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The Japanese Government's Decarbonizing Policies in the Transportation Sector

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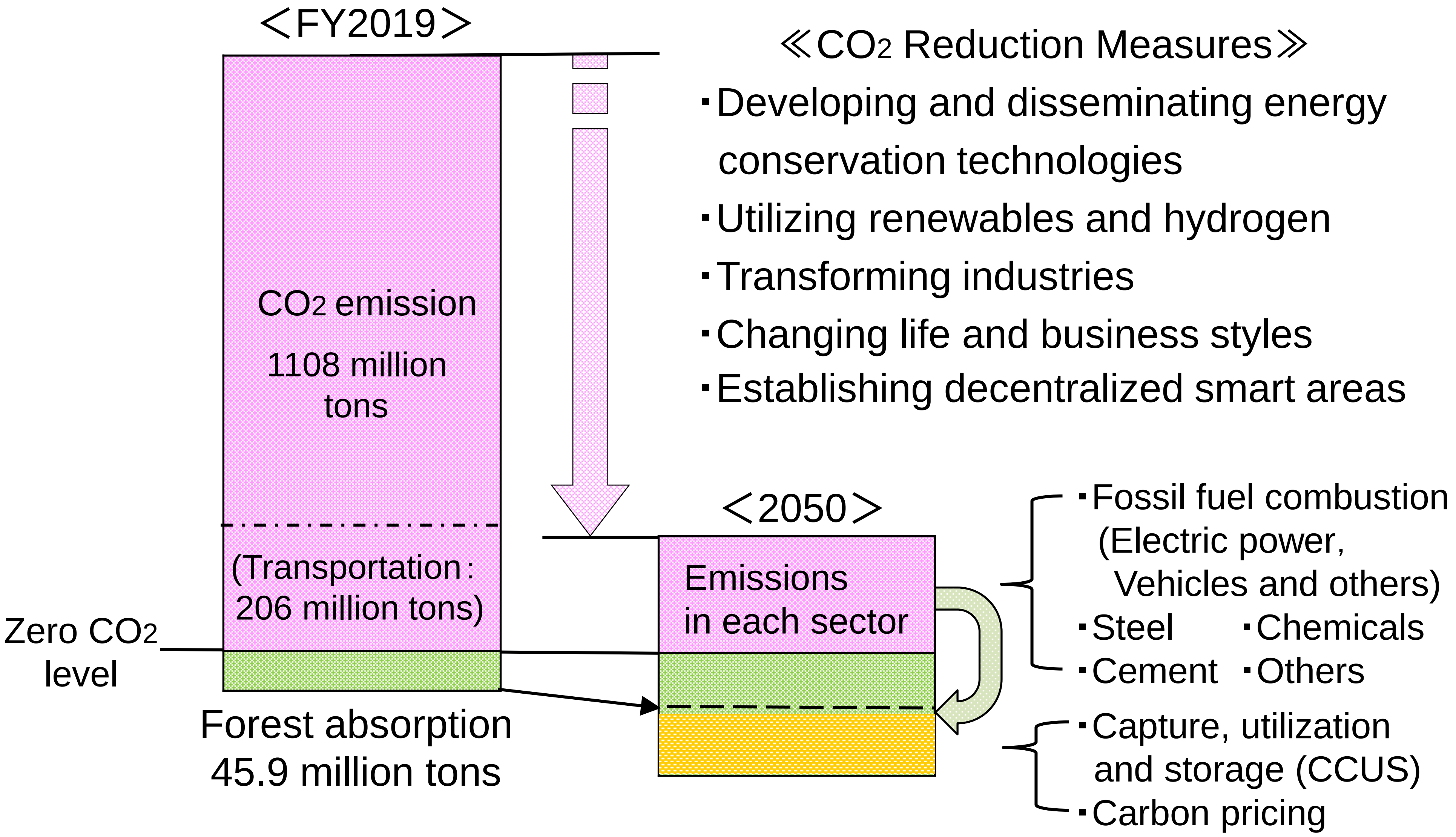
Carbon Neutrality Target in 2050 (Japan)



＜FY2019＞

CO2 emission

1108 million tons

(Transportation：206 million tons)

Zero CO2 level

Forest absorption 45.9 million tons

≪CO2 Reduction Measures≫

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

＜2050＞

Emissions in each sector

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

- Capture, utilization and storage (CCUS)
- Carbon pricing

☆Inter-sectoral approaches are necessary to achieve the carbon neutral target in 2050.

CO_2 Emission Trends and Policy Measures to Reduce CO_2 in the Transportation Sector in Japan (MLIT, 2020)

❑Disseminating next-generation vehicles or electrified vehicles
（Setting targets of their sales, Necessity to electrify heavy-duty vehicles）

❑Improving fuel economy（More stringent fuel economy regulations are needed beyond 2030）

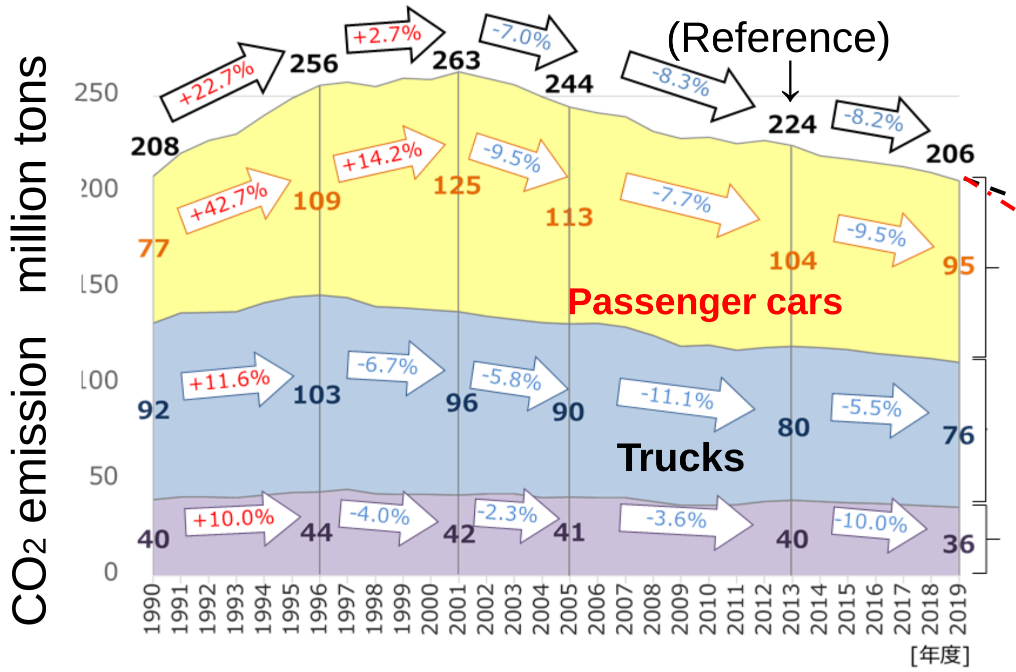
❑Improving traffic flow ❑Recommending “Eco-drive”

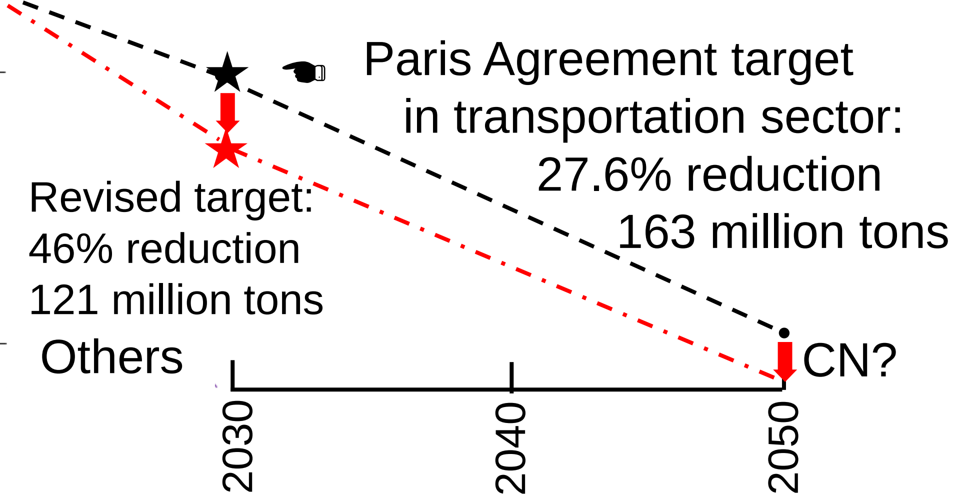
❑Enhancing the use of public transportation and modal shifts ❑Enhancing “Green Freight”

☆Intersectoral policies for low carbon society

- Nationwide movements
- Decarbonizing cities, regions and socio-economic systems
- Establishing a Hydrogen Society
- Encouraging private companies to be more environment-conscious
- Introducing “Green Taxation”

On April 22, 2021, Prime Minister Suga announced that GHGs is supposed to be reduced by 46% in FY2030, compared to the FY2013 level.





Reviewing CO_2 Emission Reduction Progress in FY2019 to Achieve the FY 2030 Target in the Transportation Sector

Ranking of the target achievement	Means of transportation (*: higher, **: lower than CO_2 reduction in FY2018)	Reduced CO_2 × 10^4 tons
A. Determined to exceed FY 2019 target to achieve FY 2030 target (14%)	Promoting eco-driving *	243.8
	Improving railway energy consumption efficiency *	177.6
	Disseminating car-sharing	55.1
	Promoting high efficiency waste logistics	1.6
	Disseminating high efficiency loading machinery	0.7
B. Estimated to exceed the target	Disseminating joint collection and delivery systems (0.1%)	2.1
C. Estimated to be comparable to the target (82%)	Disseminating next generation vehicles and improving fuel economy	2379.0
	Promoting to use public transportation and bicycles **	177.0
	Implementing green extensive coastal shipping	172.4
D. Estimated to be lower than the target	Promoting modal shit to railway freight (4%)	133.0
-	Total	3342.6

Source: “Annual Report on Progress in FY2019 for Achieving the FY2030 CO_2 Emission Reduction Plan,” MOE, Japan, March, 2021

Passenger Car and Light Duty Vehicle Fuel Economy Standards between 2020 and 2030 in Major Countries

（Converted to NEDC mode values, ICCT 2020）

Country	Year	km/L	L/100 km	CO_2 g/km	Improvement %/year
Japan[1)]	2020 2030	21.1 (17.6) 30.4 (25.4)	4.74 (5.68) 3.29 (3.93)	106 (132) 73.5 (91.5)	4.4
E U[2)]	2021 2025 2030	24.2 27.4 34.7	4.13 3.65 2.88	95.0 81.0 59.0	4.8
USA	2019 2026	17.8 20.3	5.62 4.92	128 157	2.0
China	2020 2025	19.8 25.0	5.05 4.00	117 93.4	5.3
India	2018 2022	19.6 21.0	5.05 4.76	122 113	1.8

