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Decarbonizing Motor Vehicles' Power Systems, Fuels and Energy toward 2050

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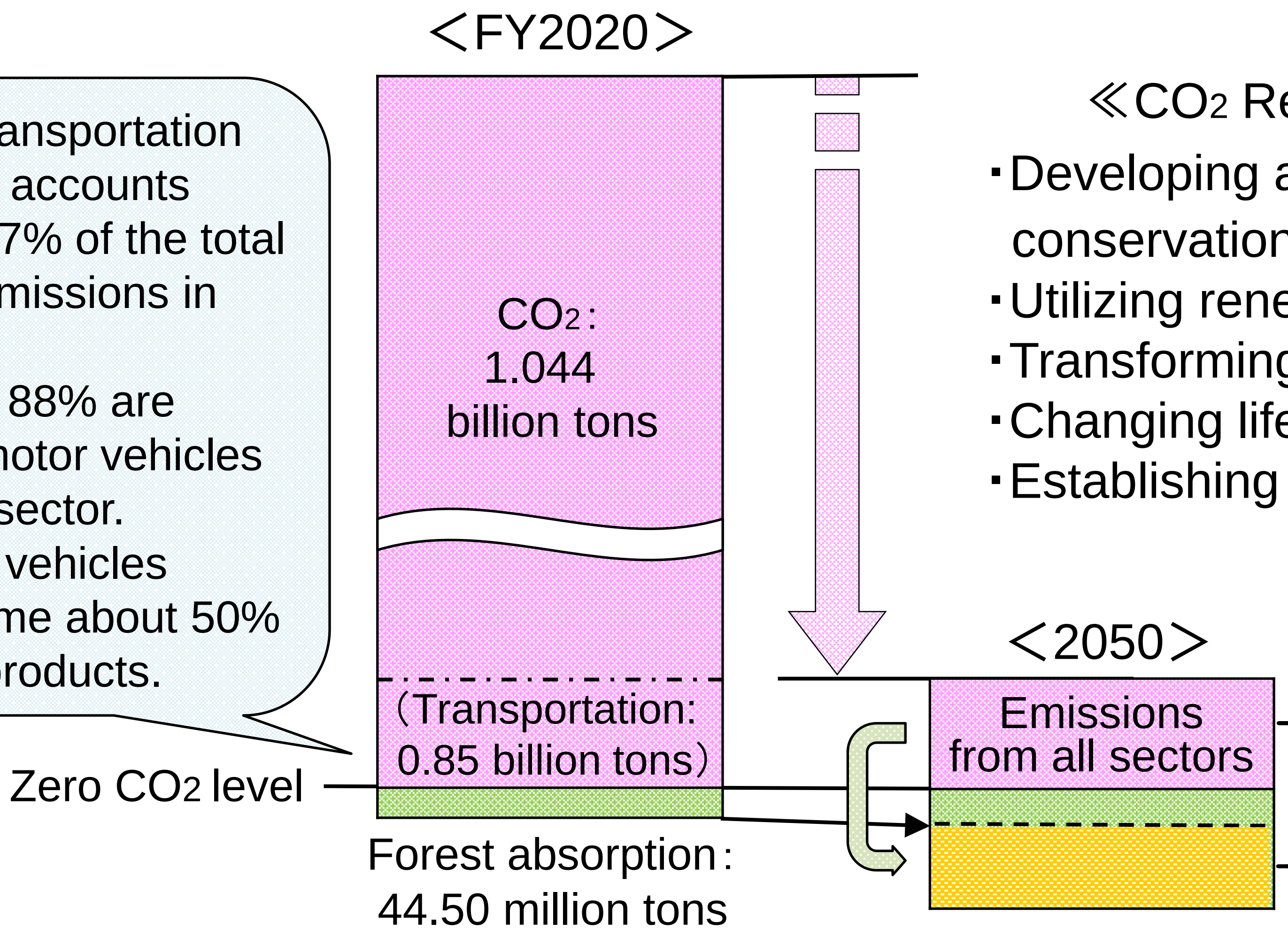
Carbon Neutrality Target in 2050 (Japan)

- ❑ 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

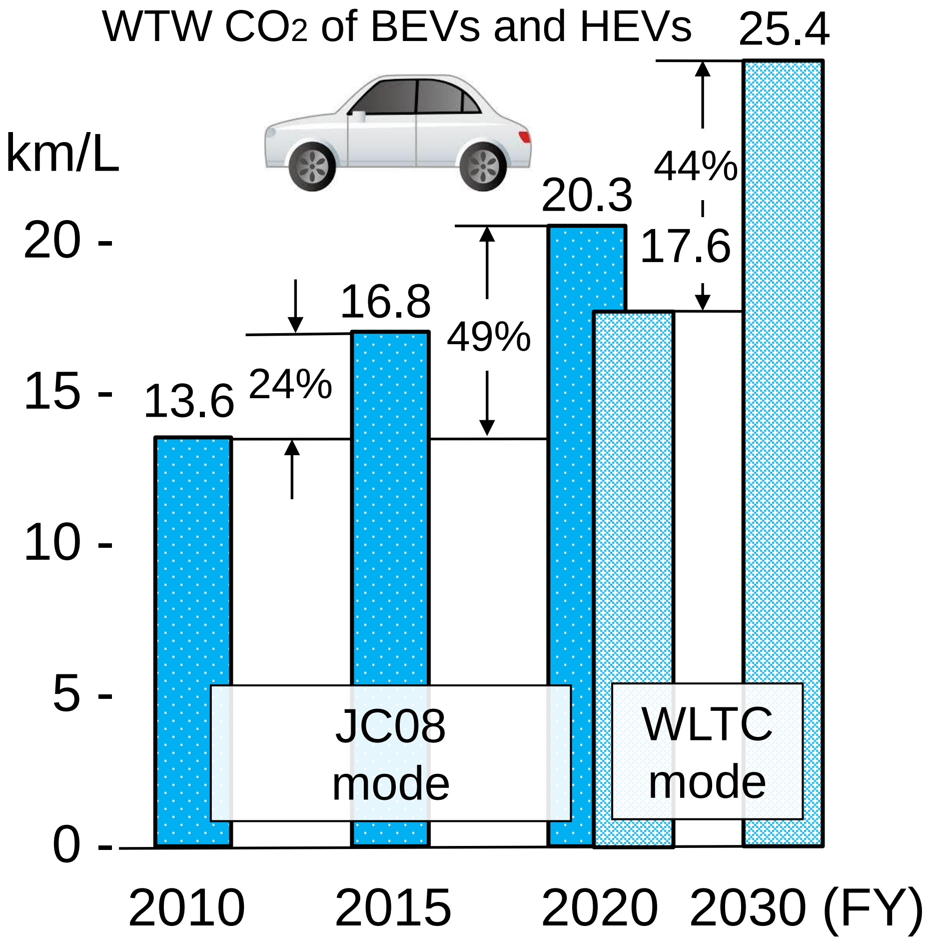
- ❑ It is significantly difficult to achieve carbon neutrality in the transportation sector.
- ❑ Negative CO_2 emissions in other sectors are indispensable to achieve the neutrality.

CO_2 Reduction Targets and Policy Trends in Electrifying Passenger Vehicles in Each Country

Country	CO_2 reduction target toward 2030 and relative year		Policy trends on passenger car electrification in each country
China	60-65%	2005 (Based on GDP)	New Energy Vehicle Mandate Policy is in effect. However, The provision of NEV subsidies ended at the end of 2022. Sales share in 2035: BEV, PHEV and FCEV=50%, HEV=50% Actively disseminating BEVs and FCEVs for trucks and buses
E U	Revised from 40% to 55% （Fit for 55）	1990	Fit for 55 to promote the European Green Deal (2019/7) The sale of engine-powered cars was to be prohibited from 2035. However, it has been decided that the sale is permissible under the condition of using synthetic fuels. (2023/4)
Japan	Revised from 26% to 46%	FY2013	The Green Growth Strategy was announced. (2020/12/25) Only new electrified vehicles can be sold after 2035 The Green Innovation (GI) fund and Green Transformation (GX) Investment policy will promote related industries to achieve CN
USA	50-52%	2005	Electrified vehicle sales: 50% from 2030, excluding HEVS. California: BEVs and FCEV sales only from 2035. Supportive acts: Infrastructure Investment and Jobs Act (2021/11) and Inflation Reduction Act (2022/8)

Fuel Economy Standard Trends in Japan（MLIT, 2019）

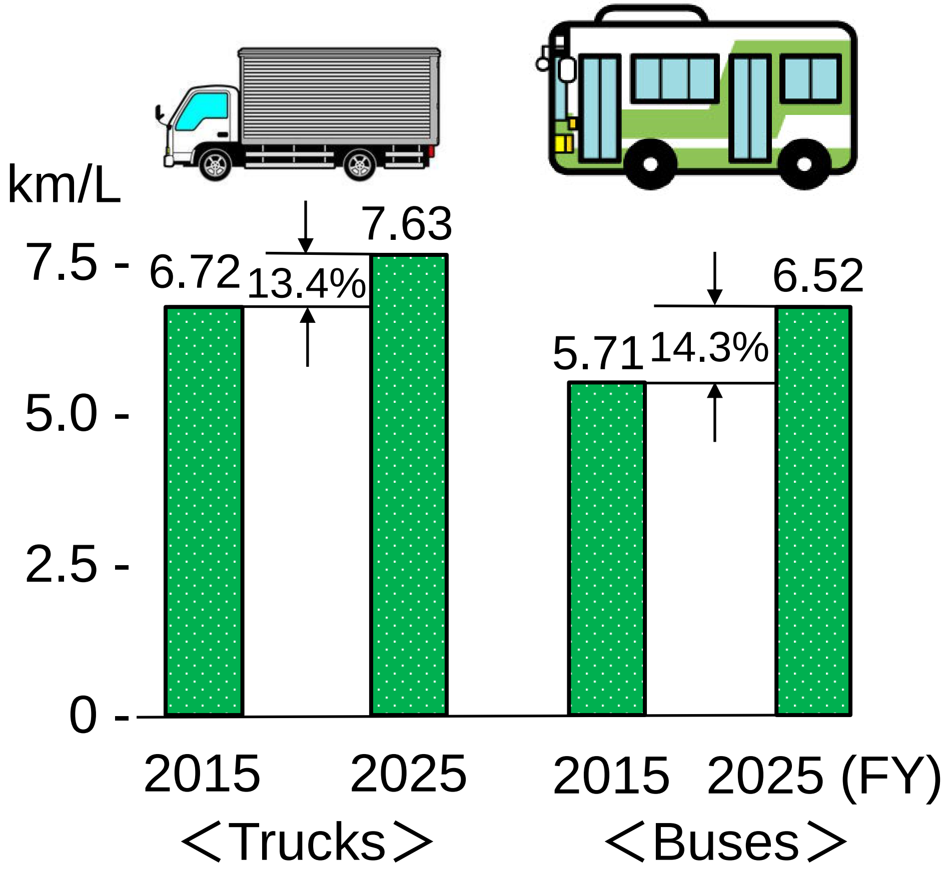
❑32.4% improvement in FY 2030 compared to FY2016 level
❑FY2030 standards consider WTW CO_2 of BEVs and HEVs



[Corporate average fuel economy]

