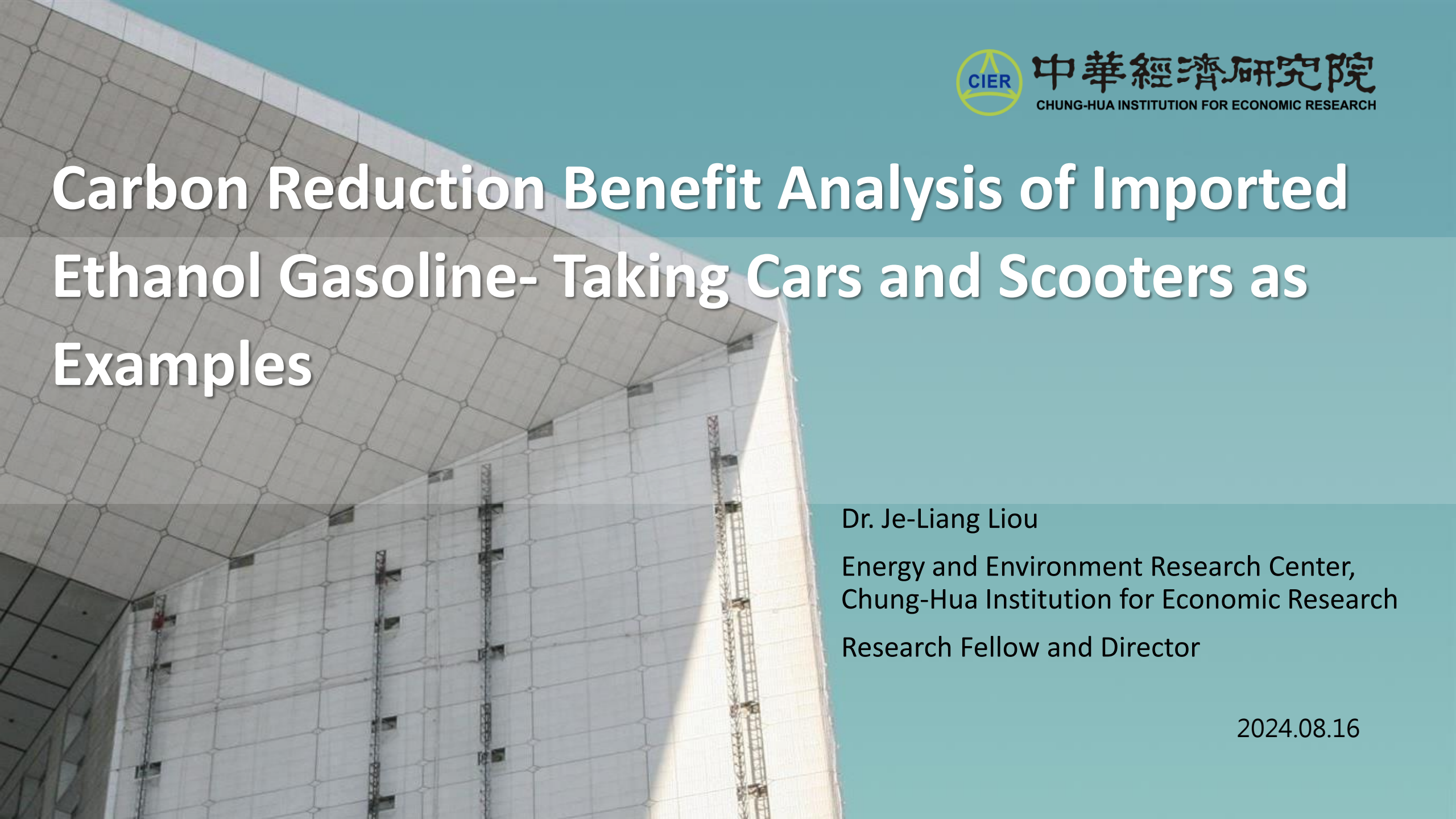


中華經濟研究院
CHUNG-HUA INSTITUTION FOR ECONOMIC RESEARCH

Carbon Reduction Benefit Analysis of Imported Ethanol Gasoline- Taking Cars and Scooters as Examples

Dr. Je-Liang Liou

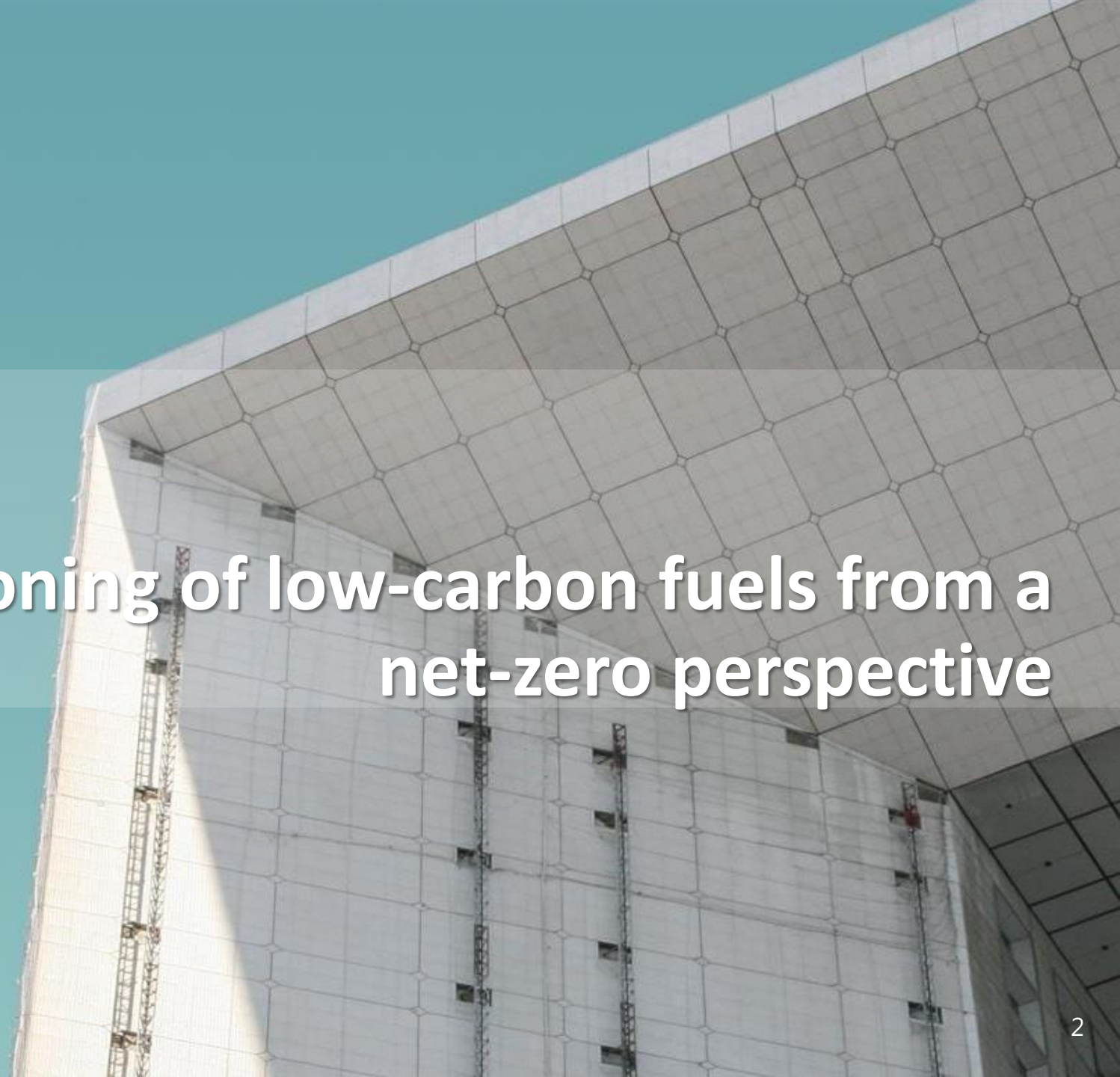
Energy and Environment Research Center,
Chung-Hua Institution for Economic Research