1) ( ): based on WLTC mode

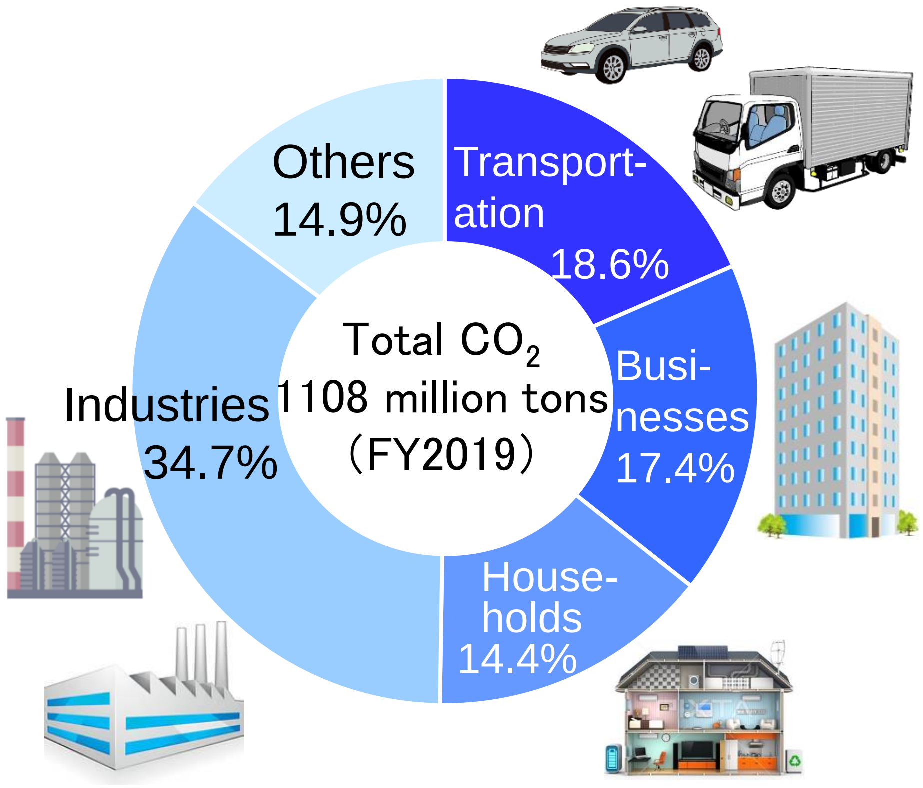
2) 37.5% reduction in 2030 compared to 2021 level（50% reduction proposed）

- ・NEDC: New European Driving Cycle
- ・ICCT: The International Council on Clean Transportation

CO_2 Emissions in Transportation Sector in Japan (FY2019)

MLIT's HP, 2021

CO_2 Emisson in each Sector



Transportation	×10^4 t	%
Motor vehicles	17,735	86.1
Private PC	9,458	45.9
Private trucks	3,390	16.5
Commercial trucks	4,193	20.4
Buses	399	1.9
Taxies	223	1.2
Motor cycles	72	0.4
Aviation	1,049	5.1
Coastal shipping	1,025	5.0
Railway	789	3.8
Total	20,600	100.0

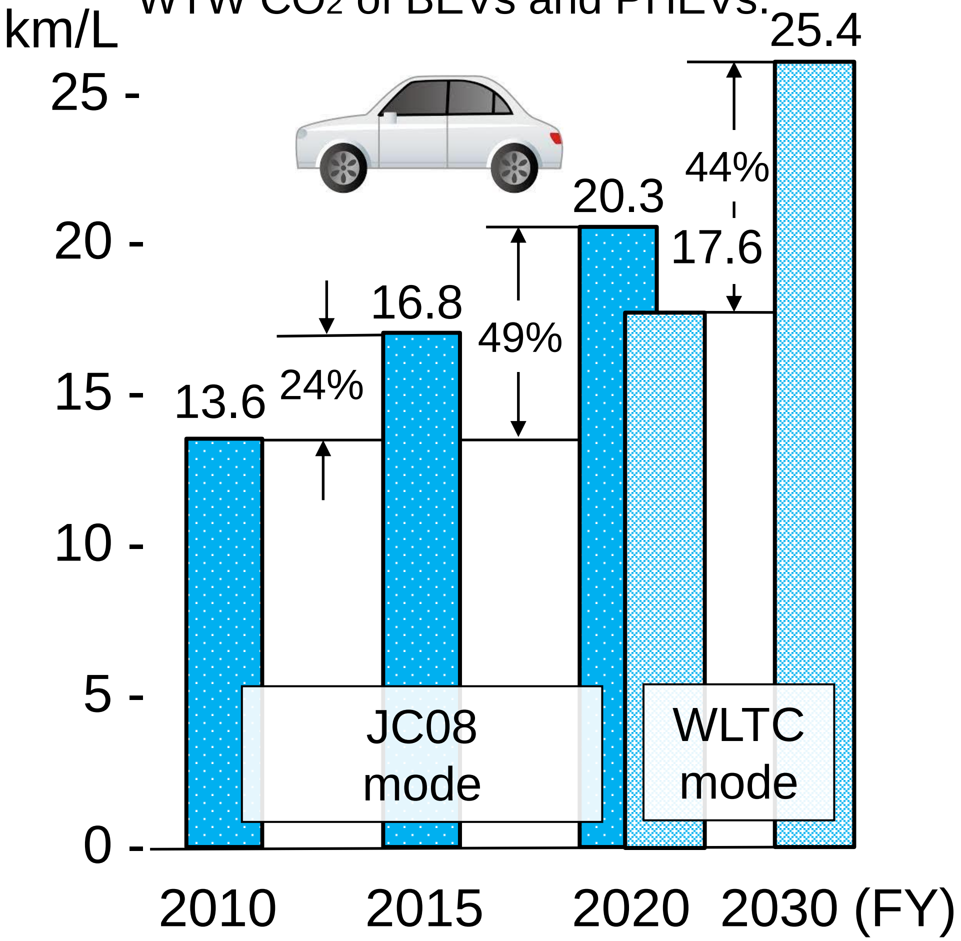
❑ CO_2 emission from motor vehicles account for 16.0 % of the total CO_2 emissions.

❑ Motor vehicle Fuels sold (% relative to crude oil) :

Gasoline = 49.107 million L（28.8%）, Gas oil = 33.657 million L（23.2%） （Source: METI ）

Fuel Economy Standard Trends in Japan（MLIT, 2019）

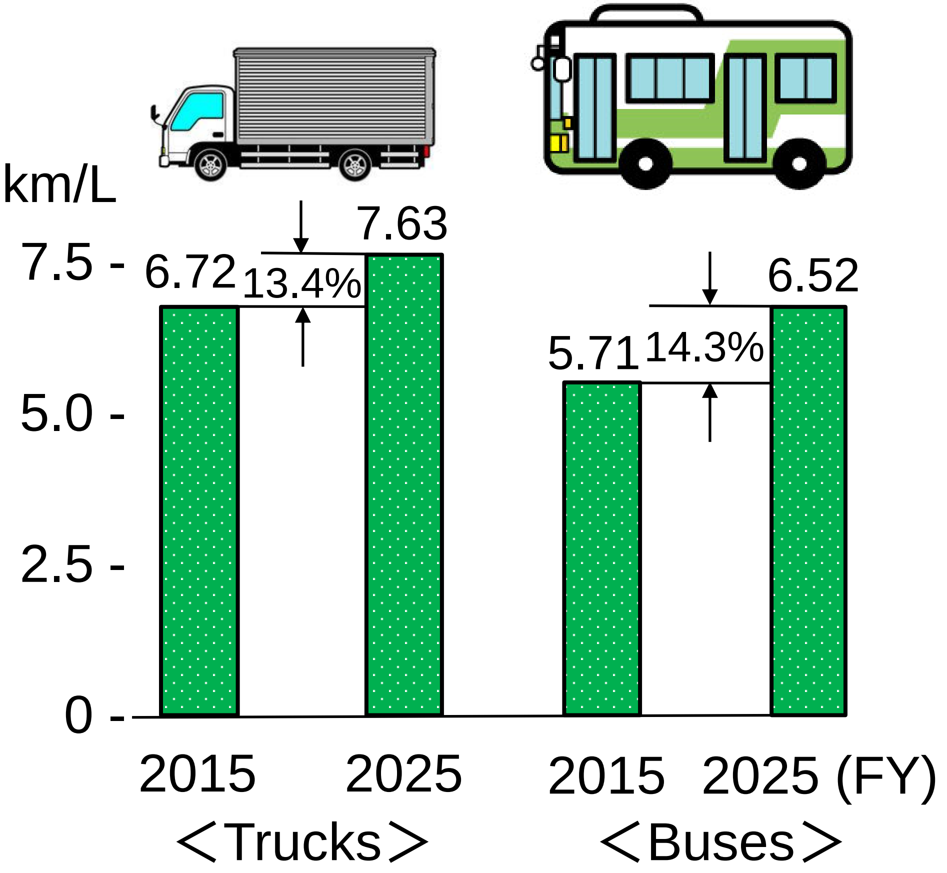
- ❏32.4% improvement in FY 2030 compared to FY2016 level
- ❏FY2030 standards consider WTW CO_2 of BEVs and PHEVs.



[Corporate average fuel economy]

≪Passenger Cars≫

- ❏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.



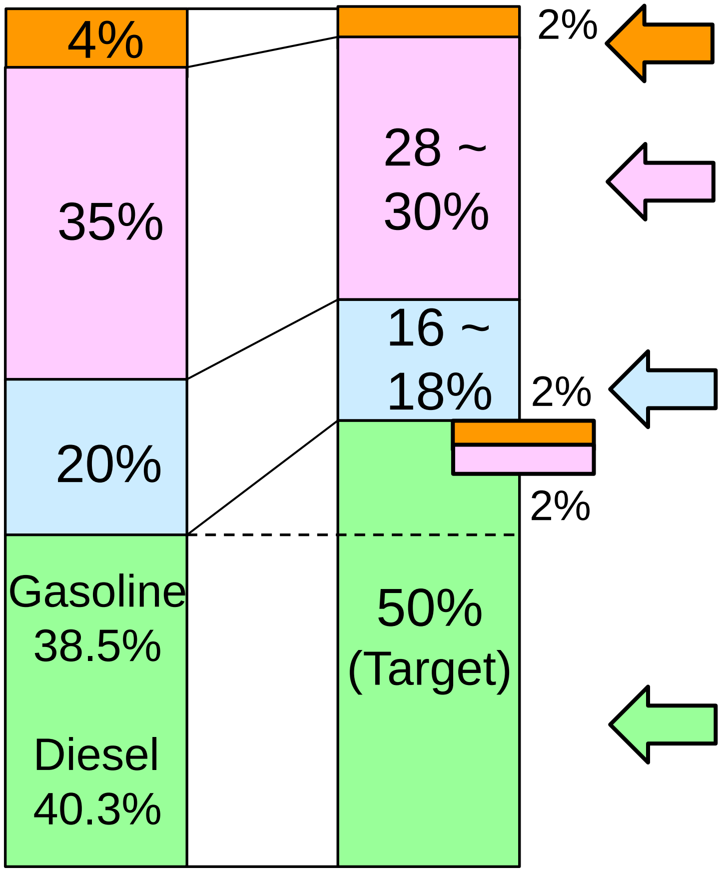
≪Heavy Duty Vehicles≫

SIP ”Innovative Combustion Technologies”（FY2014-18）

❑The ultimate goal of 50% brake thermal efficiency has been achieved in collaboration with Academia, Industry and Government.