《Passenger Cars》

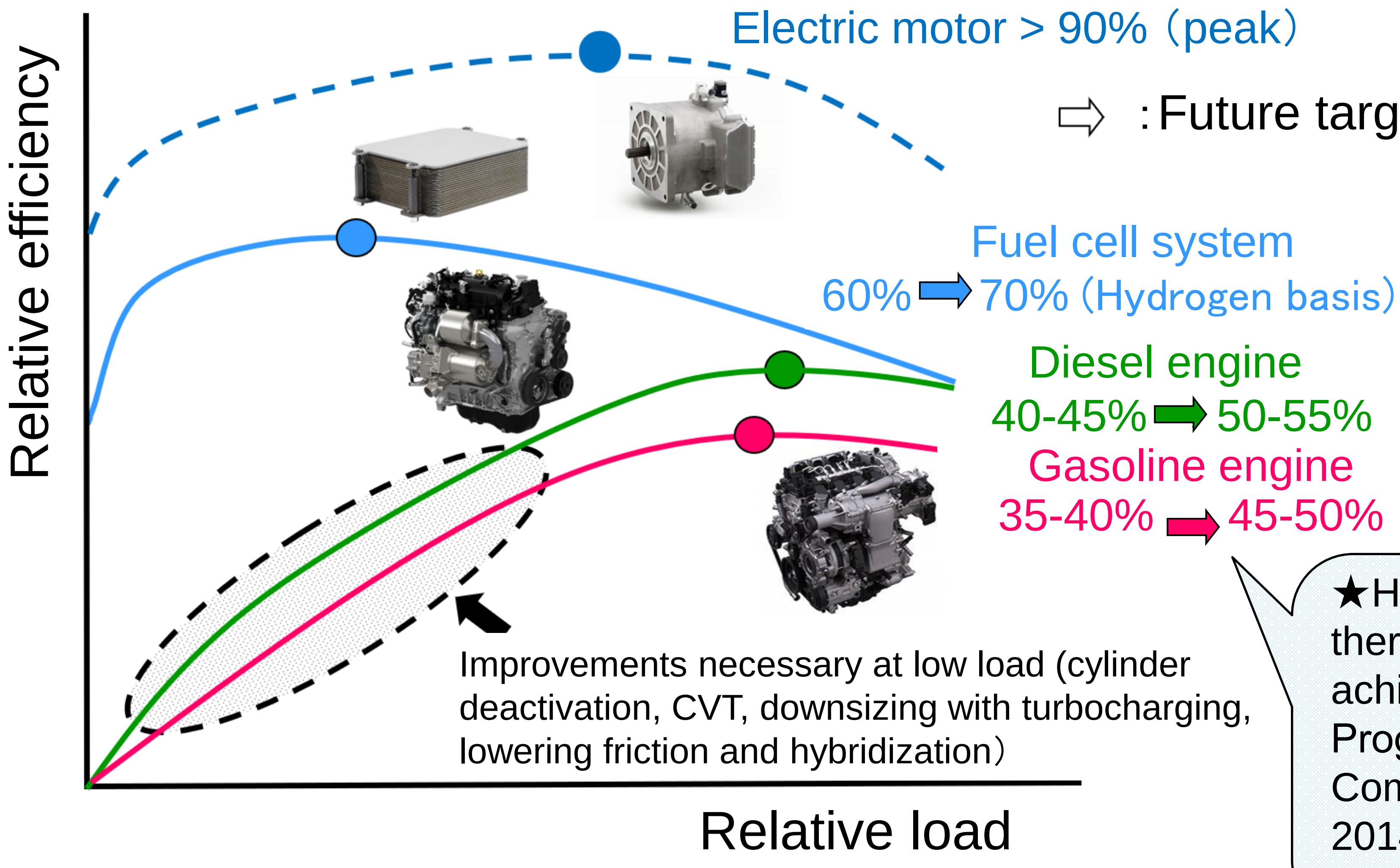
❑FY2015 standards are the world-first with 12% improvement compared to FY2002 level.
❑BEVs, PHEVs and FCVs are not included.
☆Drastic fuel economy improvement is difficult in heavy duty vehicles.



《Heavy Duty Vehicles》

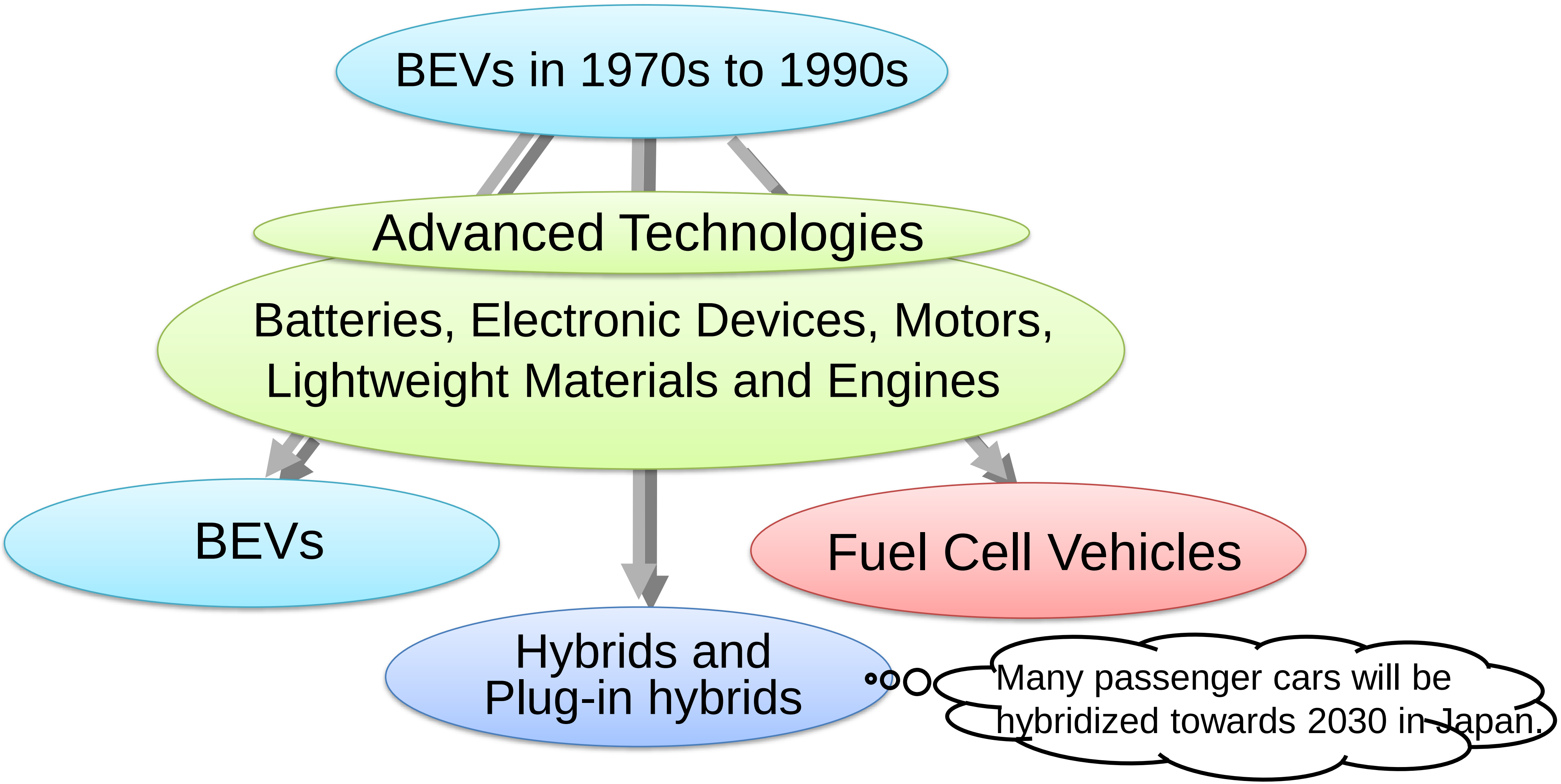
Comparison of Vehicle Power Systems in terms of Efficiency

≪Tank-to-Wheel Basis≫



★Higher than 50% brake thermal efficiency has be achieved through the SIP Program "Innovative Combustion Technologies, 2014-2018" for passenger car engines in Japan.

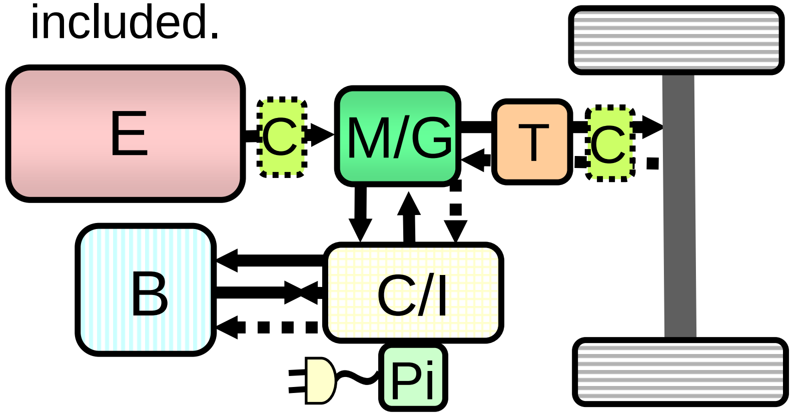
Variations of Electrified Vehicles



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.

A Variety of Hybrid Systems for Automotive Applications

ISG (integrated starter generator) systems with power assistance are included.

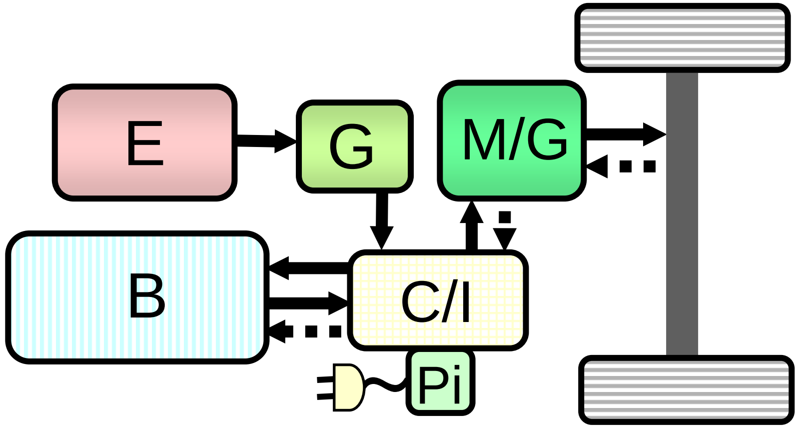


<Parallel (Mild)>【15-50%】

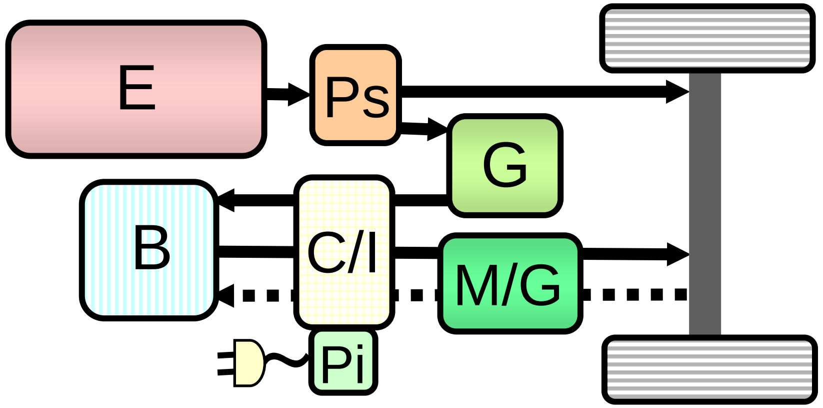
<Hybrid type>
【Improved fuel economy, %】

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

Fuel cell systems are included.