Research Fellow and Director

2024.08.16

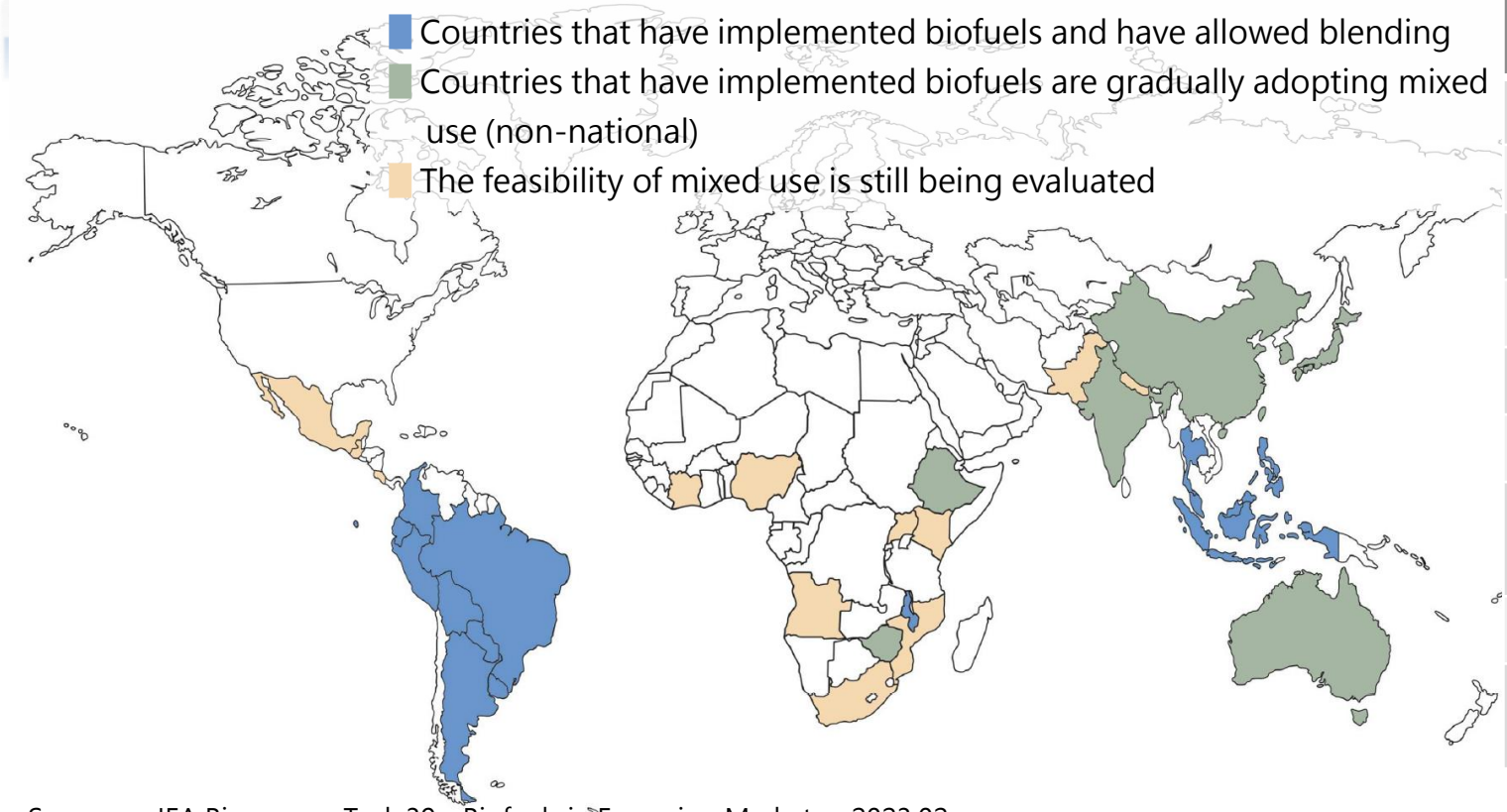
中華經濟研究院
CHUNG-HUA INSTITUTION FOR ECONOMIC RESEARCH

Positioning of low-carbon fuels from a net-zero perspective



International biofuel development

- IEA Bioenergy TCP Task 39: Biofuels to Decarbonize Transport is an international group of experts working on the use and commercialization of biofuels for sustainable transport.
- Biomass and biofuels are important options in a country's green energy mix, and while there are many renewable energy options available for heating and power generation, biofuels are currently the only alternative to **liquid fossil** fuels such as gasoline, diesel, and jet fuel.



country	Low Fuel Standard	Policy Objectives
Taiwan	E3(Pilot Program)	-
India	E10	2025 E20
Indonesia	E5	2025 E20
Philippines	E10	-
Thailand	E10、E15、E85	-
Vietnam	E5	-
Japan	ETBE (1.9% ethanol alcohol)	Prep. 2025 Biological Fuel to be Introduced in FAI Oil
Taiwan	E10	-
South Korea	-	Introduced in 2024 E10 Demonstration plan

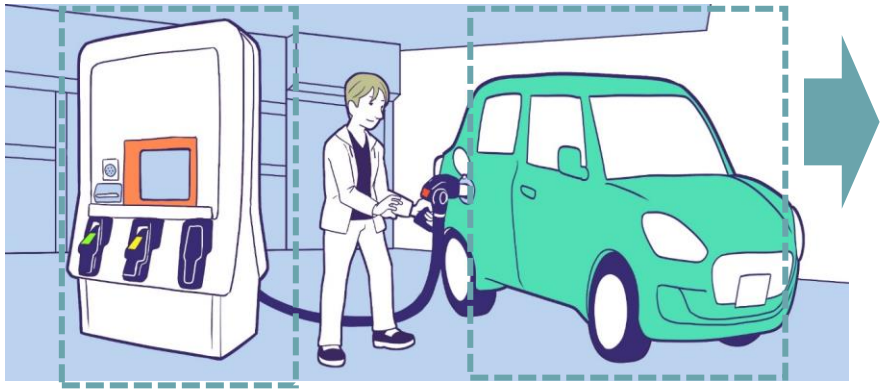
Sources:：IEA Bioenergy: Task 39，Biofuels in Emerging Markets，2023.02