❑The technologies will be utilized for the auto industry to commercialize engines for passenger engine vehicles, HEVs and PHEVs to improve their fuel economy.

≪Energy balance≫



≪Engine Technologies≫

Mechanical loss reduction by 50%

Utilizing exhaust waste energy
- Improving turbocharging efficiency up to 60%
- Thermoelectric device

Reduction in heat loss
- Ultra lean burn
- Optimizing in-cylinder flow
- Long stroke

Increasing indicated work
- Combustion improvements
  Gasoline engine: high ignition spark energy
  Diesel engine: highly distributed sprays

https://zemconso.jp

（Established in April, 2020）

≪Objectives≫

Based on SIP’s “Innovative Combustion Technologies”, the consortium aims at realizing zero emission mobility based on results on high efficiency engine research achieved by SIP’s “Innovative Combustion Technologies.”

The consortium members include 130 university researchers and **“AICE”**(The Association of Automotive Internal Combustion Engines) members from automobile related companies.

≪Activities≫

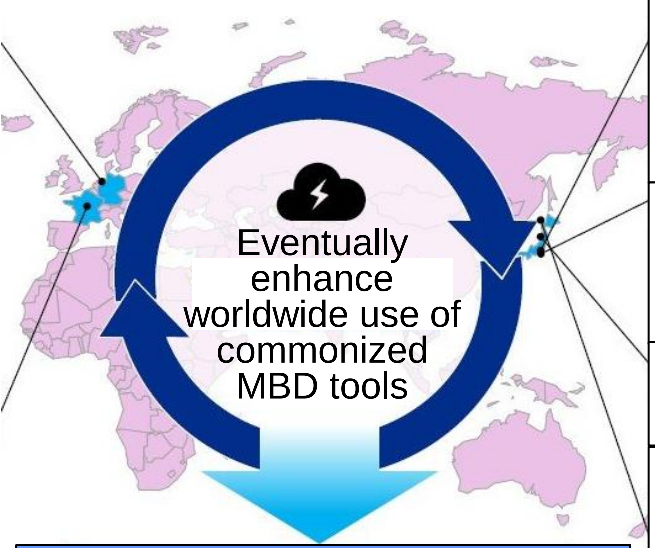
- Establishing collaborative research themes based on Needs and Seeds matching, obtaining governmental research budgets and conducting the research
- Addressing safety issues in universities’ experimental activities, supported by AICE members
- Establishing comprehensive database on the research results and related programs
- Educating university students and young engineers
- Organizing a variety of events for exchanging technical information among the members

Japan Automotive Model-Based Engineering Center Established

The center aims to contribute to making Japan's automotive industry more competitive internationally by spreading and deploying advanced MD technologies leading to high-grade virtual model development technologies based on the Suriawase 2.0 concepts initiated by the METI. The technologies are to effectively be shared among the industry and academia. (Announced on Sept. 24th, 2021)

ProStEP iViP(PSI)*:*
190 companies from the EU and the USA, German organization for international digital technology standardization and support

SystemX*: 70 companies*
French research organization for digital technologies



Eventually enhance worldwide use of commonized MBD tools

- Strengthen the development capabilities of OEMs and parts suppliers
- Create collaborative opportunities with new entrants

JAMBE *10 steering members:*
Aisin, Jatco, Subaru, Denso, Toyota, Nissan, Panasonic, Honda, Mazda and Mitsubishi Electric

AICE*: 9 OEMs, 2 organizations and 74 member companies*

TRAMI*: 11 OEMs, 26 members*

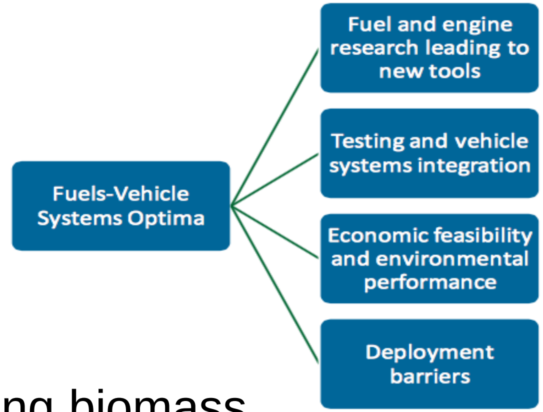
JasPar*: 237 members including 5 major and 101 regular member companies*

Source: https://www.jambe.jp

High Efficiency Engine Programs in USA and EU

USA
DOE
”Co-Optima"

CO-OPTIMIZATION OF FUELS & ENGINES


Fuels-Vehicle Systems Optima
- Fuel and engine research leading to new tools
- Testing and vehicle systems integration
- Economic feasibility and environmental performance
- Deployment barriers

＊Optimizing a combination of engines and fuels including biomass for a vehicle types ranging from passenger cars to heavy duty vehicles

＊Another program is “SuperTruck I to III to achieve 55% brake thermal efficiency in heavy-duty truck engines and electrify the vehicles. (2009-2021～)

EU
Horizon 2020
”EAGLE"

THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION
HORIZON 2020

EFFICIENT ADDITIVATED GASOLINE LEAN ENGINE

EUROPEAN COMMISSION
Horizon 2020 GV-02-2016
GA No. 724084

＊Achieving 50% brake thermal efficiency by adopting lean burn with hydrogen for light duty vehicles

Passenger Car Sales Targets by the Government

（Strategic Next Generation Vehicle Committee, METI, April, 2010 and April, 2018）

Vehicle Type	2019年	2020	2030
Internal combustion engine V	60.8%	50～80%	30～50%
Next Generation Vehicles	39.2%	20～50%	50～70%
HEV	31.2%	20～30%	30～40%
BEV / PHEV	0.49 / 0.41%	15～20%	20～30%
FCEV	0.02%	～1%	～3%
Clean diesel V	4.1%	～5%	5 ～10%

❑Total new passenger car sales: 4.30 million in FY2019

❑Percent BEV sales in major countries and area in 2019 (IEA)：

・China: 4.5%　・USA：1.9%　・EU：3.4%

・Global: 2.5%（3.2% in 2020）

Future Fuels for HD Diesel Vehicles

Fuel Types		Output	CO_2 reduction	Costs vehicle / fuel	Drive range	Sustainability	Issues
Biodiesel (B5-B30, B100)		□	○	□/△	□	○	LCA required, Improve quality
Hydrotreated BDF (HVO)		□	○	□/△	□	○	LCA required, Cost reduction
Hydrogen (Compressed)	Port injection (SI)	△	○	□/△	△	○	DI to improve efficiency Build H_2 stations
	FCEV	□/△	◎	▲/△	△	○	Cost reduction, H_2 stations
Methane (Compressed, SI)	Natural gas	△	□	□/□	△	□	Reduce methane slip, Develop LNGVs
	Bio methane	△	○	□/□	△	○	Secure methane sources
	Methanation	△	○	□/△	△	○	Secure H_2 and CO_2 sources
Bio-ethanol (SI)		△	○	□/△	□	○	Develop cellousic ethanol
Synthesized fuel (e-fuel)		□	○	□/▲	□	○	Secure CO_2 and H_2 supply Increase yield efficiency
Mobile carbon capture		△	○	▲/□	□	△	Establish CO_2 storage systems

○: superior □: comparable △: Inferior relative to conventional diesel vehicles

・SI: spark-ignition ・Assumption: H_2 is produced using renewables.

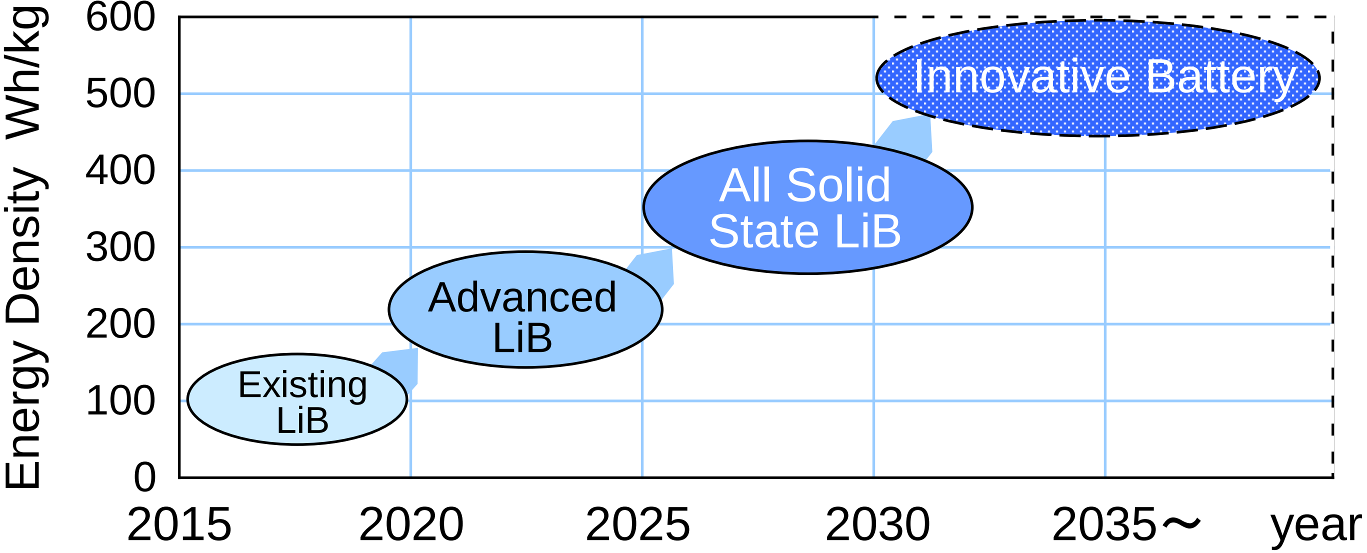
Issues on Electrifying Trucks

Type Range	HEV	BEV	FCEV
Short（LD） <100-200km	○ ・Improved by 20-30% ・limited low emissions	○ ・Zero emission ・Expected by freight industry	○ ・Zero emissions ・Electricity provision
Medium（MD） <300km	□ ・FE depends on the vehicle usage	□ ・Limited payload and drive range ・High battery costs	□ ・High vehicle and fuel costs
Long（HD） >300km	□ ・Limited FE 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 e-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 fuel cost ・Improve FC stack performance and durability ・Increase H2 stations ・Increase vehicle types ・Commonize FC parts ・Decarbonize H2 ・Secure H2 supply

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

Targets of Developing Battery Cells and Packages for PHEVs and BEVs

≪Battery Cells≫



Source: METI, Strategic Meeting for Next Generation Vehicles (2018)

≪Battery Packages≫

Vehicle Type	Period	Range km	Weight kg	Capacity kWh	Cost ×10^4 ¥
PHEV	2020 – 2030	60	50	10	20
BEV	2040 – 2050	700	80	56	26

Source: NEDO, Roadmap of Developing Batteries (2013, 2018)