<Series（Full）> 【50-100%】

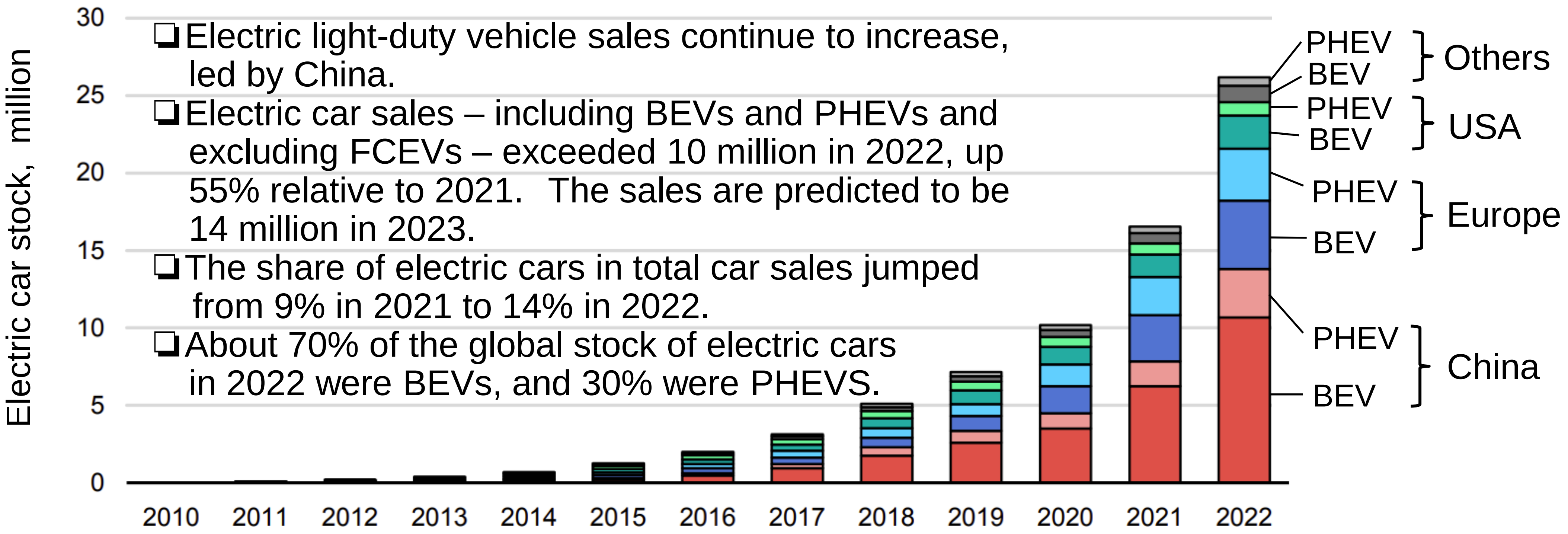


<Series/Parallel (Full)>【50-100%】

Global Electric Car Stock in Selected Regions, 2010-2022

Source: Global EV Outlook 2023, IEA

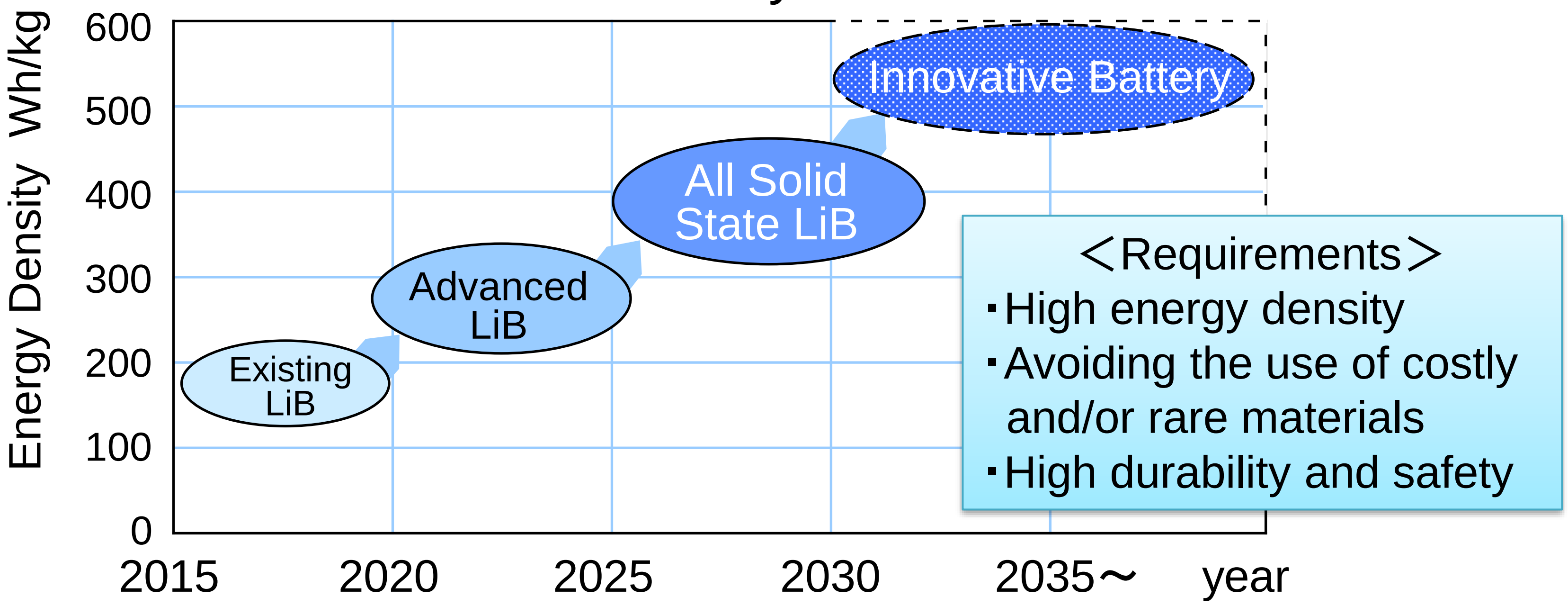
- ❑Electric light-duty vehicle sales continue to increase, led by China.
- ❑Electric car sales – including BEVs and PHEVs and excluding FCEVs – exceeded 10 million in 2022, up 55% relative to 2021. The sales are predicted to be 14 million in 2023.
- ❑The share of electric cars in total car sales jumped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

Targets of Developing Battery Cells and Packages for PHEVs and BEVs

≪Battery Cells≫



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

≪Battery Packages≫

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

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

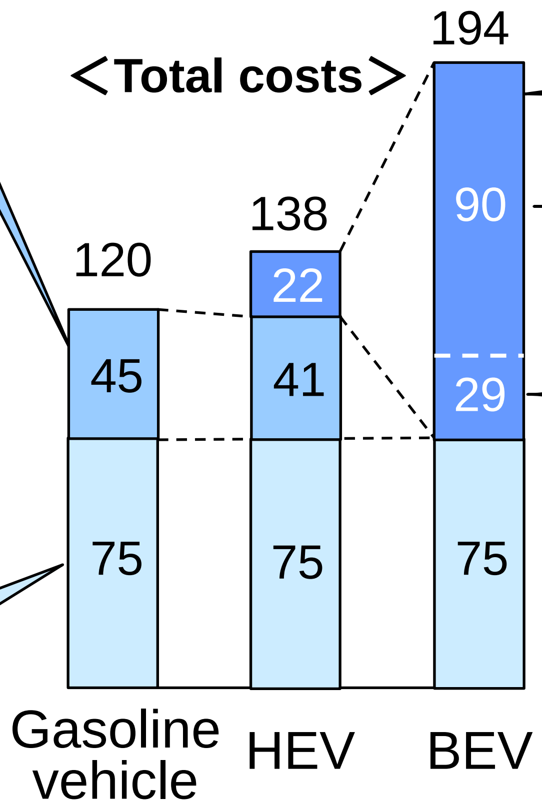
Cost Comparison of C-Segment Gasoline Vehicle, HEV and BEV

(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, DC-DC converter and recharger	12
High voltage harness	3
Reduction gear	2
Cooling/AC	7

- ❏The sales price of the gasoline vehicle: ¥2,000,000
- ❏Costs don't include management, development and related depreciation.
- ❏Battery unit cost was estimated referring to domestic market price. (There is an example of $100/kWh in the overseas market.)

Issues on Recharging BEVs and PHEVs

❑CHAdeMO Association (Japan)

・The association provides a global standard on rapid DC recharging BEVs and PHEVs.

・The power ranges from 10 kW to 50kW (125A/500V).

・Recharging power is increased to shorten recharging time as follows.

150-200 kW, 400 A/500 V in 2017

350-400 kW, 350-400 A/1,000 V in 2020

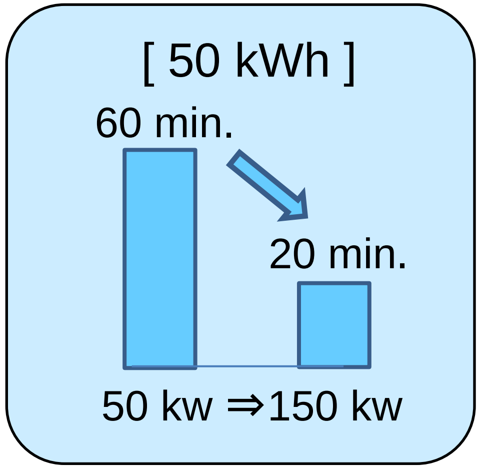
・Higher power demand and supply management systems are necessary especially for trucks and buses.

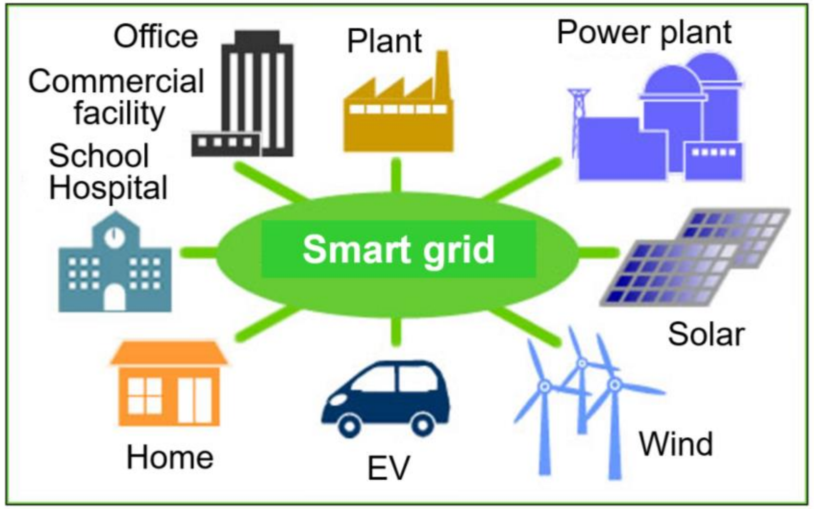
❑The battery unit can be utilized to store and supply electricity through its outlet.

(V2X; X= Home, Grid or Building)

❑The Japanese government is planning to locate 30,000 rapid recharging stations by 2030.