Note: India, Japan and South Korea have all planned policies for the use of low-carbon gasoline from 2024 to 2025

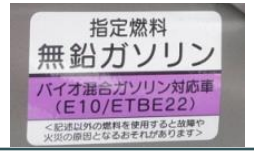
The current state of low-carbon fuel promotion in Asia: the case of Japan

Adoption of E10 in Japan: In 2011, Japan established and announced specifications for E10-compatible vehicles and fuel composition, which came into effect in April 2012。

- **Detailed rules of road vehicle safety standards:**
- **Article 3 Fuel Specifications E10 Gasoline**
- **Lead and methanol shall not be detected**
- **The sulfur capacity ratio must not exceed 0.001%**
- **The benzene capacity ratio shall not exceed 1%**
- **The capacity ratio of methyl third butyl ether (MTBE) shall not exceed 7%**
- **Ethanol capacity ratio must not exceed 10%**
- **The oxygen volume ratio must not exceed 3.7%**
- **The ratio of light diesel fuel mixing rate to capacity shall not exceed 4%**
- **The gum content should not exceed 5mg/100mL**



- **Key points of applicability of compatible vehicles:**
- **Proven durability against ethanol-induced corrosion and deterioration**
- **Vehicle emissions, as well as fuel boil-off gases, meet the emission standards for gasoline vehicles**
- **A label is affixed near the fuel filler cap to show that it is an E10 compatible vehicle**



Fuel Component Standards

①According to the detailed rules of the Road Vehicle Safety Standards Act, the relevant ingredient content specifications for various types of fuels that can be used in road vehicles are stipulated

②In the future, if the fuel specifications for road vehicles are not listed in the existing regulations, they will need to be tested for vehicle safety and emission performance

Vehicle compatibility

①Due to the use of highly concentrated alcohol fuel, it may cause corrosion of parts and cause fuel leakage, which in turn can lead to vehicle fires

②Therefore, if a vehicle uses fuel mixed with more than 3% ethanol (e.g. E10), a suitability judgment must be made to distinguish "compatible vehicles"

Sources:：https://www.mlit.go.jp/jidosha/jidosha_fr7_000007.html

Taiwan's 2050 Net-Zero Transition: The Role of Biomass Energy

Transformation strategy

Energy transformation

Industrial transformation

Lifestyle transformation

Social transformation

Governance base

R&D of science and technology

Climate law

Build a zero-carbon energy system

- Maximizing renewable energy/Expand the deployment of mature photovoltaic wind power, with forward-looking earth and ocean energy
- Zero-carbon thermal power generation Introduction of hydrogen power generation and gas-fired CCUS
- Gradually remove the coal / Short-term ammonia mixed burning reduces carbon emissions, and long-term conversion to safe backup
- Build a zero-carbon fuel supply system /Provide hydrogen, ammonia, and biomass fuel for industrial transportation
- Introduce advanced technologies in a timely manner to increase the space for the use of zero-carbon energy Grasp the global forward-looking technology trends, and introduce them in a timely manner according to domestic conditions

Enhancing energy systems

- Prioritizing the expansion of renewable energy grid infrastructure
- Expand energy storage facilities for renewable energy

Create green growth

- Build a green energy industry ecosystem Port Wind Power Zone, Green Energy New Entrepreneurship Industry Promote decarbonization investment and international cooperation
- Promote public and private sector investment in green energy, and build international partnerships to introduce key technologies, and create opportunities for the export of Taiwan's advantageous decarbonization technology

Carbon -free fuels

Establish a carbon-free fuel supply system
(Provision of hydrogen, ammonia, and biomass fuels for industry and transportation)

- Biomass energy (mainly domestic sources)
- Hydrogen energy

(Establishment of the Hydrogen Energy Promotion Group of the MOEA)
(Promotion of international cooperation and construction of demonstration systems)

- Hydrogen Energy

(Imported Green Hydrogen)
(Hydrogen production from surplus electricity)

- Biomass energy (layout of foreign sources)

Source: National Development Council, Overview of Taiwan's 2050 Net Zero Emissions Pathway and Strategy, 30 March 2022.

Taiwan's 2050 Net Zero Transition: The Role of Biomass Energy (continued)

Transformation strategy

- Energy Transition
- **Industrial transformation**
- Life transformation
- Social transformation

Governance base

- R&D of science and technology
- Climate law

Manufacturing Department：

2. 能源轉換	2.1 天然氣	擴大一般鍋爐使用天然氣	推動汽電鍋爐使用天然氣	天然氣+碳捕捉封存(CCS) 碳中和天然氣
	2.2 生質能	擴大水泥業生質燃料使用 4% 擴大造紙業生質燃料使用 5%	擴大使用生質燃料	
	2.2 使用綠電	鼓勵企業實踐RE100目標　15%使用綠電	擴大使用綠電	

Transportation sector: 100% of electric cars/electric scooters market share in 2040

運具電氣化

- **提高電動車市占率**
  市區公車2030全面電動化，
  小客車/機車 2040新售全面電動化
- **創造國內市場需求**
  電動公務車、電動計程車、補助購車
- **製造在地化**
  補助加速國產電動車產品開發與生產
- **完備使用環境**
  完善住宅與公共停車空間充電設備
- **強化車輛碳排管理**
  提升新車能效標準，逐步加嚴車輛碳排標準

01 02 03

人本綠運輸

- **推廣公共運輸**
  因地制宜強化公共運輸服務便利性
- **完備步行環境**
  改善人行步行環境
- **完備自行車環境**
  自行車友善行駛空間、共享自行車站點、通勤自行車道系統

私人汽機車管理

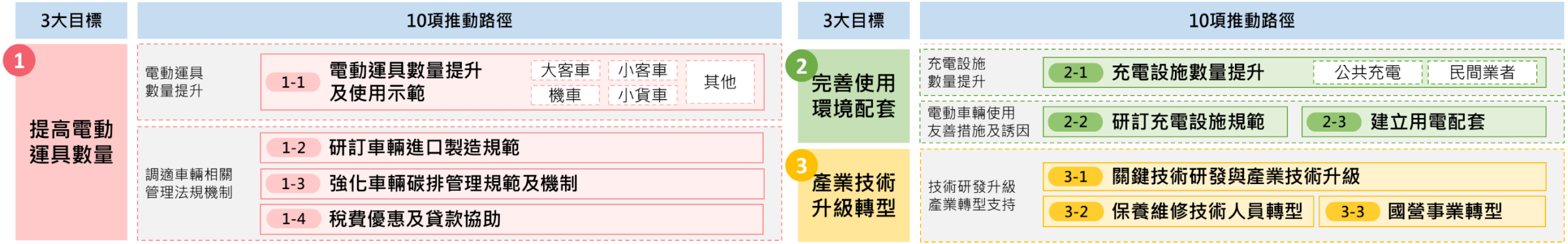
- **管理私人運具使用**
  低碳交通區、停車管理、油價回歸市場機制
- **推廣共享汽機車**
  提高共享運具使用範圍及密度、搭配公共運輸轉乘優惠

資料來源：國發會，臺灣2050淨零排放路徑及策略總說明，2022年3月30日。

Reflections on the net-zero strategy of Taiwan's transportation sector

Goals and strategies for electrifying and decarbonizing vehicles:

- Organized by the Ministry of Transport, Key Strategy 7 "Electrification and Decarbonization of Transport" is a public transport first strategy and a government-led demonstration.
- Priority will be given to the full electrification of urban abuses (11,700 units) and official vehicles by 2030; By 2040, the market sales ratio of electric passenger cars and electric locomotives will reach 100%.
- "Electrification and Carbon-free Transportation" focuses on the policy formulation and strategic objectives of electrification technology development, electric vehicle progress, and electrification environment.