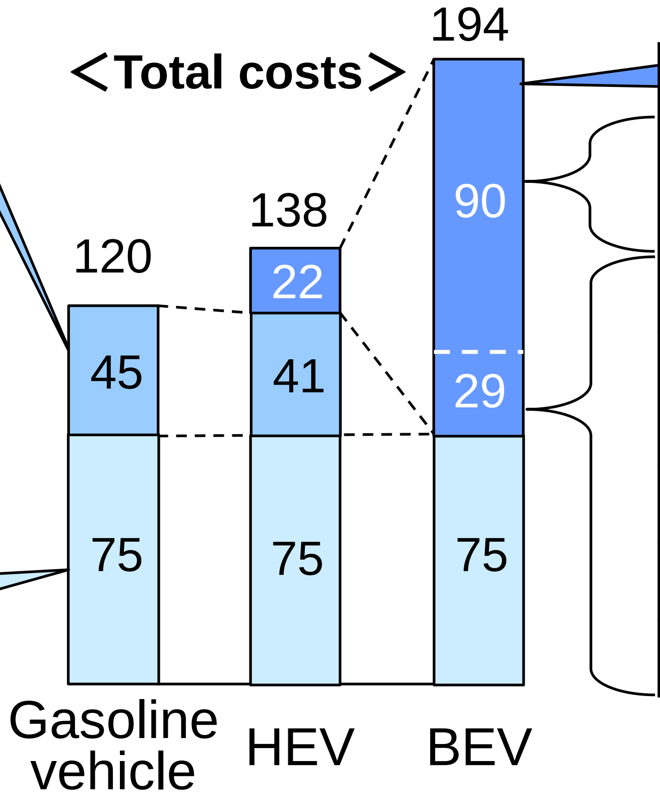
Cost Comparison of C-Segment Gasoline Vehicle, HEV and BEV

（Source: Nikkei, MarkLines, March, 2021）

Unit: 10^4¥

Engine system costs	45
Engine	20
Intake system	1
Exhaust system	3
Fuel tank and pipe	2
Transmission	13
Cooling/AC	6

Common parts costs	75
Body/Exterior	20
Interior	15
Chassis	20
Electric parts	10
Painting/Assembling	10



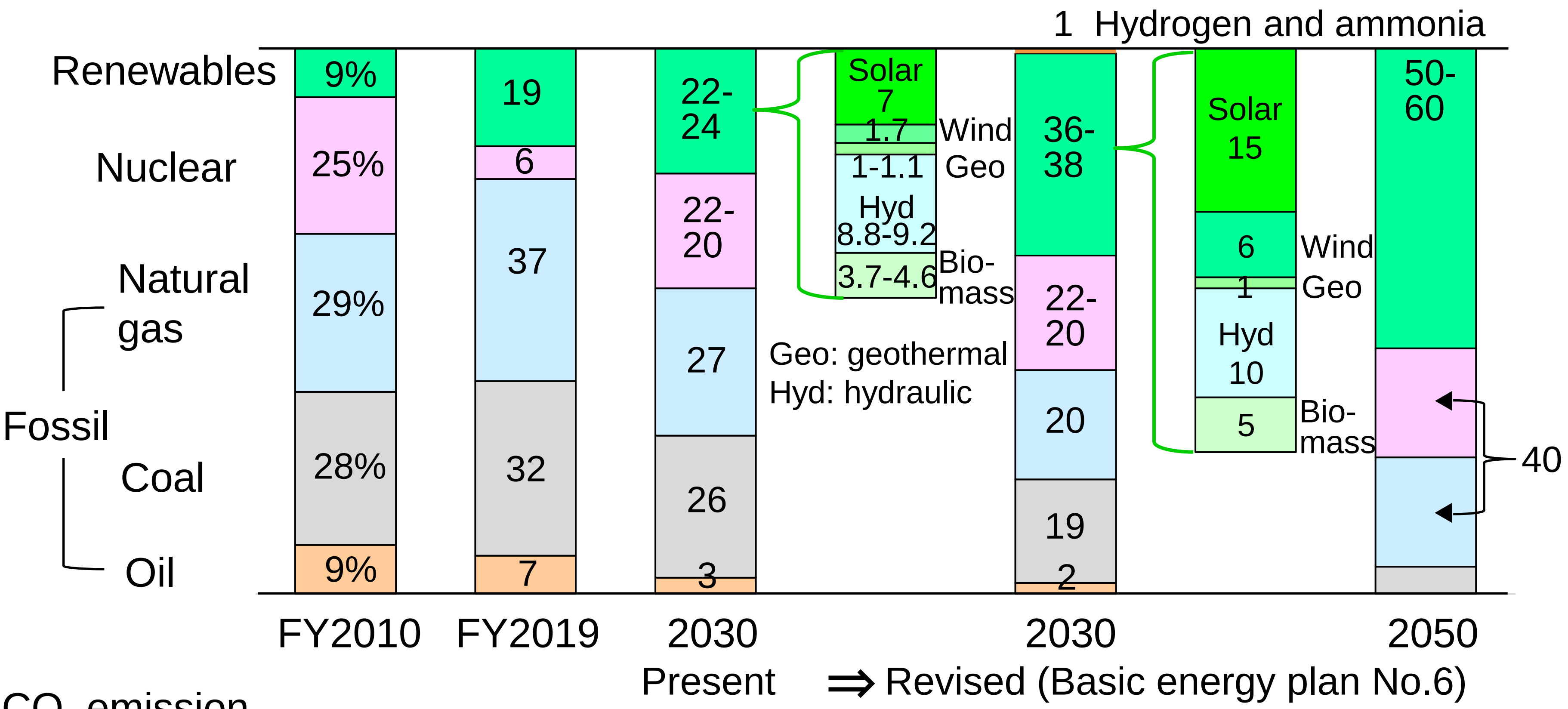
BEV parts costs	119
Battery unit （capacity: 40kWh）	90
Motor	5
Inverter, DCDC Convertor, Charger	12
High Voltage harness	3
Reduction gear	2
Cooling/AC	7

❑The sales price of the gasoline: ¥2,000,000

❑Costs don’t include management, development and related depreciation.

❑The battery unit cost was estimated referring to domestic market price. There is an example of $100/kWh in the overseas market

Electricity Generated by Source（METI, 2018, 2021 ）



CO_2 emission kg/kWh	0.413	0.444	0.37	0.28（estimated）	0.20（estimated）

- ❏Revised targets are as follows. Renewables: 22-24% ⇒ 36-38%, Fossil: 56% ⇒ 41%
- ❏Electricity demand is predicted to change from 1,024 billion kWh in FY2019 to 930-940 kWh in FY2030 by 9% reduction. (July, 2020)
- ❏Demand and supply management systems are necessary for changeable renewable energy and recharging BEVs and PHEVs.
- ❏Increased renewable and nuclear energy will favorably reduce CO_2 from BEVs and PHEVs.

Hydrogen and Fuel Cell Strategy 2020 (METI)

❑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 and ¥8.7/kWh, respectively)

・Yearly supply targets: 3.0 million tons by 2030 and 20 million tons 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. （¥400 ⇒ ¥200 million ）

❑Station business should be profitable in late 2020s.

Staions and vehicles	Present	～2020	～2025	～2030
Hydrogen station	162（2020/11）	160	320	1,000
FC passenger cars	3,433（2020/7）	40,000	200,000	800,000
FC buses	84（2020/9）	100	—	1,200
FC folklifts	250（2020/3）	500	—	10,000

Comparison of Electrified Vehicle Types

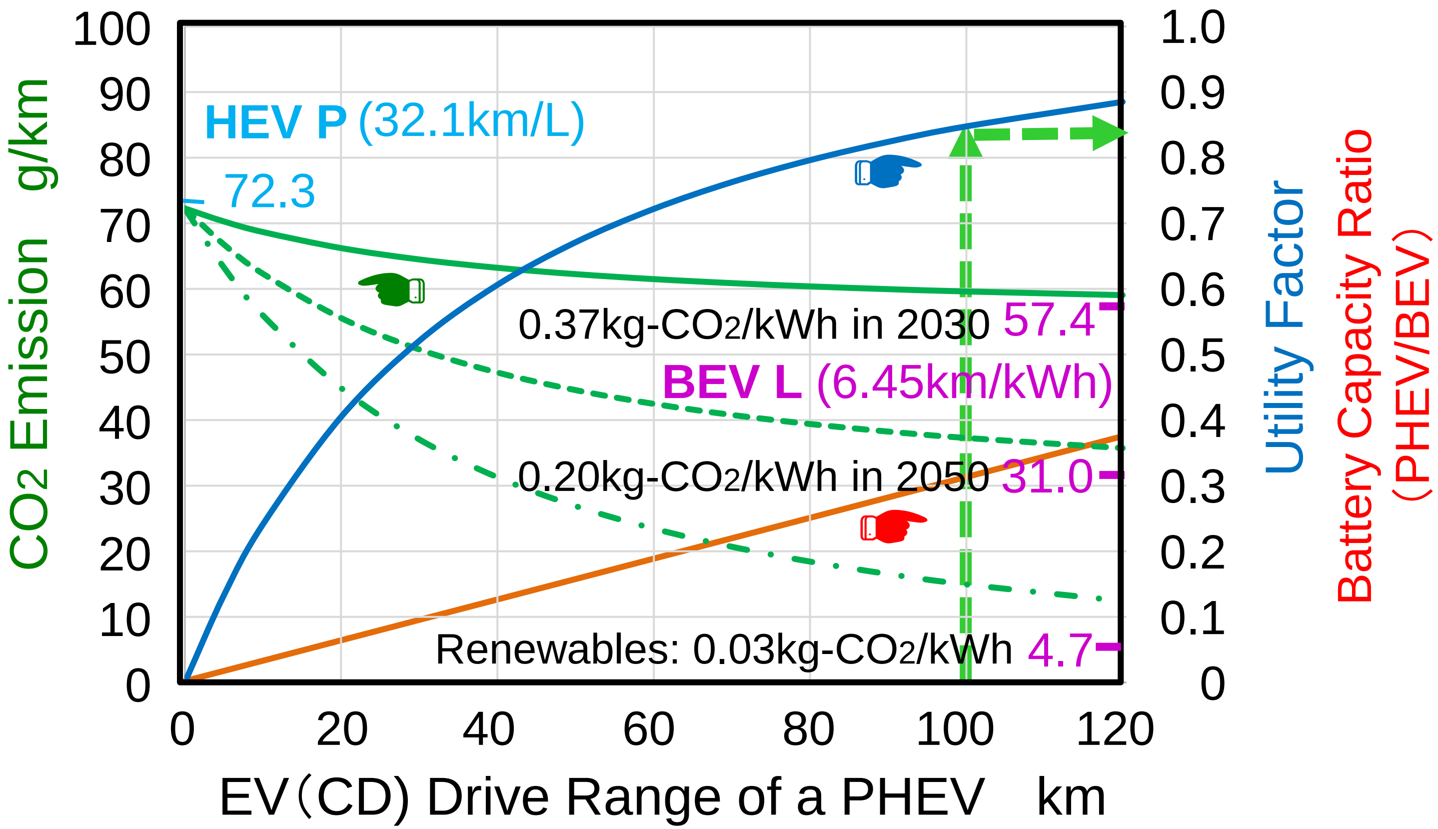
Based on the data released by automakers

Vehicle Type	Battery Capacity kWh	Vehicle Weight Ratio	Energy Efficiency Ratio
Gasoline Vehicle	（Fuel: 400 – 500）	1.00 (reference)	1.00 (reference)
Diesel Vehicle		1.06	1.15 – 1.20
HEV	1 – 2	1.05 – 1.15	1.20 – 1.90
PHEV	10 – 20	1.15 – 1.20	1.8
BEV	20 – 80	1.20 – 1.30	3 – 4*
FCV	1 – 2 （H_2: 150 – 170）	1.30 – 1.40	1.8 – 2.5*

*：Estimated from energy consumption（Wh/km）

- The weights of BEVs and FCVs tend to increase due to their heavy battery units and hydrogen fuel cell systems, respectively.
- The rapid expansion of BEVs will cause the increased costs of Cobalt, Nickel and Neodymium, resulting in creased vehicle prices.
- PHEVs which will serve as a bridge from HEVs to BEVs or co-exist with BEVs by taking advantage of minimizing the battery capacity.