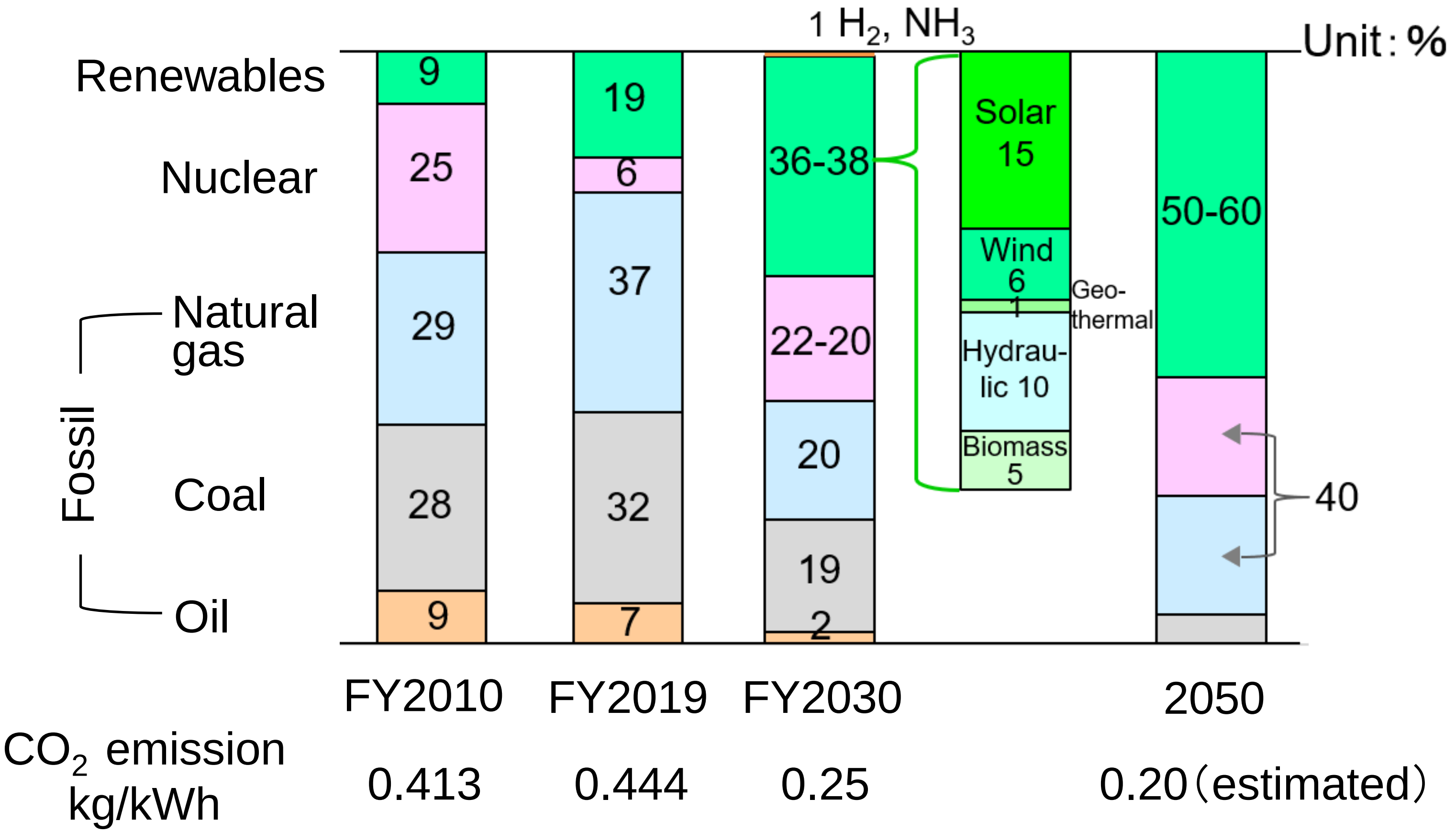
<Shortening recharging time>





SHIZUKI ELECTRIC CO.

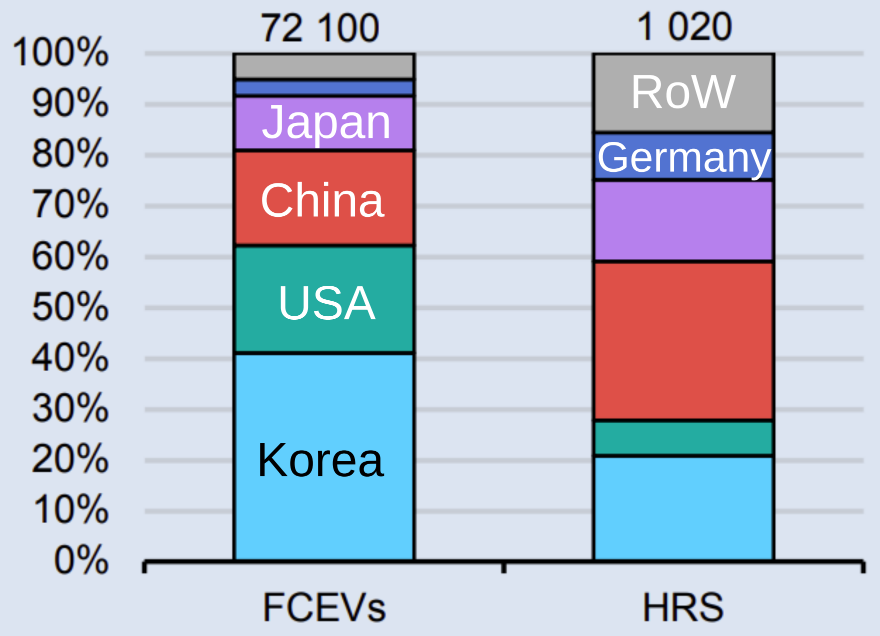
Planned Electricity Generation by Source (METI, Japan, 2020)



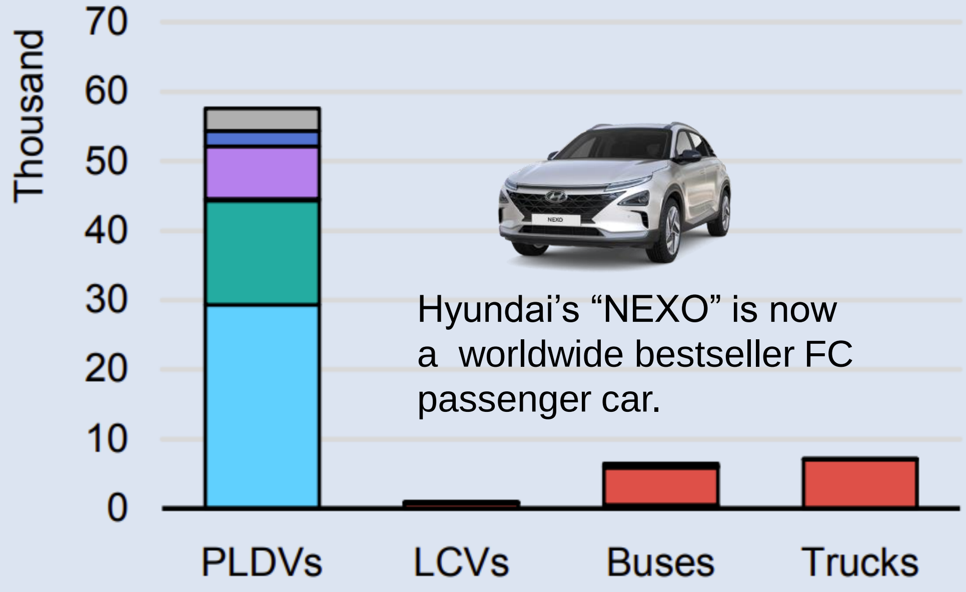
- ❑The 6th basic energy plan for FY2030 by METI is shown in the figure.
- ❑Electricity demand was 1,024 billion kWh in FY2019 and is projected to be 934 billon kWh in FY2030, resulting in 9% reduction.
- ❑Demand and supply management systems are necessary to recharge BEVs and PHEVs by using more amount of renewable electricity.

FCEV and Hydrogen Refueling Station Stock by Region, 2022

Share of FCEV and HRS stock by region



FCEV stock by region and mode



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.

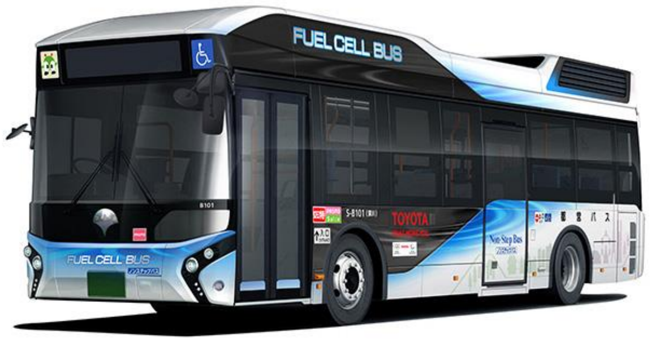
Source: Global EV Outlook 2023, IEA

Toyota’s Strategy for Disseminating FCVs

“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” intraduced in Tokyo, in
2017, Feb., using two Mirai’s FC stacks,
Drive range: about 200 km

Heavy-duty FC truck based on Hino XL
series for the US market, using Mirai’s
stacks. The road test began in 2021.

- ❑ Major FC components are communized for a variety of FCVs.
- ❑ It is necessary for other automakers are expected to launch their own FCVs or to collaborate with the FCV 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 target supply is 3.0 million tons/y by 2030 and 20 million tons/year 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 FCVs 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	≪

Comparison of Electrified Vehicle Types

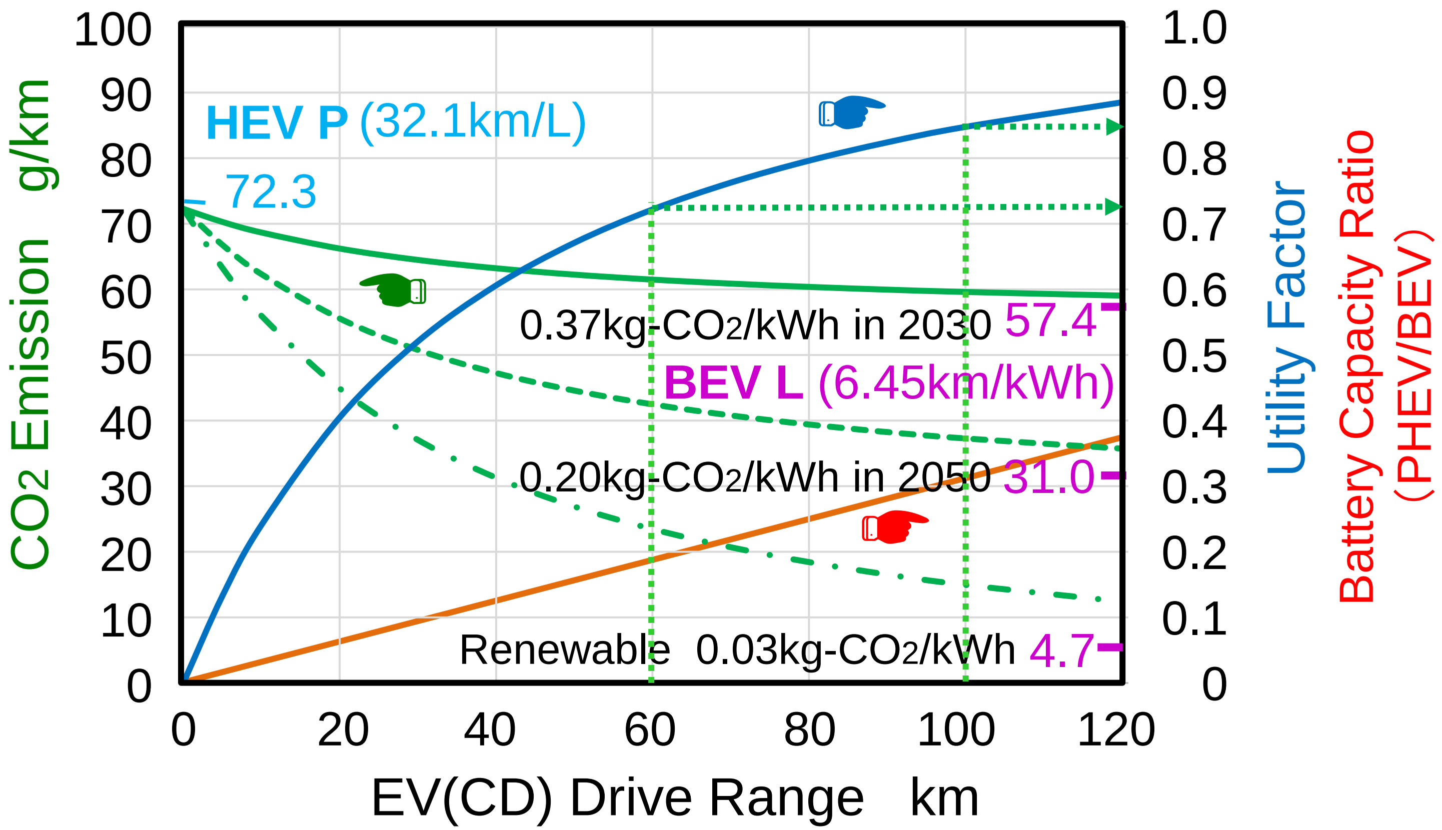
Based on the data released by automakers