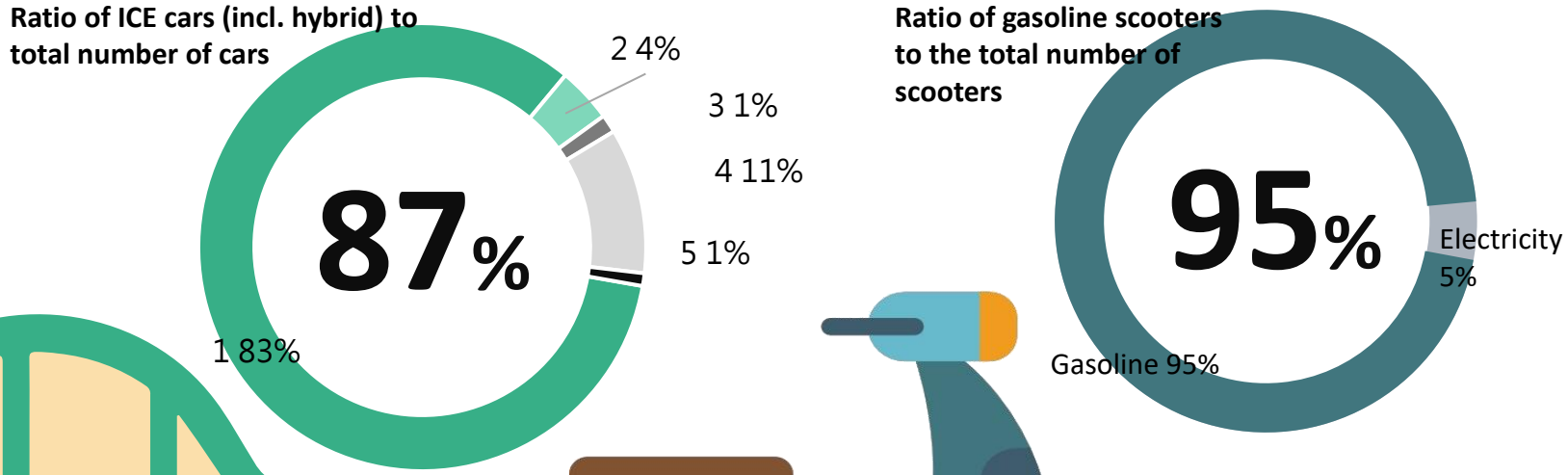


Most of the transport-related net-zero strategies are zero-carbon policies.
Lack of low-carbon transition strategies for gasoline-powered vehicles.

Source: NDC, 12 Key Strategies: Electrification and Decarbonization of Vehicles, 28 December 2022.

Reflections on the Net Zero Strategy of Taiwan's Transport Sector (continued)

- According to the statistics as of the end of June 2024, there are about 8.6 million cars and 14.6 million locomotives registered in Taiwan, totaling 23.2 million.
- There are about 7.2 million cars using gasoline and about 340,000 gasoline and electricity, and about 87% of the total number of cars using gasoline as fuel. There are about 13.86 million scooters running on gasoline, accounting for 95% of the total number of scooters.



Transportation-related net-zero strategies lack low-carbon transition strategies for gasoline-powered vehicles and **scooters** ...

Maybe we could...

Note: The number of registered vehicles in the country is retrieved from the General Administration of Highways of the MOTC. The number registered vehicles is divided by county and city and fuel used, and the statistics are as of the end of June 2024.

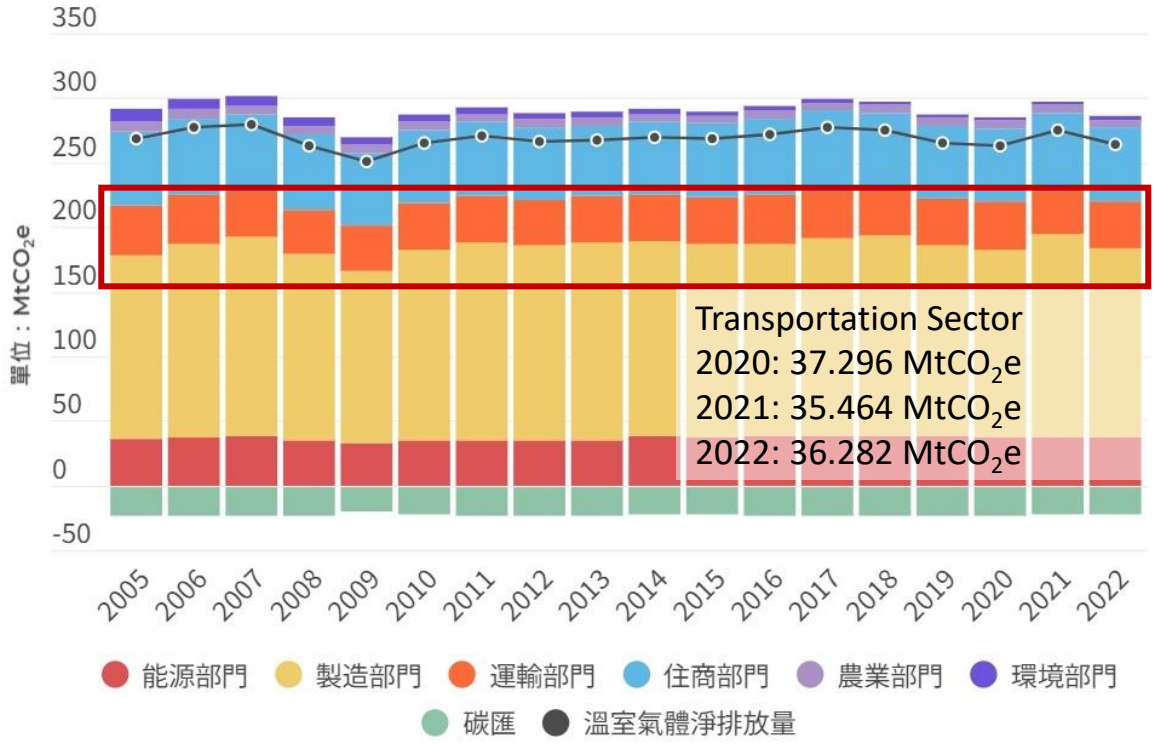
CIER 中華經濟研究院
CHUNG-HUA INSTITUTION FOR ECONOMIC RESEARCH