Estimated CO2 Emission Characteristics of HEV, PHEV, BEV

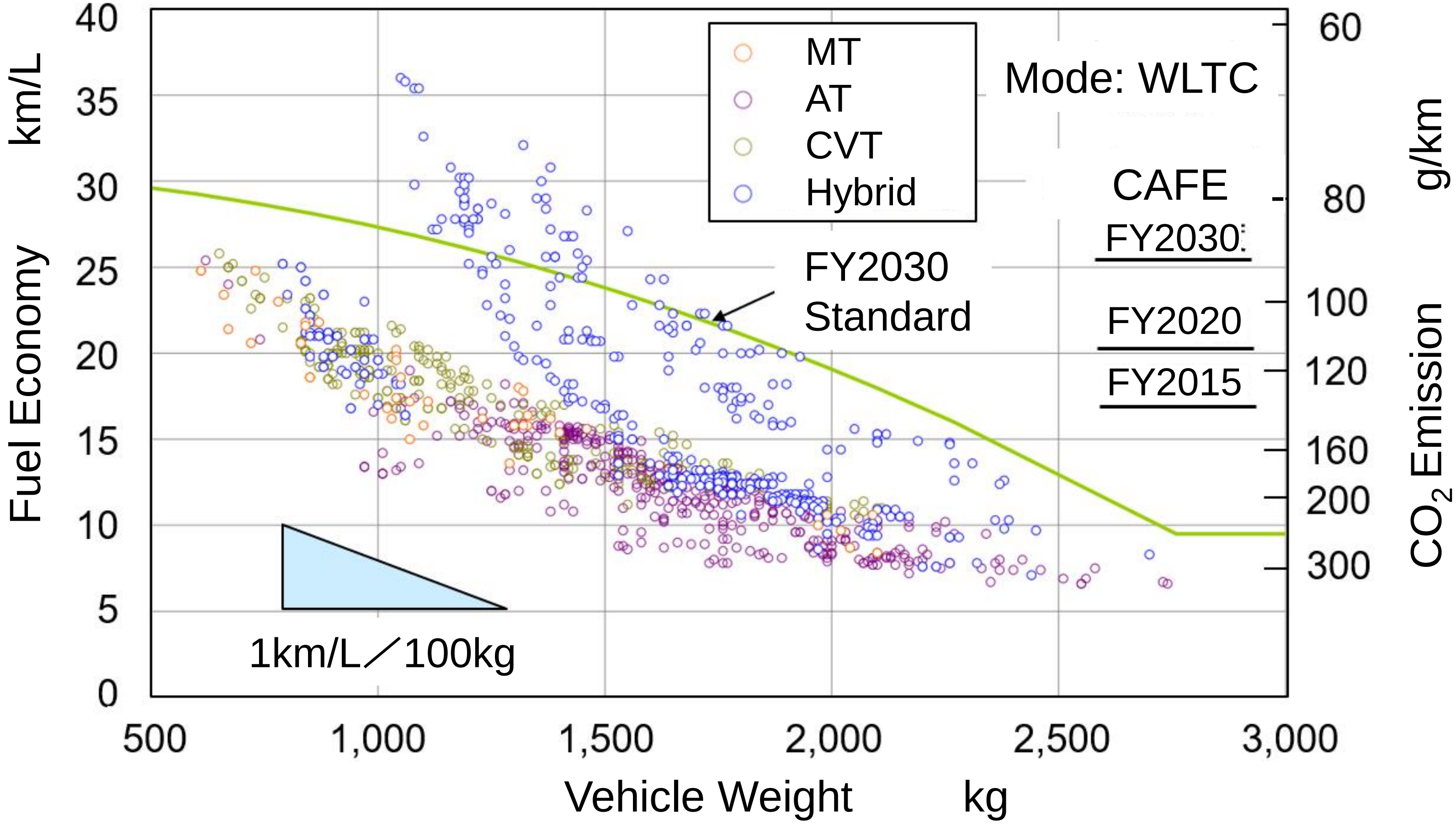


Assumptions

- BEV: Automaker N's Passenger EV, **L**
- HEV: Automaker T's Passenger HEV, **P**
- PHEV: CO_2 emission is estimated using utility factors determined by the EV drive range and their WLTC based fuel economy.
- CO_2 emissions for battery charging are shown in the figure in 2030 and 2050 and in case of using renewable electricity.

Passenger Cars' Fuel Economy Trends in Japan

MLIT, March, 2020

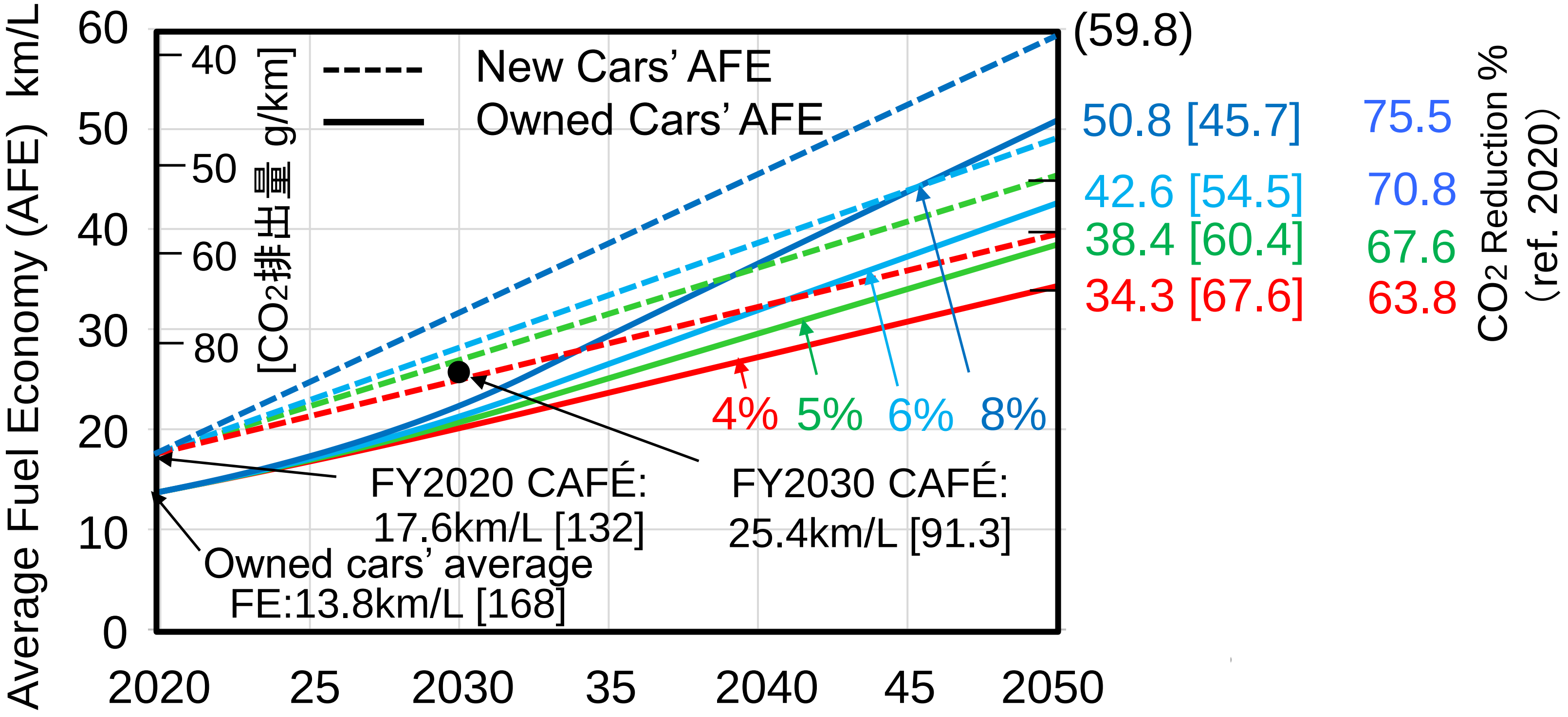


- ❏Some HEVs' fuel economy levels are twice higher than those of ICEVs.
- ❏More fuel economy improvements are required for K cars and heavier vehicles.

Major Technologies to Improve Fuel Economy and Reduce CO_2

Technologies	Contents	Fuel economy improvement [CO_2 reduction] （yearly rate, period）
① Improving engine efficiency	Achieving brake thermal efficiency of 50-55% in 2030	15～25% [13～20%] (1.5～2.5%/year in 10 years)
② Decarbonizing electricity and fuels	Using renewable electricity for BEVs and PHEVs	30～140% [23～58%] (1.5～7%/year in 20 years) ＊
	Using renewable hydrogen and synthesized fuels	？(after 2030)
③ Improving batteries and electrification technologies	Hybridization (mild ～ strong)	20～80% [17～44%] (1.3～5.3%/year in 15 years)
	Disseminating BEVs and PHEVs (Decarbonizing electricity)	30～140% [23～58%] (1.5～7%/year) ＊
④ Reducing the body mass	Using lightweight materials for all vehicle types	20～30% [17～23%] (1.0～1.5%/year in 20 years)

The Effect of Annually Improved New Cars' Average Fuel Economy on Owned Cars' Average Fuel Economy and CO_2 Emission (in Case of Passenger Cars)

