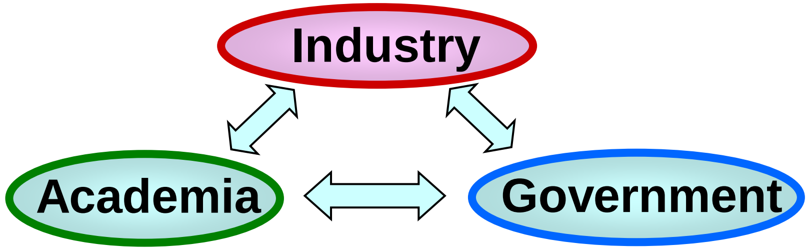
❑ GX (Green Transformation) Promotion Bond has been initiated by the government to financially support the promotion of carbon neutrality and stable energy supply beyond 2030 toward 2050.

▨ : related to motor vehicles

Areas¥	Eighteen Programs	x10^9 ¥
Enhance green power	▨ 1: Reduce the costs of offshore wind power systems	119.5
	▨ 2: Reduce the costs of next generation solar power systems	49.8
Transform Energy conversion structures	▨ 3: Construct large-scale hydrogen supply chains	300.0
	▨ 4: Develop renewable hydrogen production systems using electrolysis	70.0
	5: Utilize hydrogen for steel production processes	193.5
	6: Construct ammonia supply chains	68.8
	7: Develop technologies of producing plastic materials utilizing CO_2	126.2
	▨ 8: Develop synthetic fuel production technology using CO_2	115.3
	9: Develop technologies of producing concrete absorbing CO_2	56.8
	10: Develop CO_2 capture technology	38.2
	11: Develop CO_2 reduction technologies in incineration systems	-
Transform industrial structures	▨ 12: Develop next generation batteries and motors	151.0
	▨ 13: Develop parts supply networks for vehicle electrification	42.0
	▨ 14: Build smart mobility societies	113.0
	15: Build next generation digital infrastructures	141.0
	16: Develop airplanes using hydrogen or electricity	21.1
	17: Develop next generation ships using hydrogen or ammonia	35.0
	18: Develop CO_2 reduction and capture technologies in agriculture, forestry and fisheries	15.9

Innovations for HD Vehicles beyond 2030 and toward 2050





❑ The shift from ICEVs to BEVs is the most predominant trend toward carbon neutrality. In order to promote this, it is necessary to improve battery performance, reduce costs, and secure a supply chain from related materials to parts along with locating low-carbon rapid recharging spots.

❑ In addition, there should be various combinations of HD vehicle power systems and the fuels and energy, depending on the vehicle type, costs, convenience and drive milage. In the next ten years to come, efforts will have to be made to solve the problems with FCEVs, HEVs and PHEVs that use hydrogen or synthetic fuels, searching for a direction to co-exist with BEVs by considering their own advantages, LCA-based CO_2 emissions and cost-effectiveness.

❑ Furthermore, in the transportation sector, various information technologies and smart city initiatives should be utilized to optimize personal mobility and logistics. It is necessary to promote cross-sectoral efforts in parallel, by promoting innovation by sharing long-term goals for a stable supply of energy and decarbonization under industry-academia-government collaboration. Technical and policy support should actively be provided to the transportation areas in emerging and motorizing economies.