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*
FCEV	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 CO_2 Emission Characteristics of HEV, PHEV and BEV



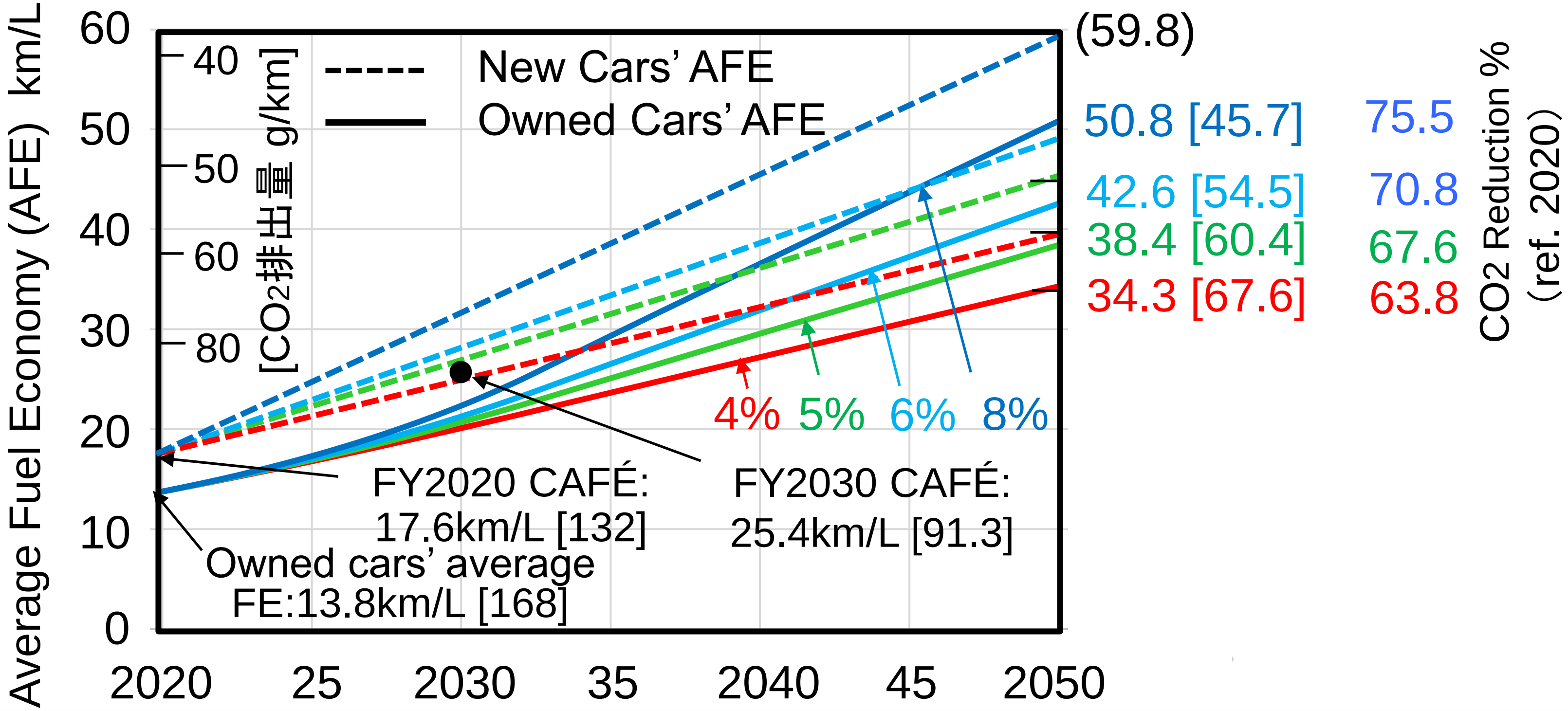
❑Assumptions:

- 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.

Major Technologies to Improve Fuel Economy and Reducing 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 electiricity)	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)

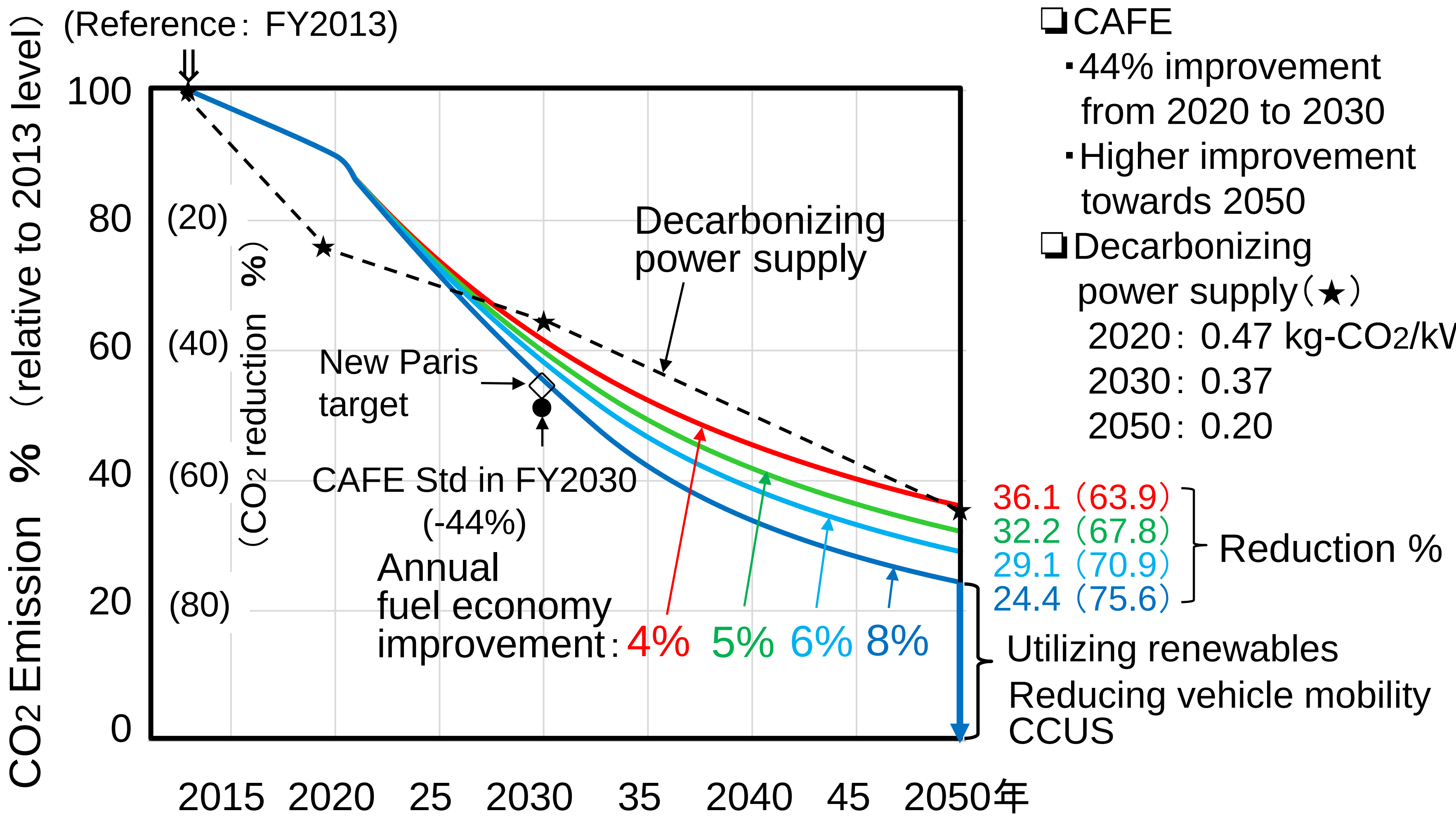


<Assumptions>

- 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 extra-polated 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 CO_2 Reduction



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

❑Decarbonizing power supply（★）
- 2020：0.47 kg-CO_2/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 policies.

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

Item	HEV（P）	BEV（L）	FCEV（M）
Fuel / energy economy（WLTC）	32.1km/L（Gasoline） 3.47 km/kWh	6.45 km/kWh	152 km/kg-H_2 4.52 km/kWh
CO_2 emission g/km	72.3	-	-
・Emission in 2019 / 2030 / 2050	-	68.8 / 38.8 / 31.0	141 / 118 / 64
・Renewables（0.03kg/kWh）	-	4.65	9.60
Energy costs Present/Future	¥200 /L	¥35 / 12 /kWh	¥1,120 / 224 /kg
Annual fuel/energy consumption	266 L	1,324 kWh	56.2 kg (630Nm^3)
Annual energy consumption costs	¥53,200	¥ 46,340～15,900	¥ 62,900～12,600
・Energy for 1～10 million vehicles	0.266～2.66 GL	1,324～13,240 GWh	56.2～562 ktons
・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 total electricity consumption in Japan: 9.278×10^5 GWh（FY2019）

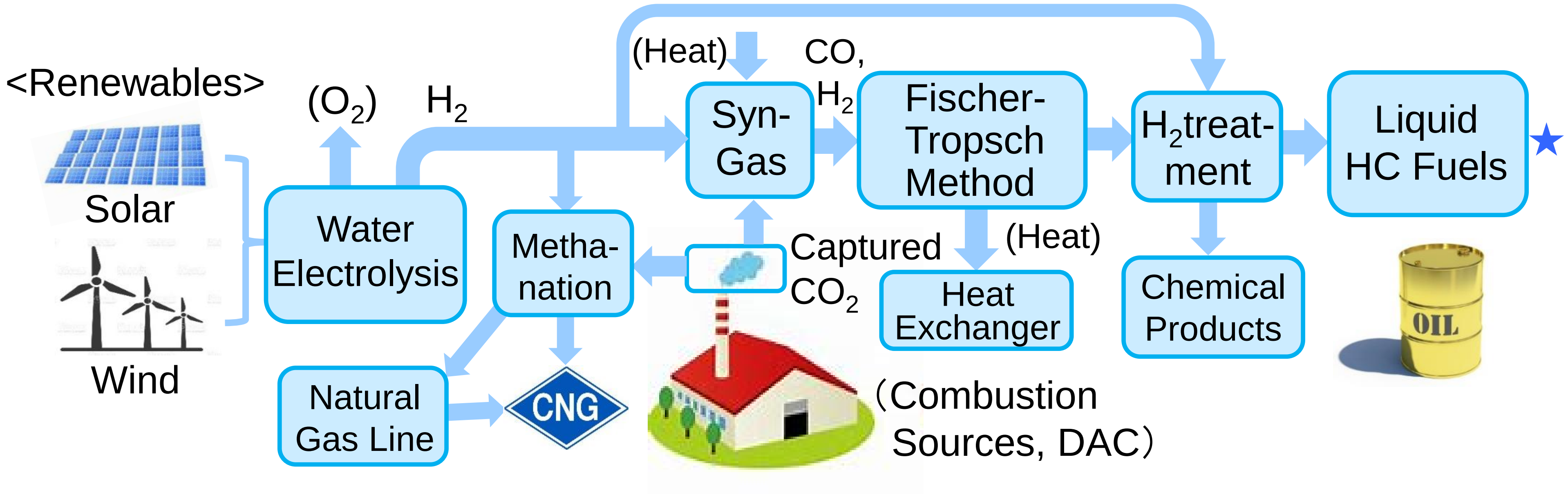
❏CO_2 emission（kg/kWh）from powerplants: 0.444（FY2019）/0.25（FY2030）/0.20（2050）

❏Theoretical electricity necessary 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.