Opportunities for low-carbon fuels to decarbonize the transport sector

Trends in greenhouse gas emissions from the transport sector

An overview of Taiwan's greenhouse gas emissions

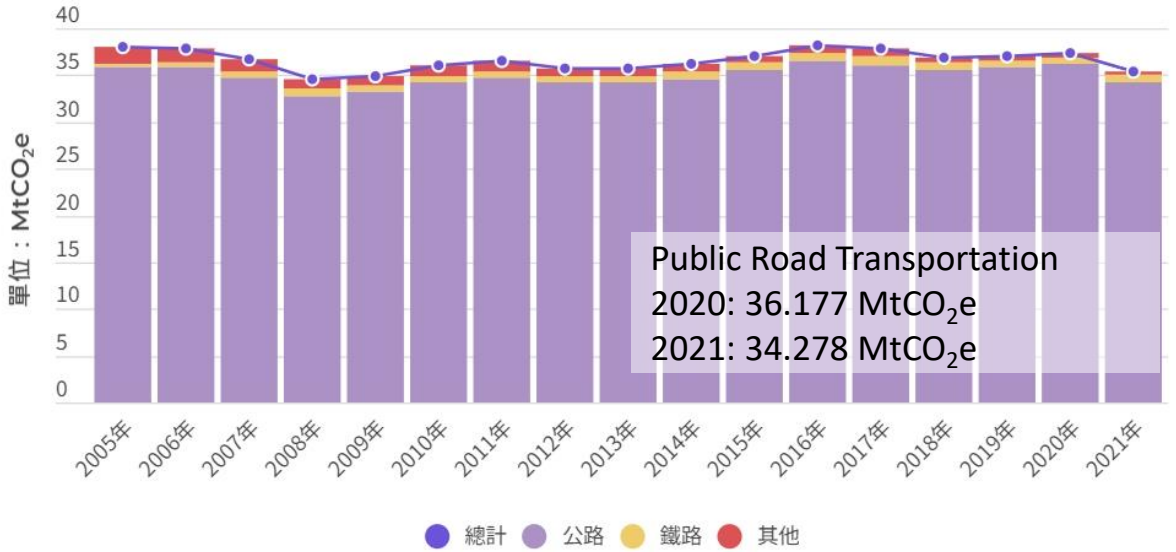
- The total greenhouse gas emissions in Taiwan in the year 2021 were approximately 297.007 million metric tons of carbon dioxide equivalent (MtCO2e). After deducting 21.851 MtCO2e from carbon sinks, the net emissions amounted to 275.157 MtCO2e.



Source: National Greenhouse Gas Emissions Inventory Report (2024 Edition), emissions statistics updated from 1990 to 2022.

Transport sector: greenhouse gas emissions

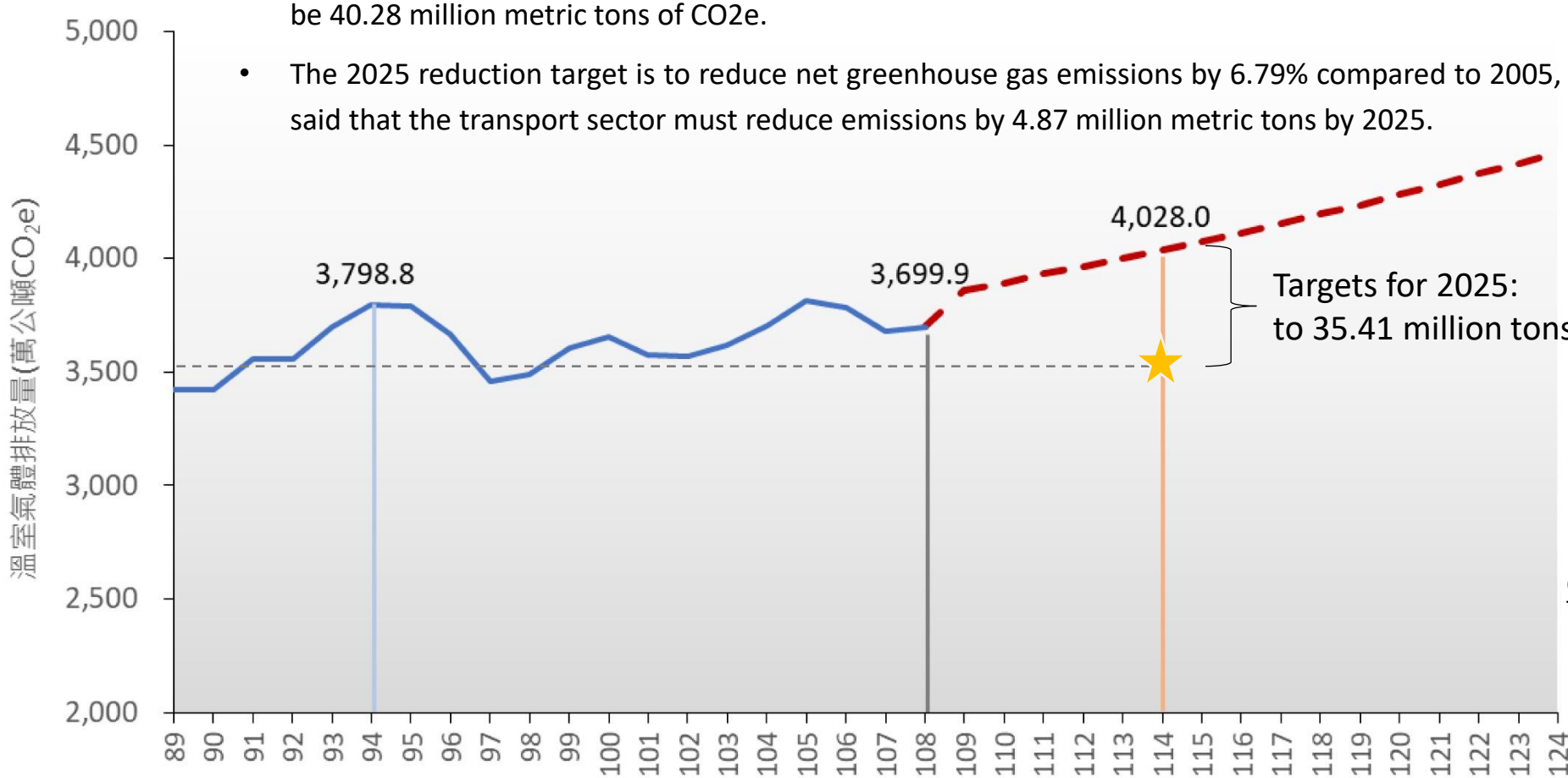
- The greenhouse gas emissions of Taiwan's transportation sector in 2021 was about 35.464 million metric tons of carbon dioxide equivalent (MtCO2e), accounting for about 11.94% of the total emissions, and the emissions mainly came from road transportation (such as oil for automobiles and locomotives).