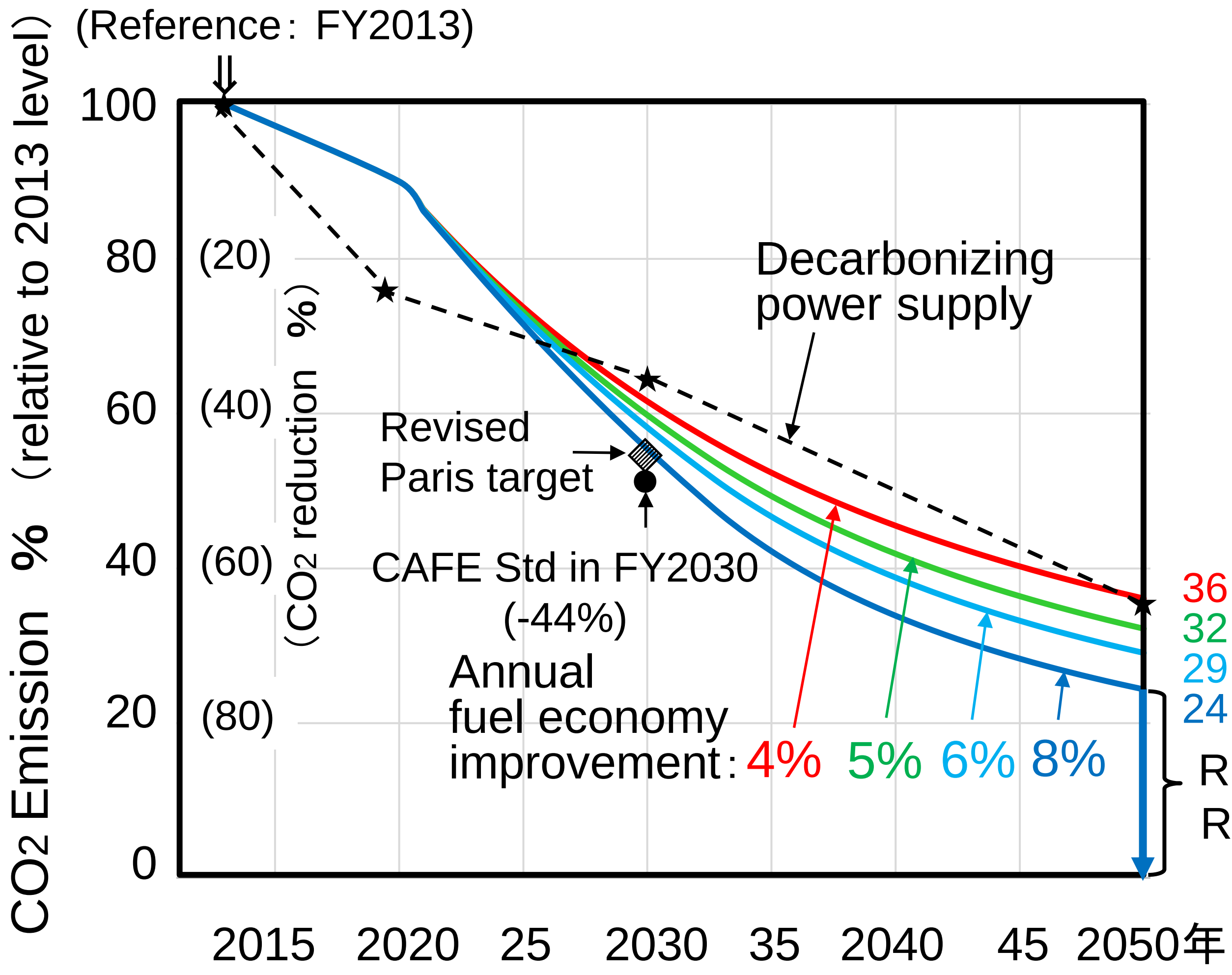


<Assumptions>

- New cars' fuel economy based on WLTC mode is improved at the annual rates of 4, 5, 6 and 8% compared to FY2020 standard level.
- The fuel economy of owned cars registered before 2020 is interpolated or extrapolated linearly between the standards of FY2010 and FY2015 converted to WLTC levels.
- Vehicle types and their owned numbers don't vary.
- The vehicles having the age of 13 years are replaced with new ones.

❑ Since owned cars' average fuel economy is improved by replacing them with new ones as well as by implementing increasingly more stringent fuel economy standards.

The Effect of Annual Fuel Economy Improvement on Stock-Based CO2 Reduction



36.1（63.9）
32.2（67.8）
29.1（70.9）
24.4（75.6）

Reduction %

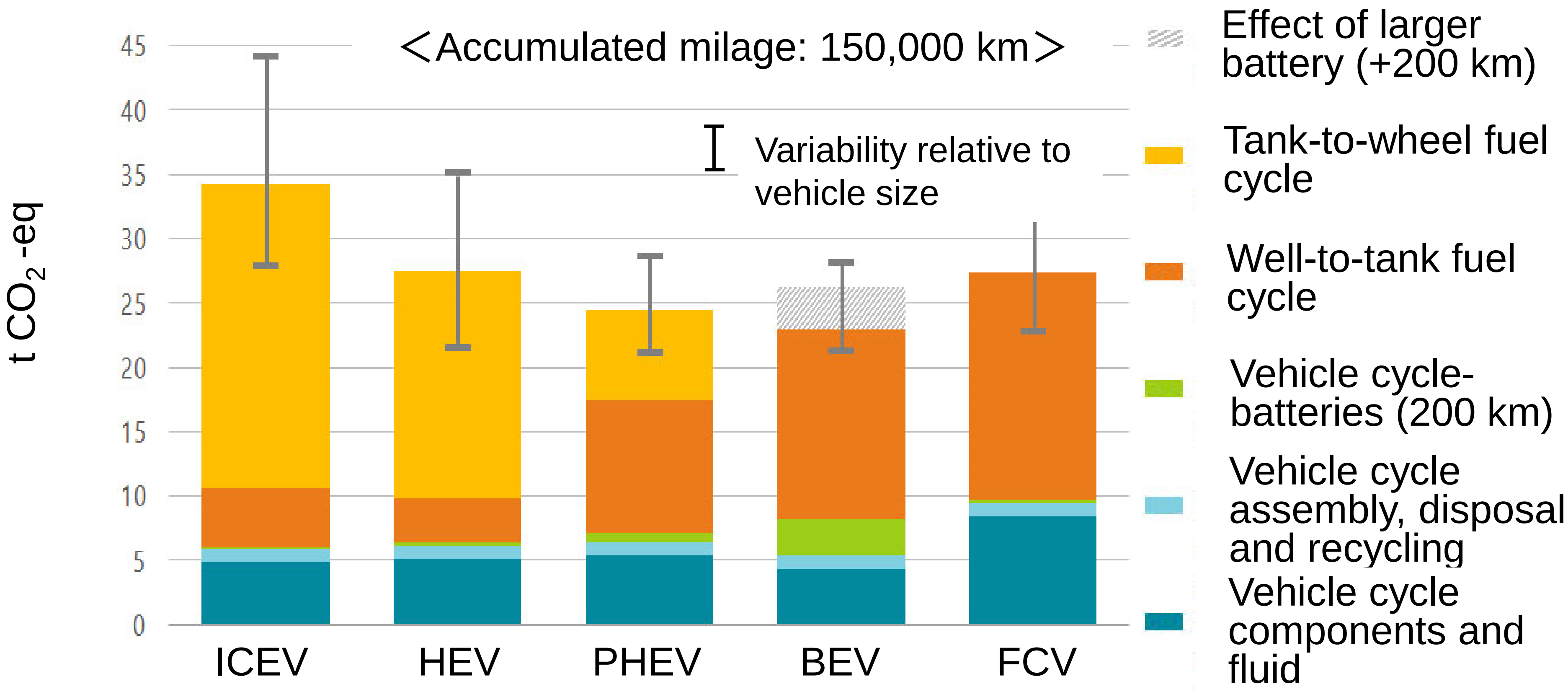
Reduced vehicle stock: 20%
Reduced vehicle mobility：20%

❏CAFE
- 44% improvement from 2020 to 2030
- Higher improvement towards 2050

❏Decarbonizing power supply（★）
2020：0.47 kg-CO2/kWh
2030：0.37
2050：0.20

❏To achieve carbon neutrality in the transportation sector, it is necessary to change the way of using the vehicle as well as utilizing vehicle and energy technologies and polycies.

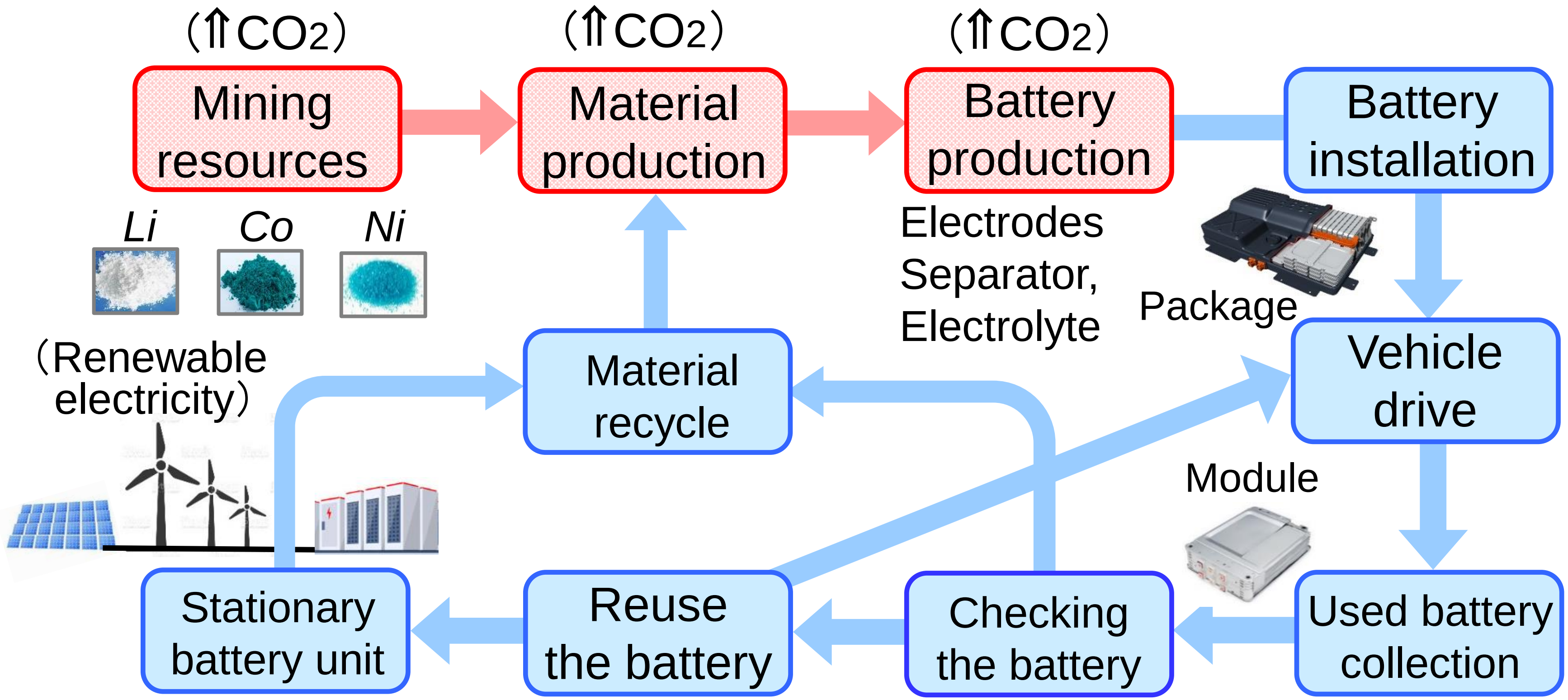
LCA CO_2 Emission Comparison of Different Vehicles



- The EU plans to limit CO_2 emission based on LCA and require automakers to report the emission for their new models starting in July, 2024.
- Increasing the battery energy density is essential for BEVs.
- Decarbonizing electricity is essential to reduce CO_2 emission in BEVs and PHEVs.
- Using low carbon hydrogen and reducing the weight of related parts are necessary in FCEVs.