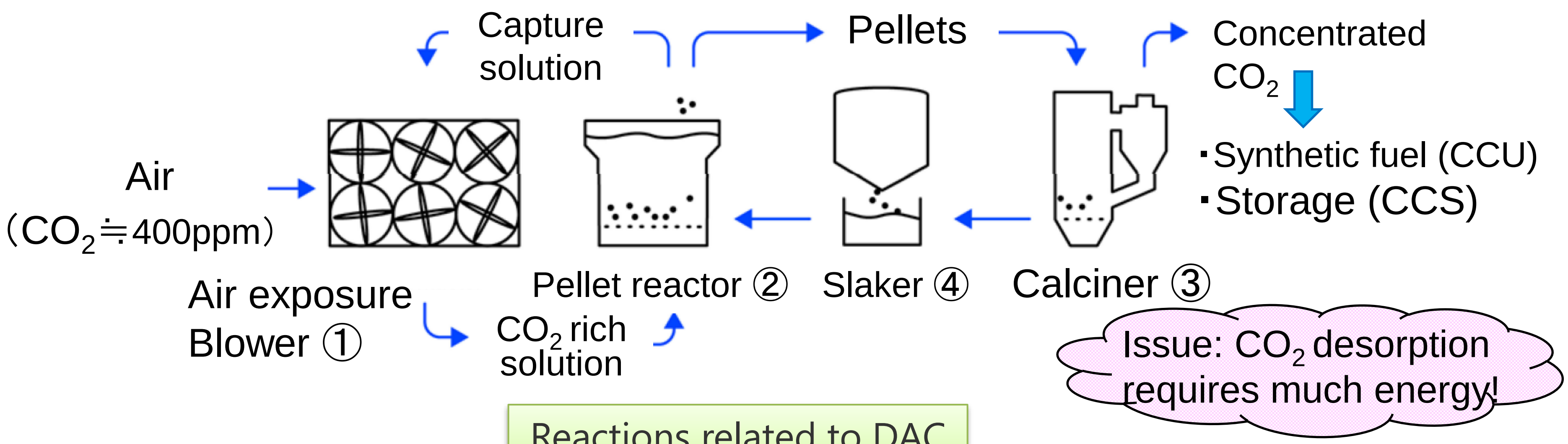
Developing Synthetic Low Carbon Fuels for ICE Vehicles



- ❑A synthetic fuels or "e-fuels" might reduce CO_2 emitted from ICE vehicles as well as HEVs and PHEVs. ★ : The Green Innovation Fund provided to ENEOS, in 2022-2028
- ❑It can be mixed with the conventional fuels as "Drop-in Fuel" for the introductory stage.
- ❑It will be significantly advantageous that the existing oil delivery systems and stations can be utilized.
- ❑Quantitative LCA is necessary to evaluate its production efficiency and cost effective-ness relative to other low carbon fuels and energy.
- ❑The methanation reactions can yield methane called "e-gas" from CO_2 and H_2 for compressed natural gas vehicles.

A New Method of Direct Air Capture

≪A DAC Method proposed by Carbon Engineering (Canada)≫



Reactions related to DAC

① $CO_2 + 2KOH(aq) \rightarrow K_2CO_3(aq) + H_2O(l)$ ΔH=-105.2 kJ/mol

② $K_2CO_3 + Ca(OH)_2(aq) \rightarrow CaCO_3 + 2KOH$ ΔH= -2.5 kJ/mol

③ $CaCO_3 \rightarrow CaO + CO_2$ ΔH=-183.5 kJ/mol

④ $CaO + H_2O \rightarrow Ca(OH)_2$ ΔH= -80.4 kJ/mol

Companies dealing with DAC

・Climeworks (Switzerland) ・Antecy, Skytree (Hollands) ・Hydrocel (Finland)

・Global thermostat, Infinitree, CarbonCapture, Occidental, 1PointFive (USA)

・IHI, Kawasaki Heavy Industry, Mitsubishi Heavy Industry (Japan)

Source: Direct Air Capture - A key technology for net zero, IEA, 2020

Efficiency of Synthesizing Fuels by the Fischer-Tropsch Method

❑Overall Reaction in the Fischer-Tropsch Method（Exothermic）

$$mCO_2 + nH_2 \rightarrow C_mH_{2(n-2m)} + 2mH_2O$$

❑Assuming producing 1 kmol of Octane

$$8CO_2 + 25H_2 \rightarrow C_8H_{18} + 16H_2O$$

❑Theoretical H_2 production efficiency

- Energy required to capture CO_2 through DAC: Q_d = 1,468MJ
- Lower heating value of H_2: Q_h = 6,050MJ ▪LHV of Octane: Q_i = 5,016MJ
- Production efficiency
  - ✓Efficiency (1)：Q_i/Q_h = 83%, excluding energy for DAC
  - ✓Efficiency (2)：$Q_i/(Q_d+Q_h)$ = 66.7%, including energy for DAC

❑Examples of R&D projects on synthesizing fuels:

▪Audi, WESTKUSTE and SunFire, etc (Germany), Siemens and Porsche (Germany and Peru (Haru Oni)) ▪Repsol (Spain) ▪Topal (France) ▪ENEOS (GI Fund, Japan) ▪Norsk e-fuel, Nordic Blue Crude (Norway) ▪Infinium, etc. (California, USA) ▪Haldor Topsoe (Denmark) ▪Oxford Univ. (UK) ▪Carbon Engineering (Canada)

❑Challenges include improving overall fuel production efficiency, scaling up mass production, significantly reducing costs and controlling fuel properties for conventional engines.

Source: The Interim Report of the Research Committee on Synthetic Fuels, METI, April, 2021

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.

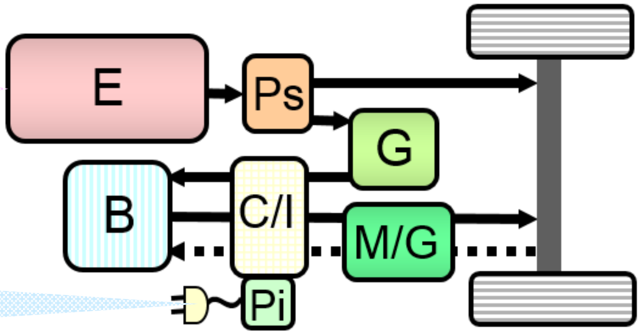
＜Issue＞ A significant reduction in H_2 cost even lower than ¥20/Nm³ must be achieved to commercialize synthetic fuels around 2040 by procuring massive amounts of H_2 and CO_2 from overseas. Synthetic fuels could mitigate the sharp demand for recharging the vhicles

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

- ❑Low-carbon fuels are indispensable for engine-powered vehicles including gasoline and diesel engine vehicles, 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

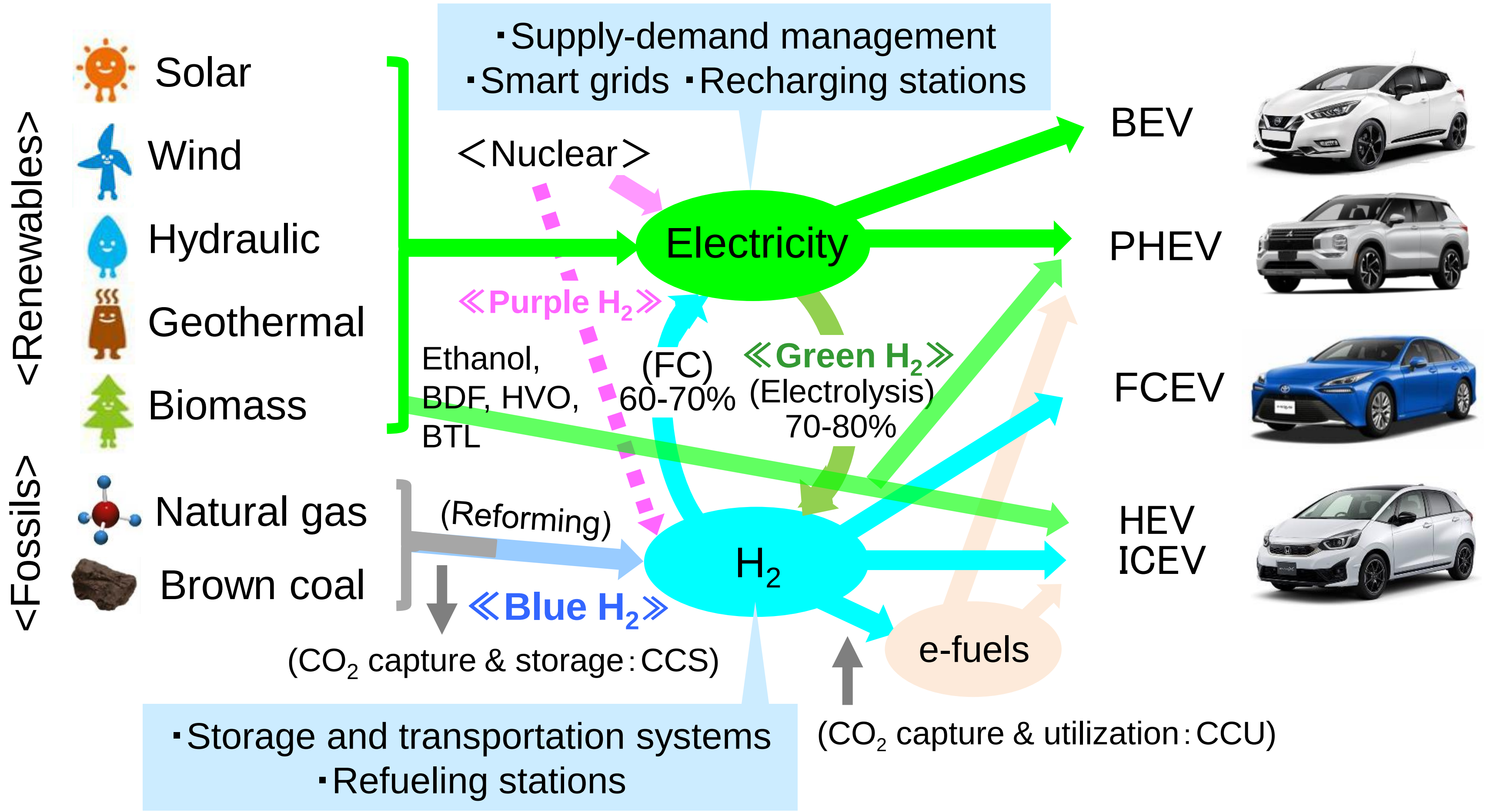
≪Low-carbon Electricity≫
Renewables, Nuclear