Source: Climate Citizen Dialogue Platform · https://www.cca.gov.tw/climatetalks/emission-and-reduction/sectoral/transportation/1877.html

Trends in GHG emissions from the transport sector under the baseline scenario

- According to the MOTC's Phase II Action Plan for Greenhouse Gas Emission Control in the Transport Sector, it is estimated that the emissions of the transport sector in 2025 will be 6.03% higher than that in 2005, and the net emissions in 2025 are estimated to be 40.28 million metric tons of CO2e.
- The 2025 reduction target is to reduce net greenhouse gas emissions by 6.79% compared to 2005, or 35.41 million metric tons; It said that the transport sector must reduce emissions by 4.87 million metric tons by 2025.



Targets for 2025:
to 35.41 million tons

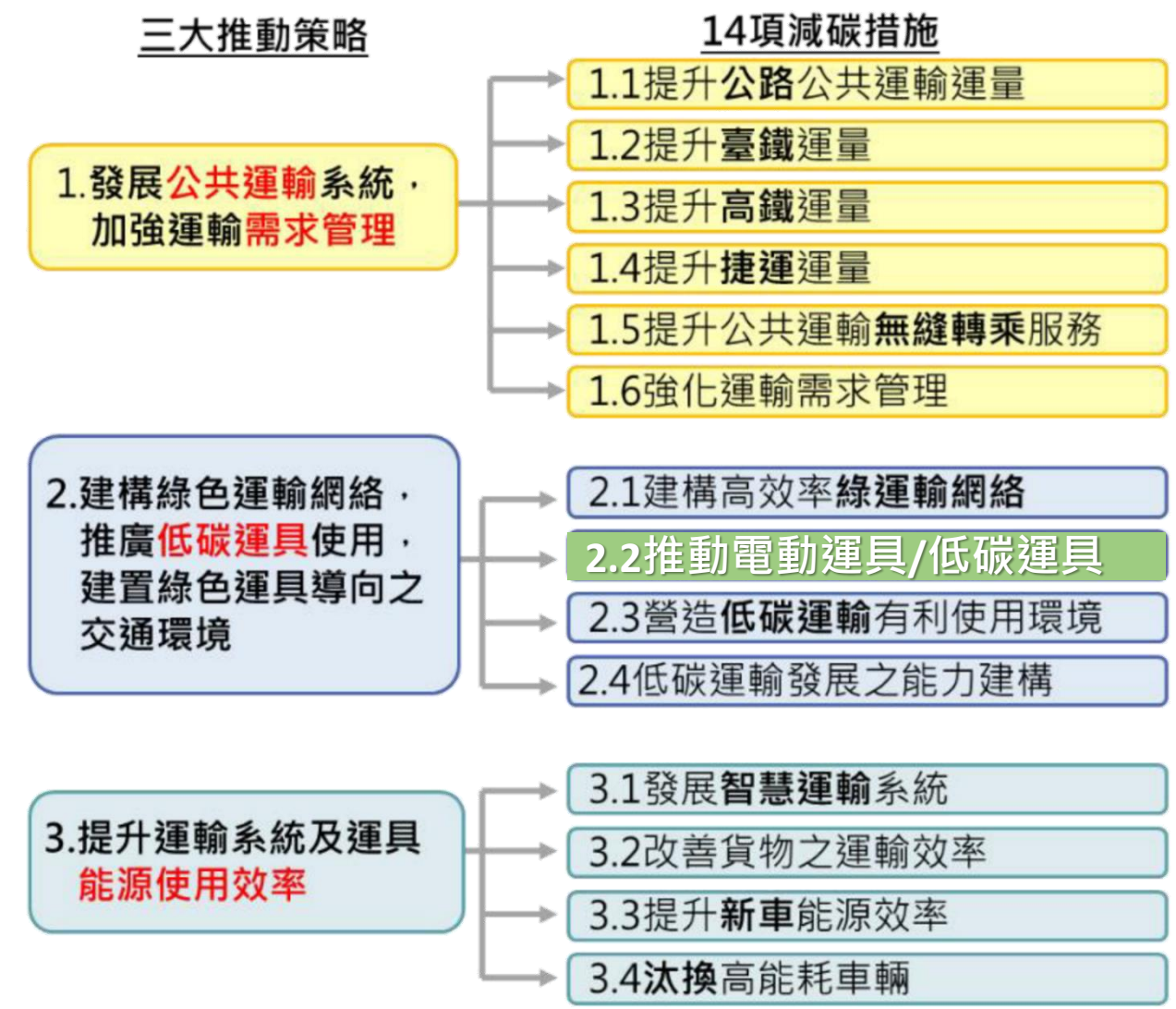
gap
4.87 million tons

Formulating Promotion Strategies and Measures (Action Plan for Greenhouse Gas Emission Control in the Transport Sector Phase II)

Note: Forecast values after 109 years

Source: Ministry of Transport and Communications, Phase II Action Plan for the Control of Greenhouse Gas Emissions in the Transport Sector (Verified Version), September 2022.

Phase II Action Plan for the Control of Greenhouse Gas Emissions in the Transport Sector



2.2 Promote electric vehicles/low-carbon transportation

1. Continue to promote electric buses
2. The use of electric locomotives is encouraged
3. Plan to promote the electrification of passenger cars
4. Review the replacement of official vehicles with electric vehicles
5. Push other electric carriers
6. Promote the use of low-carbon alternative fuels (such as biofuels) for transportation vehicles: Promote the E3 alcohol gasoline demonstration program and expand the scale of domestic transportation of alcohol gasoline

Note: (5) and (6) do not see the specific allocation of funds in the transportation sector action plan promotion strategy and specific plan summary table.

The expected effect of the Phase II (110-114) Action Plan

- Estimated reduction effect: 2.886 million tons
- There is still a gap to the 2025 control target: 1.984 million tons

Source: Ministry of Transport and Communications, Phase II Action Plan for the Control of Greenhouse Gas Emissions in the Transport Sector (Verified Version), September 2022.

Greenhouse Gas Reduction: Assess the carbon emissions from the use of conventional gasoline and E10

Objective: To evaluate the difference between the tailpipe carbon emissions of conventional gasoline and E10 of gasoline vehicles in Taiwan.

	Conventional gasoline	E10 gasoline
Greenhouse gas emissions($kgCO_2e/L$)	2.36	2.18 [1]

The amount of carbon reduction per year for a single car[2]

0.23 metric tonCO_2e

Vehicles run on gasoline switching to E10 can reduce approximately

The amount of carbon reduction per year for a single scooter[2]

0.02 metric tonCO_2e

7.3% carbon emissions

Note 1: E10 (using 10% bioethanol, 90% gasoline) greenhouse gas emissions: According to the IPCC statement, the CO2 produced by the combustion of biomass fuels is part of the natural cycle reaction and does not increase the concentration of CO2 in the atmosphere, so it only needs to be quantified and tabulated separately, and does not need to be aggregated into emissions; And the calorific value is used to estimate fuel consumption: 1L gasoline = 1.03L E10 gasoline.

Note 2: Refer to Appendix 1 of the Administrative Measures for Incremental Offset of Greenhouse Gas Emissions of the Ministry of Environment, and replace old automobiles as the framework for calculating the reduction benefits of electric vehicles, but update the parameters based on the latest survey data of the MOTC.