Source: Global EV Outlook 2019, IEA

Reuse and Recycle of Automotive Batteries



(⇑CO_2)
Mining resources

(⇑CO_2)
Material production

(⇑CO_2)
Battery production

Battery installation

Li *Co* *Ni*

Electrodes
Separator,
Electrolyte

Package

(Renewable electricity)

Material recycle

Vehicle drive

Module

Stationary battery unit

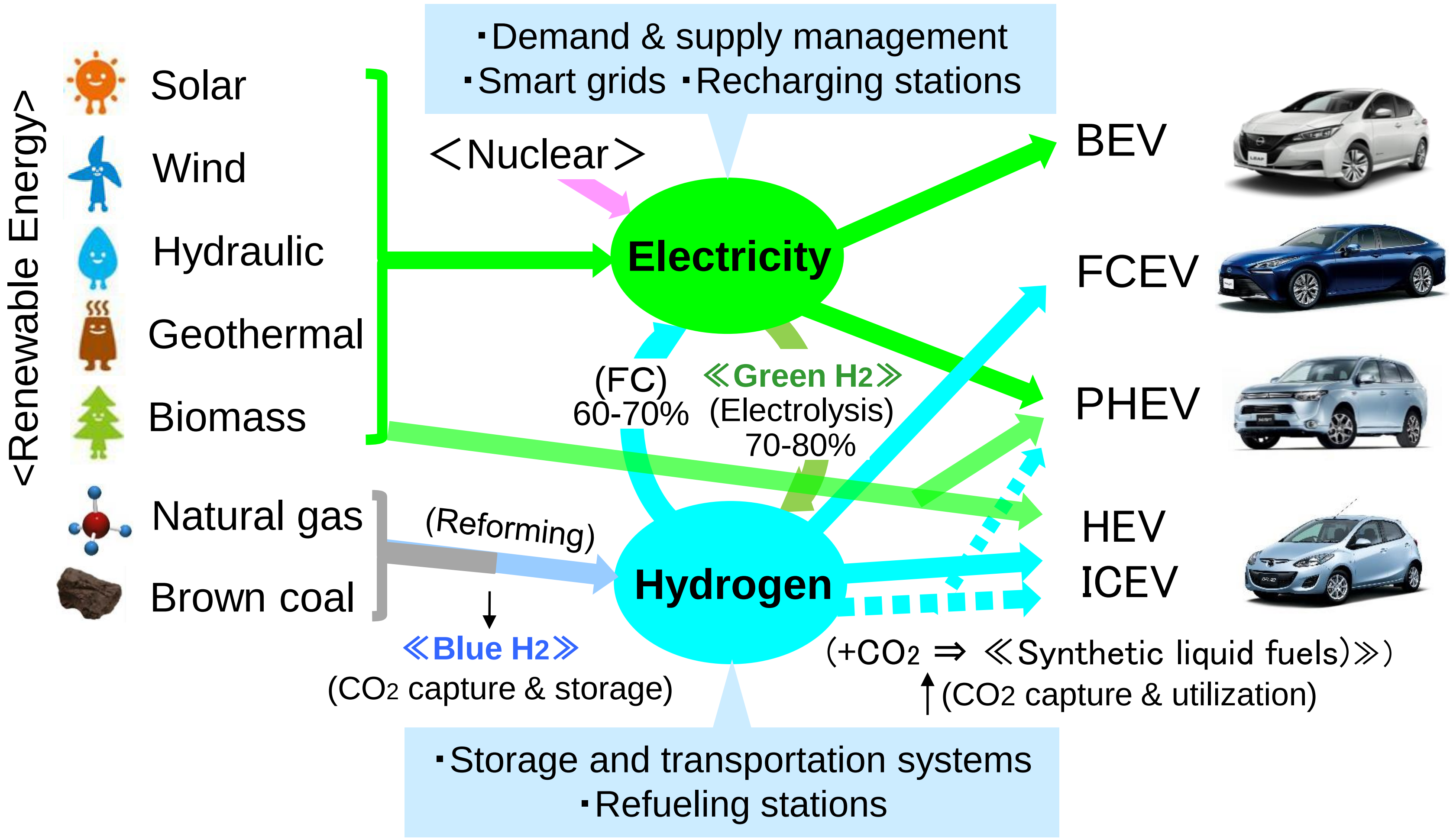
Reuse the battery

Checking the battery

Used battery collection

- The reuse and recycle of the used batteries are essential to reduce CO_2 emissions and save the raw materials. Comprehensive LCA evaluations should be conducted for these purposes.
- Reused batteries are useful to store renewable electricity.
- *Nissan* and *Sumitomo Corporation* have established a company *"4 R Energy"* to promote the reuse of used batteries and their materials recycle.

Renewable Electricity and Hydrogen for Vehicles



<Renewable Energy>

Solar

Wind

Hydraulic

Geothermal

Biomass

Natural gas

Brown coal

- Demand & supply management
- Smart grids
- Recharging stations

<Nuclear>

Electricity

(FC) 60-70%

≪Green H_2≫
(Electrolysis)
70-80%

(Reforming)

≪Blue H_2≫
(CO_2 capture & storage)

Hydrogen

(+CO_2 ⇒ ≪Synthetic liquid fuels)≫)
↑(CO_2 capture & utilization)

- Storage and transportation systems
- Refueling stations

BEV

FCEV

PHEV

HEV
ICEV

❑Large scale CO_2 free hydrogen is supposed to be introduced towards 2040.

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

Comparison of Passenger HEV, BEV and FCV in terms of Fuel and Energy Consumption

Items	HEV（P）	BEV（L）	FCEV（M）
Energy consumption（WLTC)	32.1km/L（Oil）	6.45km/kWh	152km/kg-H_2
CO_2 emission g/km	72.3	-	-
･Emission in 2019/30/50	-	68.8/57.5/31.0	141/118/64
･Renewables（0.03kg/kWh）	-	4.65	9.60
Energy costs Present/Future	150 ¥/L	25/12 ¥/kWh	1,120/224 ¥/kg
Annual fuel/energy consumption	266 L	1,324kWh	56.2kg (630Nm^3)
Annual energy consumption costs	¥39,900	¥33,100/15,900	¥62,900/12,600
･Energy for 1-10 million vehicles	0.266-2.66 GL	1,32-13,200 GWh	52.6-562 k･tons
･Electricity for 1-10 million vehicles	-	0.143-1.43%	0.295-2.95%

❏Annual average milage of passenger cars: 8,540 km/year（MLIT）

❏Annual electricity consumption: 9.278×10^5 GWh（FY2019）

❏CO_2 emission（kg/kWh）:0.444（FY2019）/0.37（FY2030）/0.20（2050）

❏Theoretical electricity for water electrolysis: 140 MJ/kg-H_2 = 38.9 kWh/kg-H_2

❏Annual FCEV's electricity consumption: 2,186 kWh (2,733 kWh for 80% efficiency)

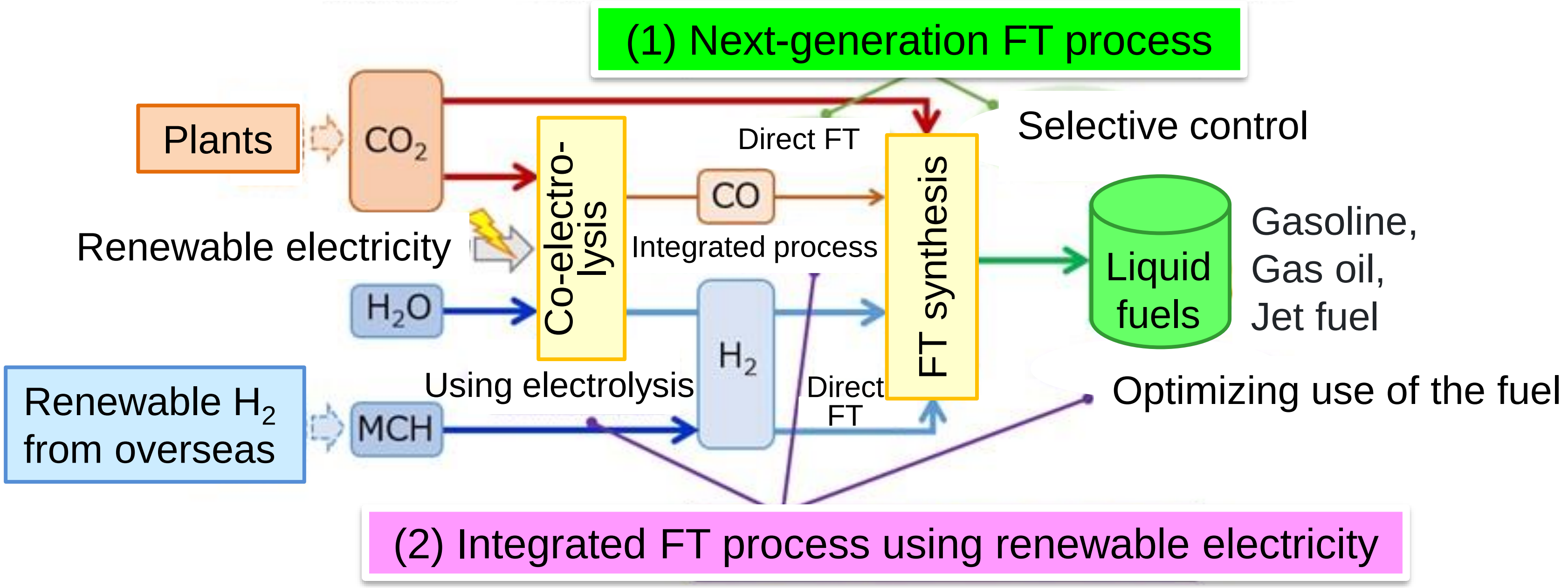
☆Large scale hydrogen procurement from overseas will be necessary.

Developing Integrated Liquid Fuel Synthesizing Processes Using Captured CO_2 (NEDO, February, 2021)

Two projects (1) and (2) have been adopted by NEDO (New Energy and Industrial Technology Development Organization). The projects include the use of captured CO_2 and renewable H_2 to produce liquid fuels by means of the Fischer-Tropsch methods. Syngas (H_2+CO) is produced using a co-electrolysis process. Detailed LCA is necessary on the entire processes. Optimizing the entire processes and proposing future large scale production processes are expected.