High efficiency PHEV

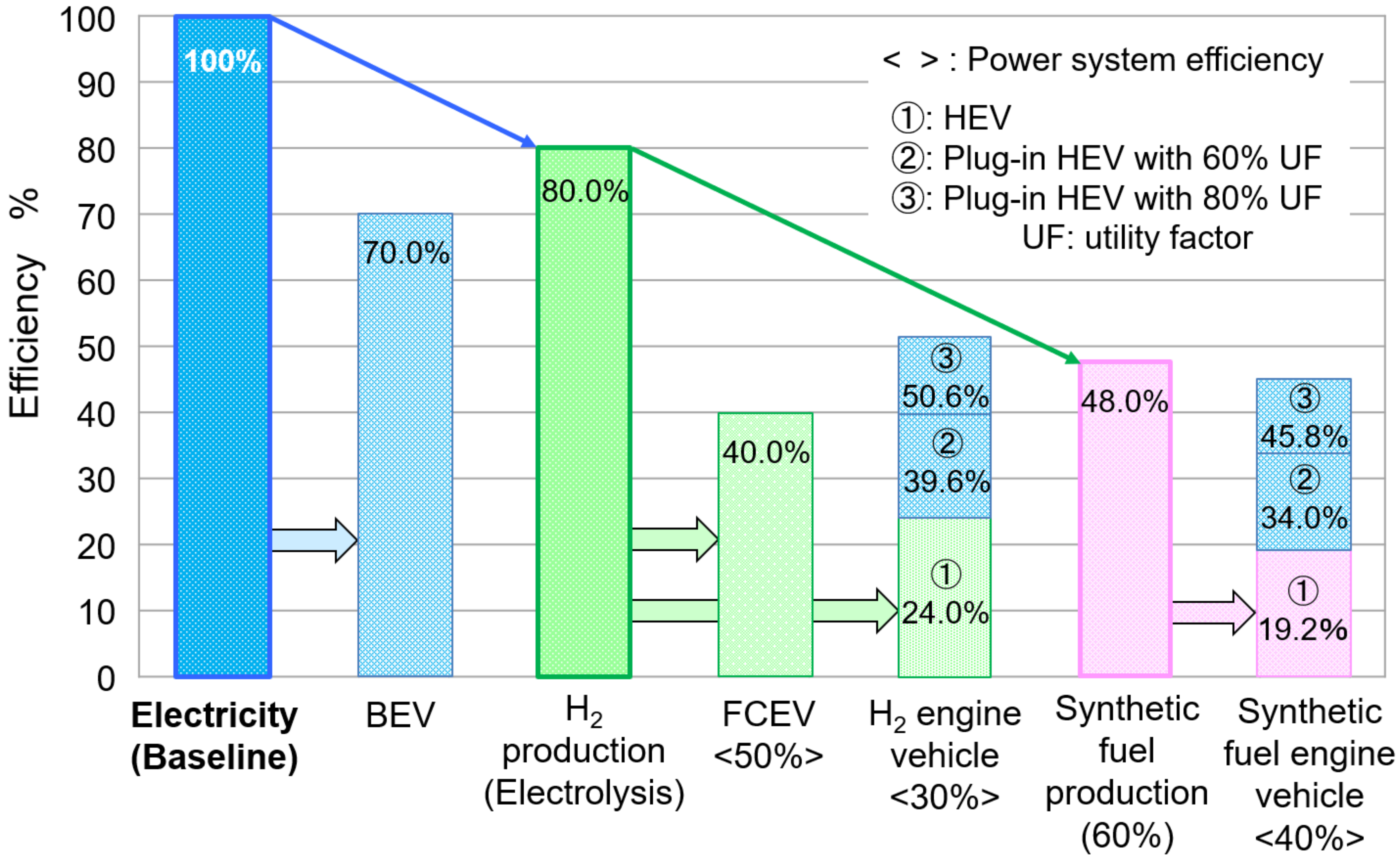
M: Motor G: Generator
C/I: Controller / Inverter
B: Battery unit
T: Transmission C：Clutch
Ps: Power splitter
Pi: Plug-in
→ : Drive / Power generation
←···· : Regeneration

Renewable Electricity and Hydrogen for Vehicles



- ❑ Large scale CO2 free hydrogen is supposed to be introduced towards 2040.
- ❑ Total LCA should be conducted including electricity and hydrogen in terms of production, transportation, storage and consumption.

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)

Future Alternative Fuel Candidates for Heavy-duty Vehicles

Fuel type		Power	CO_2 re-duction	Cost vehicle/ fuel	Range	Sustain-ability	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 fuel		□	○	□/▲	□	○	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

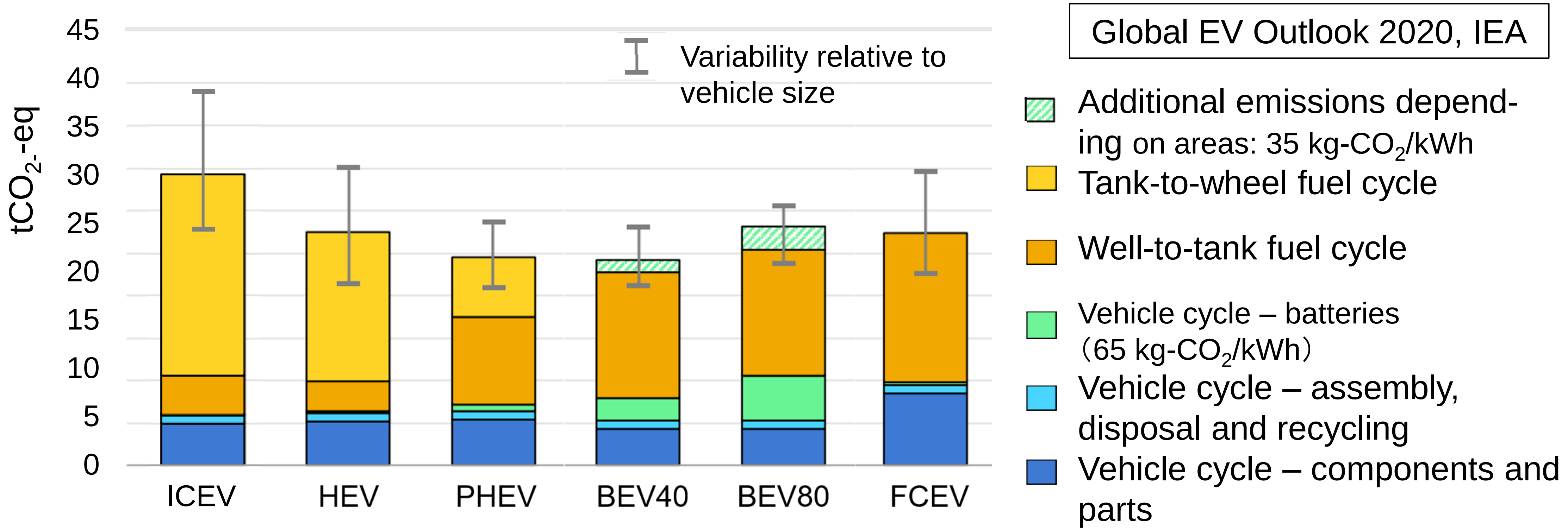
- Renewable resources should be used to produce energy and fuels based on LCA.
- Production efficiency should be high.
- Sufficient supplied amount and convenience should be realized at reasonable costs.

Electrifying Trucks and Related Issues

Type / Range	HEV	BEV	FCEV
Short（LD） <100-200km	○ ・Improved by 20-30% ・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 per-formance and durability ・Increase H2 stations ・Increase vehicle types ・Commonize FC parts ・Decarbonize H_2 ・Secure H_2 supply chain

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

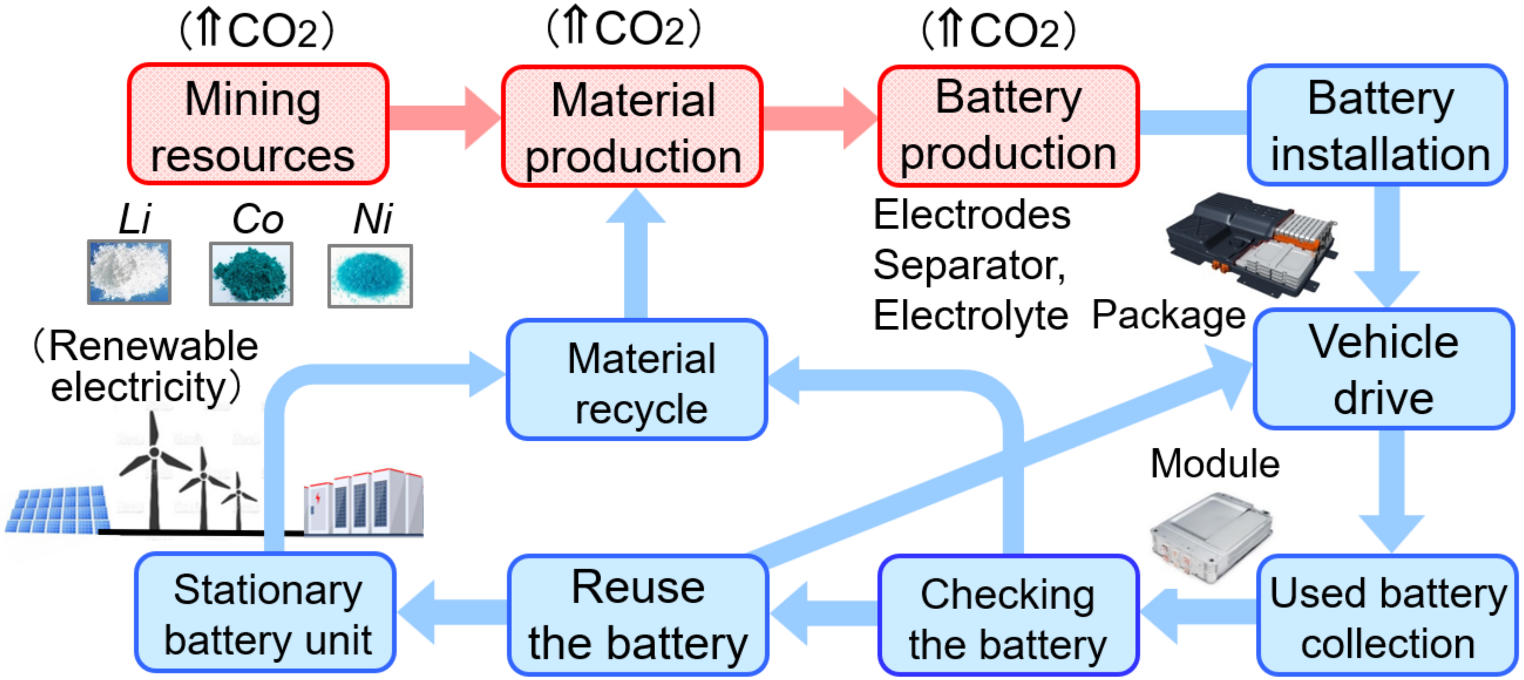
Comparative Life-cycle GHG Emissions of an Average Midsize Car by Powertrain