Policy promotion goals and carbon reduction benefit analysis

E10 penetration	Cars carbon reduction (10,000 metric tons CO_2e/year)	Scooter carbon reduction(10,000 metric tonsCO_2e/year)	Total amount of reduction (10,000 metric tonsCO_2e/year)	Number of vehicles (10,000 units)
5%	8.4	1.7	10	105
10%	16.8	3.4	20	211
20%	33.6	6.9	40	421
30%	50.4	10.3	61	632
40%	67.2	13.8	81	843
50%	84.0	17.2	101	1,053
60%	100.9	20.6	121	1,264
70%	117.7	24.1	142	1,475
80%	134.5	27.5	162	1,685
90%	151.3	31.0	182	1,896
100%	**168.1**	**34.4**	**202**	**2,107**

It closes the reduction gap of the Phase II Action Plan (1.984 million tons), which is a low-carbon strategy worth considering and promoting.

Note: The number of registered vehicles in the country is retrieved from the General Administration of Highways of the MOTC. The number registered vehicles is divided by county and city and fuel used, and the statistics are as of the end of June 2024.

GHG Emissions Comparison between Gasoline, E10 and Electricity

Objective: To evaluate the greenhouse gas emissions of vehicles using different energy sources such as gasoline, E10, and electricity under the condition of providing the same services.

Greenhouse gas emissions from each vehicle for the same use behavior.

	Target: 2024 model	Energy efficiency	Service Levels	Emissions
car 	**Electric:** For the cars that fall between 182.1-262 hp (1,801-2,400 c.c.), choose the one with the highest and lowest horsepower; and the highest and lowest energy efficiency. **Gasoline:** The exhaust volume is between 1,801 and 2,400 c.c., and the highest and lowest energy efficiency is selected.	The data obtained from the energy efficiency standard (laboratory test value) of each vehicle is multiplied by an empirical factor of 0.7 to reflect the actual road operation of each vehicle.	Average annual travel kilometer's: 15,473	**Electrical energy: unit** $KgCO_2e$/degree nationwide：0.494 Taiwan power firepower：0.621 **Gasoline:**unit $KgCO_2e$/L gasoline：2.357 E10 gasoline：2.185
Scooter 	**Electric:** The scooters with highest hp (17hp) highest energy efficiency. For the scooters that fall between 9-12hp, choose the highest and lowest energy efficiency. If the hp is less than 9hp, choose the one with the highest energy efficiency. **Gasoline:** With a displacement of more than 100 to 150 c.c., choose the continuously variable automatic transmission, the highest and lowest energy efficiency.		Average annual travel kilometer's: 3,389	

Fuel Cost Comparison between Gasoline, E10 and Electricity

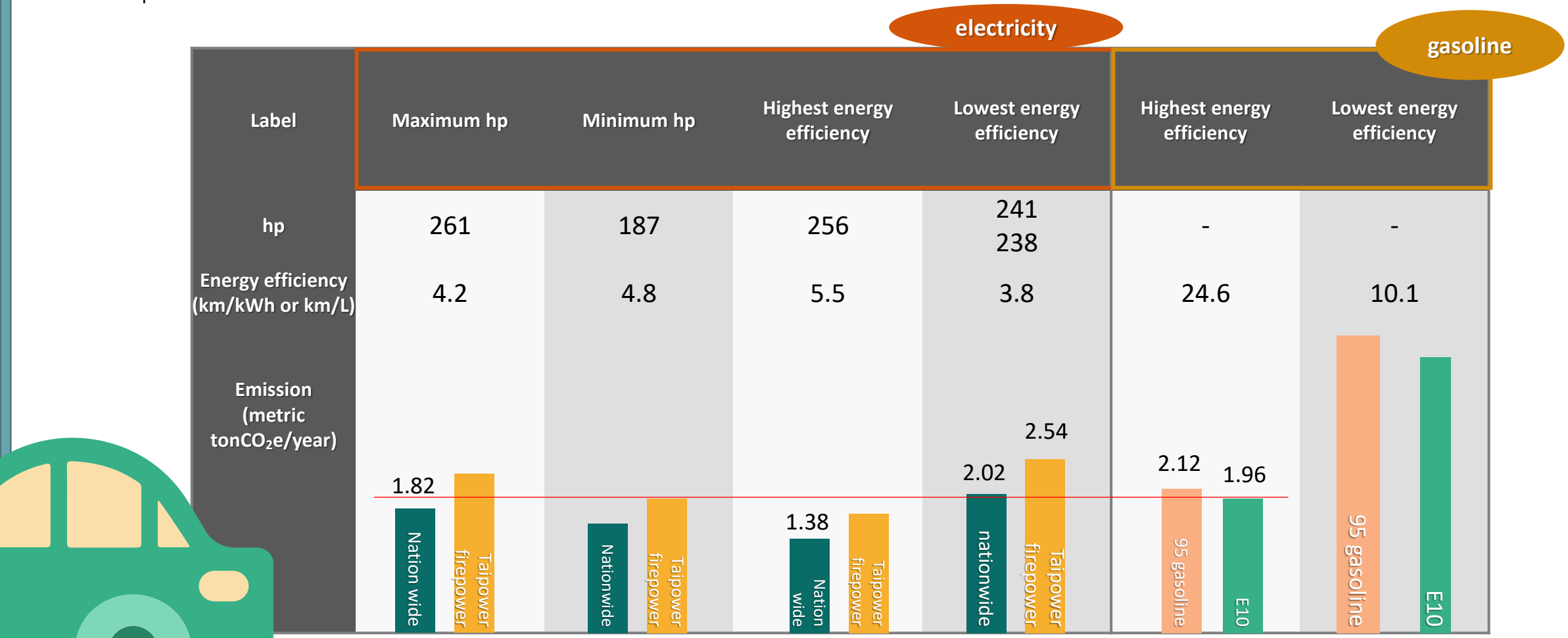
Objective: To evaluate the fuel cost of vehicles running on gasoline, E10, and electricity with different energy sources under the condition of providing the same services.

The fuel cost of each vehicle for the same use behavior.

	Target: 2024 model	Energy efficiency	Service Level	Fuel cost
car	**Electric:** For those cars that fall between 182.1-262 hp (1,801-2,400 c.c.) between, choose the one with the highest and lowest horsepower; and the highest and lowest energy efficiency. **Gasoline:** The displacement volume is between 1,801 and 2,400 c.c., and the highest and lowest energy efficiency is selected.	The data obtained from the energy efficiency standard (laboratory test value) of each vehicle is multiplied by an empirical factor of 0.7 to reflect the actual road operation of each vehicle.	Average kilometers traveled per year: 15,473	**Electric energy: The** electricity price of low-voltage electric vehicle charging and swapping facilities, and according to the user's charging habits, the electricity fee of the peak time in summer is 8.35 NTD/kWh. Gasoline: **Gasoline:** 30.82 NTD/liter E10 gasoline: 29.46 NTD/liter
Scooter	**Electric:** The scooters with highest hp (17hp) and highest energy efficiency. For the scooters that fall between 9-12hp, choose the highest and lowest energy efficiency. For the scooters that are less than 9hp, choose the one with the highest energy efficiency. **Gasoline:** With a displacement of more than 100 to 150 c.c., choose the continuously variable automatic transmission, the highest and lowest energy efficiency.		Average kilometers traveled per year: 3,389	**Electrical energy:** Referring to the tariff scheme of the enterprise with the highest market share of electric scooter, the following options are selected: (1) it can meet the demand of 3,389 kilometers per year, and the cost is 519 NTD/month; and (2) limited time plan: 500~1,000 kilometers per month at a cost of 199 NTD/month. **Gasoline:** Gasoline: 30.82 NTD/liter E10 gasoline: 29.46 NTD/liter