- Period: FY2020-2024
- Budget: 4.5 billion yen
- Participants: Seikei University, ENEOS, Nagoya University, Yokohama National University, Idemitsu, AIST and JPEC

- Sources - Syn-gas production - Fuel production - Using the fuel -



(1) Next-generation FT process

Plants

CO_2

Renewable electricity

H_2O

Renewable H_2 from overseas

MCH

Co-electro-lysis

Direct FT

CO

Integrated process

H_2

Using electrolysis

Direct FT

FT synthesis

Selective control

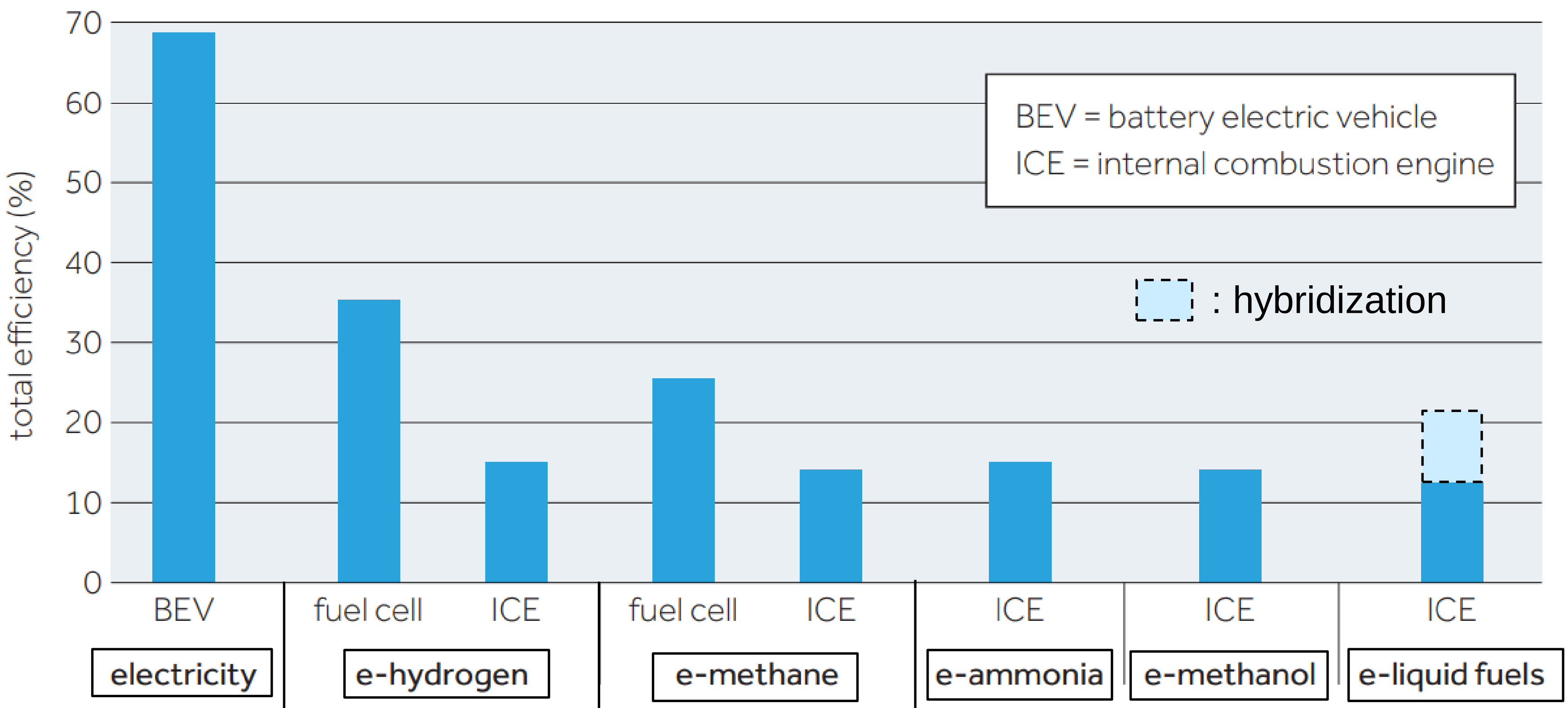
Liquid fuels

Gasoline, Gas oil, Jet fuel

Optimizing use of the fuel

(2) Integrated FT process using renewable electricity

Well-to-Wheel Efficiency Comparison of Alternative Energy and Fuels for Passenger Cars



discharging & recharging efficiency
×
power system efficiency

water electrolysis efficiency
×
Power system efficiency

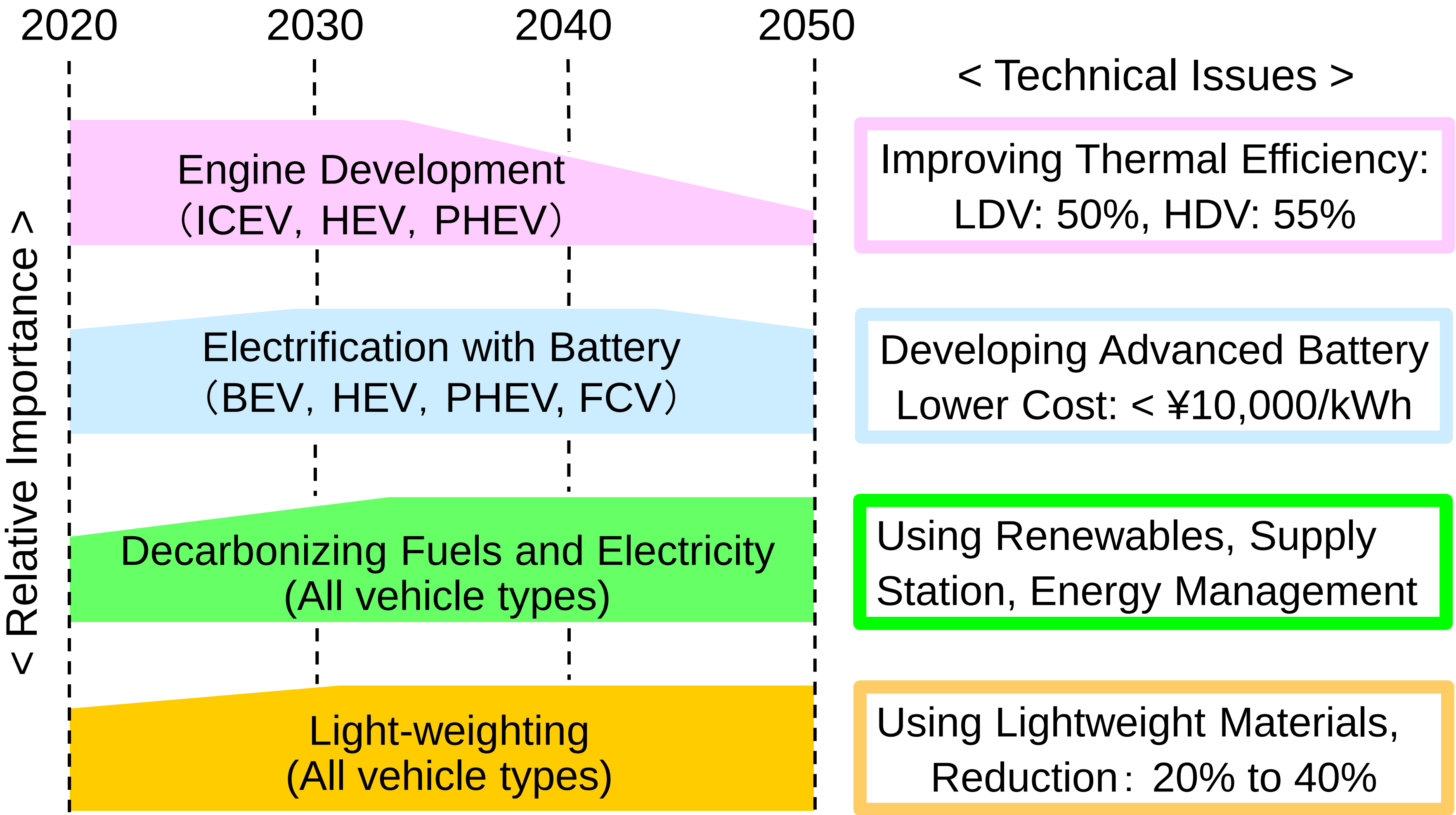
methanation efficiency
×
power system efficiency

production effiiciency
×
engine system efficiency

❏Assumption: Renewable energy is used to generate electricity and produce fuels.

（Source: Concawe Review, Vol. 28, No. 1, October 2019）

Relative Importance of Vehicle Technologies towards 2050



< Technical Issues >

Engine Development
（ICEV，HEV，PHEV）

Improving Thermal Efficiency:
LDV: 50%, HDV: 55%

Electrification with Battery
（BEV，HEV，PHEV, FCV）

Developing Advanced Battery
Lower Cost: < ¥10,000/kWh

Decarbonizing Fuels and Electricity
(All vehicle types)

Using Renewables, Supply Station, Energy Management

Light-weighting
(All vehicle types)

Using Lightweight Materials,
Reduction：20% to 40%

- Comprehensive validated numerical modeling is dispensable to develop and design all technologies shown above, taking into account their overall effects on vehicle efficiency, emissions and cost-effectiveness for their real-world usage.

Green Growth Strategy Achieving 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 payload 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 payload 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 synthesized 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.

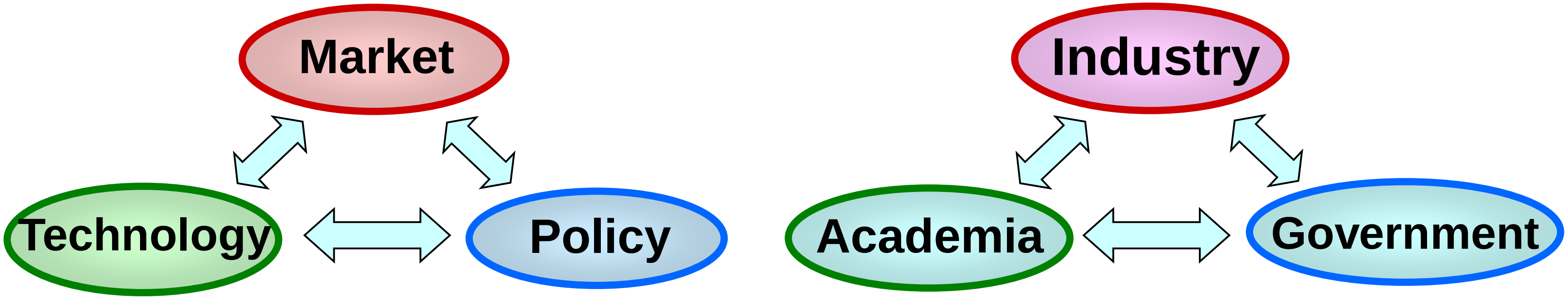
Green Innovation Fund Established to Encourage Companies to Take on Ambitious R&D Challenges by MITI

- “Green Growth Strategy through Achieving Carbon Neutrality in 2050” was announced by the Japanese government in December, 2020.
- Based on the strategy, a 2 trillion yen Green Innovation Fund 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 part of the strategy, the METI announced that eighteen research and development programs will financially be supported by the fund as shown in the table in April, 2021.
- Programs 3 and 4 have been adopted. At most 300 billion yen and 70 billion yen are supposed to be provided, respectively.

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

🟦 : related to motor vehicles

Mobility Innovations beyond 2030 and towards 2050



- Much more stringent fuel economy standards should be enforced beyond 2030. Improving engine efficiency will be significantly important for ICEVs, HEVs and PHEVs as far as oil can be used beyond 2030. The possibility of using e-fuels should be explored for these vehicles.
- To achieve carbon neutrality towards 2050, renewables are indispensable for all vehicle types, based on LCA CO_2 emission and cost effectiveness.
- It is essential to improve energy density and safety, reduce the costs and establish reuse and recycle systems for vehicular batteries.
- Power demand and supply management systems are necessary to utilize changeable renewable electricity and conduct rapid recharging for electrified vehicles.
- To disseminate FCEVs, long-term related policies, social awareness, drastic overall cost reduction and a large scale hydrogen procurement from overseas are strongly required.
- To achieve carbon neutrality in the transportation sector towards 2050, in addition to vehicle and energy technologies, drastic changes in transportation systems and the way of using the vehicle must be realized.
- In collaboration with industry, academia and government, Japan is strongly expected to contribute to motorizing countries by providing lower carbon transportation technologies and associated policy measures as a technology-oriented nation.