＜Assumptions＞
- ❏Accumulated milage: 150,000 km
- ❏A BEV with a 40 kWh or a 80 kWh battery
- ❏Electricity CO2 emission based on the global average
- ❏A PHEV with 60% on electricity and 40% on gasoline
- ❏An FCEV with hydrogen from steam reforming of natural gas

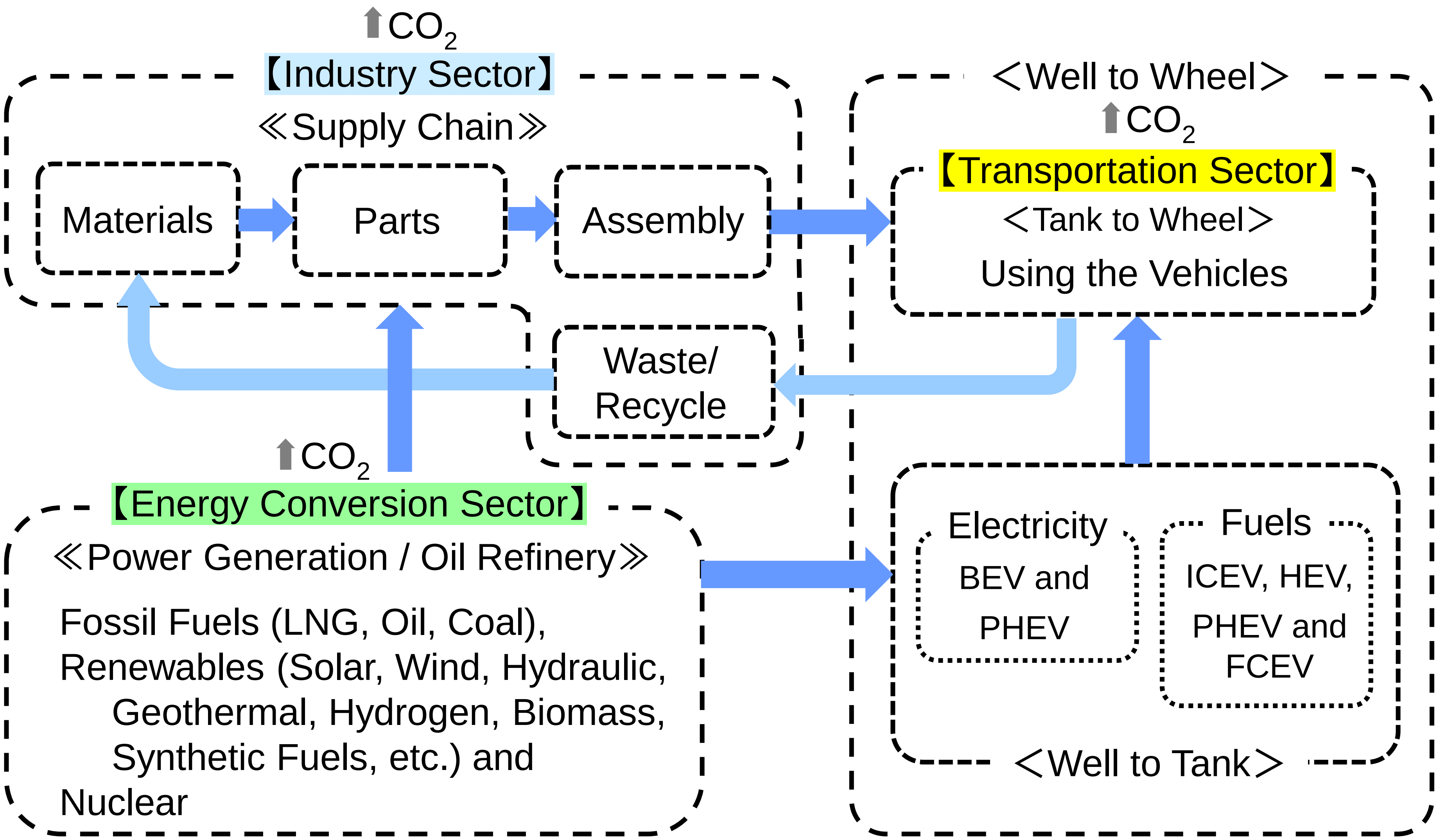
＜Issues＞
- ❏Vehicle CO_2 emissions should be based on TTW ⇒ WTW ⇒ LCA.
- ❏Decarbonized electricity is necessary to reduce CO2 emissions in manufacturing all vehicle types and in driving PHEVs and BEVs.
- ❏Decarbonized components and hydrogen are essential for an FCEV.

Reuse and Recycle of Automotive Batteries



- ❑The reuse and recycle of the used batteries are essential to reduce CO_2 emissions and save the raw materials. Comprehensive LCA should be conducted for these processes.
- ❑Reused batteries are useful to store renewable electricity for stationary purposes.
- ❑Nissan and Sumitomo Trading established a company “4 R Energy” in 2010 to promote the reuse of used batteries.
- ❑The EU is supposed to apply “the Carbon Border Adjustment Mechanism” on the battery to be used in the EU areas.

Life Cycle Analysis on Vehicle CO_2 Emissions



❑The LCA methodology must be internationally harmonized to determine CO_2 emissions not only from the transportation sector but also from other related sectors.

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

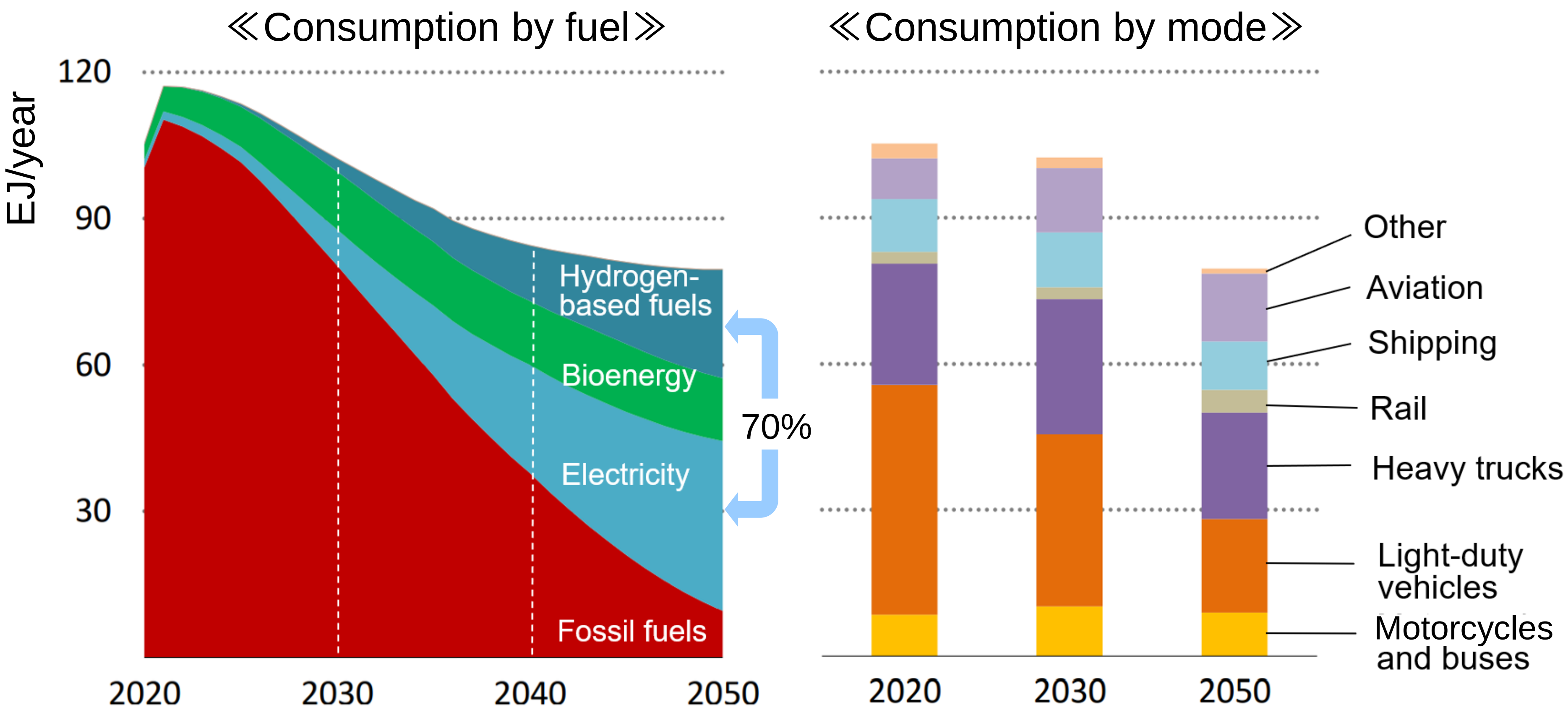
- "Green Growth Strategy through Achieving Carbon Neutrality in 2050" was announced by the Japanese government in December, 2020.
- Based on the strategy, Green Innovation Fund up to 2 trillion yen has been established to encourage Japanese companies to tackle ambitious challenges including the development of advanced technologies for the next ten years to eventually achieve carbon neutrality.
- As 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

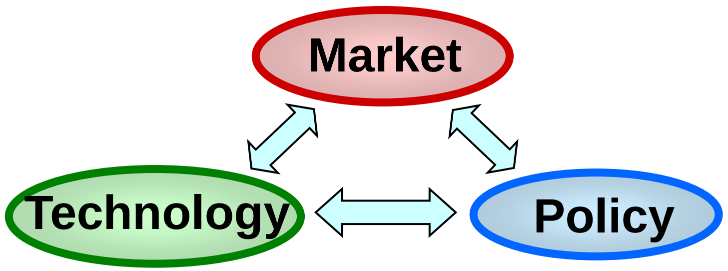
Global Transport Final Consumption by Fuel Type and Mode

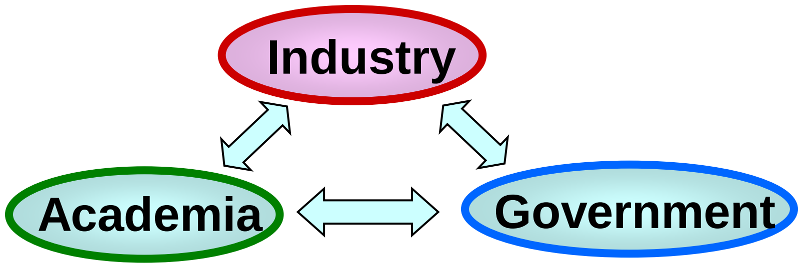
"Net Zero Emissions by 2050" Scenario, IEA, October, 2021



☆Electricity and hydrogen-based fuels should account for more than 70% of the global transport energy demand to reach the net zero emissions by 2050 and limit the rise in global temperatures to 1.5ºC.

Mobility Innovations beyond 2030 and toward 2050





- The shift from ICEVs to electric vehicles, especially BEVs, is the most influential trend toward carbon neutrality. In order to promote this, it is necessary to improve battery performance, reduce costs, secure a supply chain from related materials to parts.
- In addition, there should be various combinations of vehicle power systems and the fuels and energy, depending on the vehicle type, costs and convenience. In the next two decades, 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.
- It is essential to properly estimate CO2 emissions and cost-effectiveness by internationally harmonized LCA on each vehicle, which includes vehicle manufacturing, running, disposal/recycling, power generation and fuel production.
- 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 emerging and motorizing economies in the transportation areas.