Cars: Comparison of emissions between electricity, gasoline and E10

- Under the same service benchmark (average annual driving of 15,473 km) and a maximum horsepower between 182.1 and 262 hp or displacement between 1,801 and 2,400 c.c., the most energy-efficient gasoline car with E10 will have emissions comparable to cars with maximum hp or even better than the lowest energy-efficient electric cars.
- Although the emissions of electric cars are generally lower than that of gasoline vehicles, the emissions of electric vehicles will also be affected by different power generation structures. For gasoline vehicles with improving energy efficiency, and the use of E10 gasoline, it should have a significant effect on reducing the emissions of on-road transportation in Taiwan.



Cars: Comparison of fuel cost between gasoline, E10 and electricity

- Under the same service as the benchmark (average annual driving of 15,473 km), and the maximum horsepower of the cars is between 182.1-262hp or the displacement is between 1,801-2,400c.c., the fuel cost of the most energy-efficient cars using E10 gasoline is mostly lower than that of the electric vehicles selected in this study, and the fuel cost is only NT$3,110 away from the most energy-efficient electric vehicle.
- Although the cost of setting up energy supply infrastructure, such as dedicated lines, charging piles, etc., is outside the scope of this study. However, for the supply of E10 gasoline, the existing refueling facilities or equipment can be used without the high cost of equipment construction.

	electricity				gasoline	
Label	Maximum hp	Minimum hp	Highest energy efficiency	Lowest energy efficiency	Highest energy efficiency	Lowest energy efficiency
Energy consumption (kWh/year or liter/year)	3,684	3,204	2,798	4,093	899	2,189
Energy costs (NTD/kWh or NTD/L)	8.35				95 Gasoline: 30.82 NTD/L E10 gasoline: 29.46 NTD/L	
Fuel cost (NTD/year)	30,762	26,749	23,363	34,180	95 Gasoline: 27,693 E10 gasoline: 26,474	95 Gasoline: 67,451 E10 gasoline: 64,480

Scooter: Comparison of emissions between electricity, gasoline and E10

- On a basis of providing the same service (an average annual driving of 3,389 km), gasoline scooters are classified according to horsepower with a displacement of more than 100 to 150 c.c., while scooters are classified according to horsepower.
- The most energy-efficient gasoline scooters with continuously variable transmissions and the highest efficiency of gasoline with E10 gasoline have emissions comparable to those of the most powerful electric vehicles.

electricity

gasoline

Label	Maximum hp	9-12hp		<9hp	Continuously variable transmission	
	Highest energy efficiency	Highest energy efficiency	Lowest energy efficiency	Highest energy efficiency	Highest energy efficiency	Lowest energy efficiency
hp	17	10	10	3	-	-
energy efficiency (km/kWh or km/L)	11.3	17.5	14.3	23.3	44.7	28.9
Emissions (metric tons.CO_2e/year)	0.15 Nation wide; 0.19 Taipower firepower	0.10 Nation wide; 0.12 Taipower firepower	0.12 Nation wide; 0.15 Taipower firepower	Nation wide; Taipower firepower	0.18 95 gasoline; 0.17 E10	95 gasoline; E10

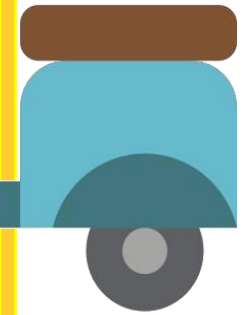
Scooter: Comparison of fuel cost between gasoline, E10 and electricity

- On a basis of providing the same service (an average annual driving of 3,389 km), gasoline scooters are classified according to horsepower with a displacement of more than 100 to 150 c.c., while electric scooters are classified according to horsepower.
- In order to meet the mileage of "providing the same service" set in this study, the battery replacement cost (fuel cost) is NT$6,228 per year from the perspective of the normal tariff scheme, which is higher than the fuel cost of gasoline scooters. However, if the tariff of the time-limited plan is calculated, the annual battery replacement cost (fuel cost) is NT$2,388, which is not much different.
- However, the time-limited scheme is not the norm, and the comparison of fuel cost is an economic incentive to promote the use of E10 gasoline in gasoline scooters, and it is a great help.

electricity

gasoline

Label	Maximum hp	9-12hp		<9hp	Continuously variable transmission	
	Highest energy efficiency	Highest energy efficiency	Minimal energy efficiency	Highest energy efficiency	Highest energy efficiency	Lowest energy efficiency
hp	301	194	237	145	76	117
Energy efficiency (km/kWh or km/L)	Refer to the tariff plan of the enterprise with the highest market share of electric scooters, and select: (1) It can meet the demand of 3,389 kilometers per year, and the cost is 519 NTD/month. (2) Limited time plan: 500~1,000 kilometers per month, the cost is 199 NTD/month.				95 Gasoline: 30.82 NTD/liter E10 gasoline: 29.46 NTD/liter	
Fuel cost (NTD/year)	(1) Regular scheme: 6,228 (2) Limited offer: 2,388				95 Gasoline: 2,335 E10 gasoline: 2,232	95 Gasoline: 3,613 E10 gasoline: 3,454



Conclusion: The Role and Opportunities of E10

Environmental aspect:

- Switching to E10 gasoline for gasoline-running vehicles can reduce greenhouse gas emissions by about 7.3% compared with regular gasoline.
- If gasoline-powered scooters are encouraged to fully use E10 gasoline, it will reduce carbon emissions by 2.02 million tons per year, which can help the transport sector achieve the phased reduction target.

Economic aspect:

- The use of E10 gasoline in vehicles can reduce fuel costs by about 4.4% compared with regular gasoline. (And this savings does not include government grants)
- Under the condition that the user's riding behavior does not change, the fuel cost of electric scooters is higher than that of gasoline scooters. It is suggested that priority should be given to the strategy of promoting the use of E10 gasoline by "gasoline scooters", which has financial incentives.
- Although the fuel cost assessment results of electric vehicles are lower than those of gasoline vehicles, the basic equipment such as charging piles for electric vehicles is not widely installed at present, and the assessment results do not take into account the set-up cost, indicating that gasoline vehicles are competitive in terms of fuel cost performance.

The gasoline cars account for about 87% of the total number of car in Taiwan, and the gasoline scooter accounts for 95%, but there is little focus on the related net-zero strategic planning.

中華經濟研究院
CHUNG-HUA INSTITUTION FOR ECONOMIC RESEARCH

Thank You

- https://www.ciercge.org.tw/
- https://www.cier.edu.tw/research-unit/the-center-for-energy-and-environmental-research