31st International Input-Output Conference at Malé, Maldives, June 6-11, 2025

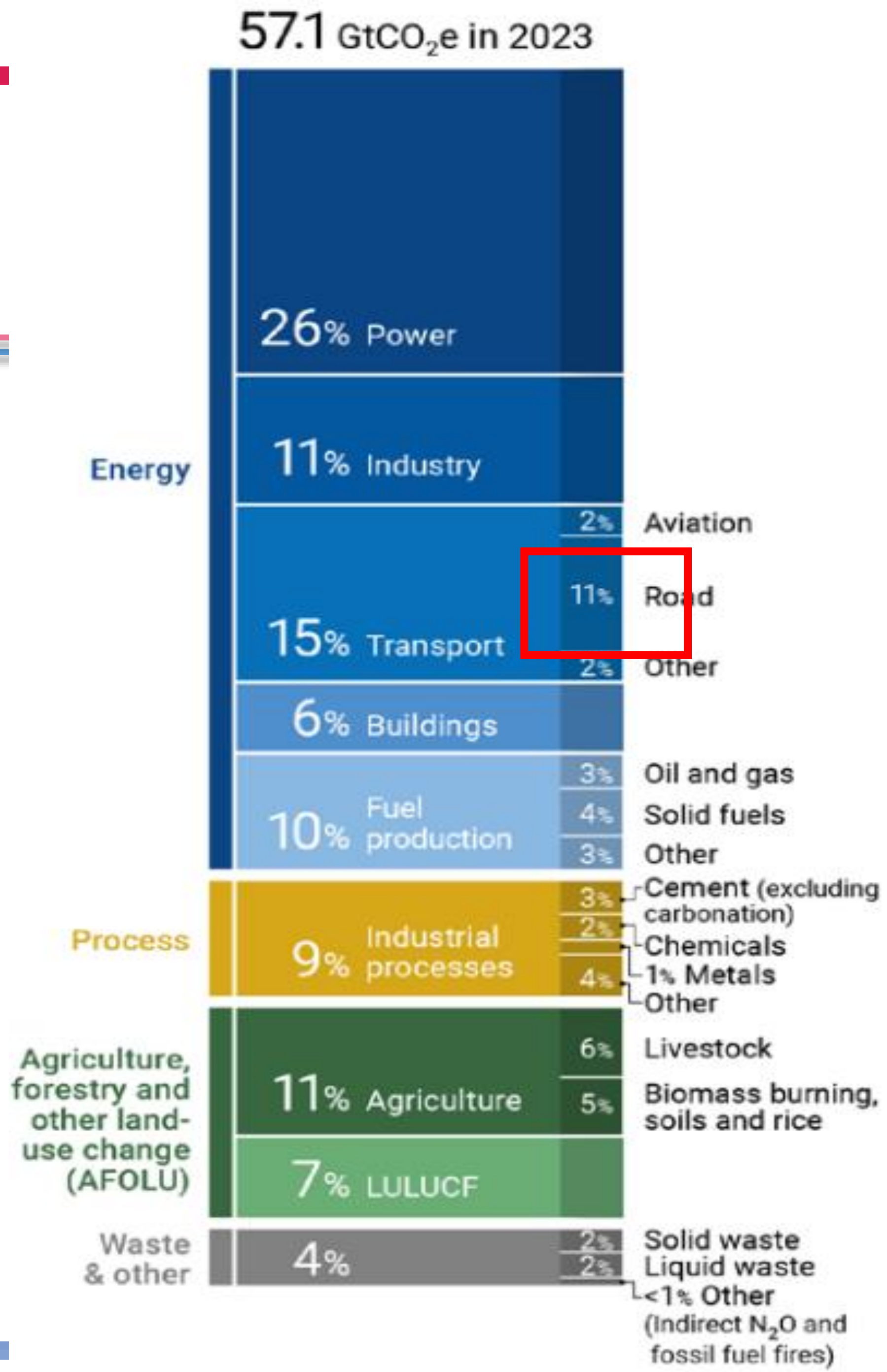
An Impact Assessment of the Motorcycle Electronification Policy in Taiwan:

From the Economy-Energy-Environment (3E) Perspective

Tony S.-H. Hsu, Sheng-Ming Hsu, Min-Long Chen,
Hsing-Chun Lin, Wen-Hung Huang, Ching-Cheng Chang

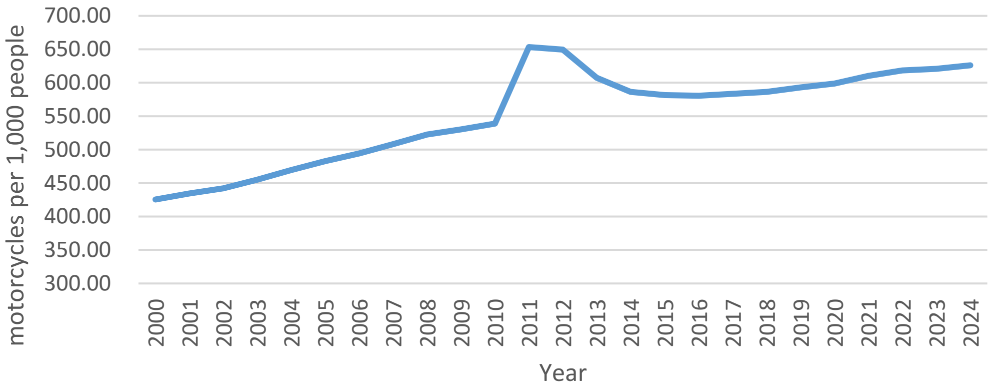
2| Introduction_1

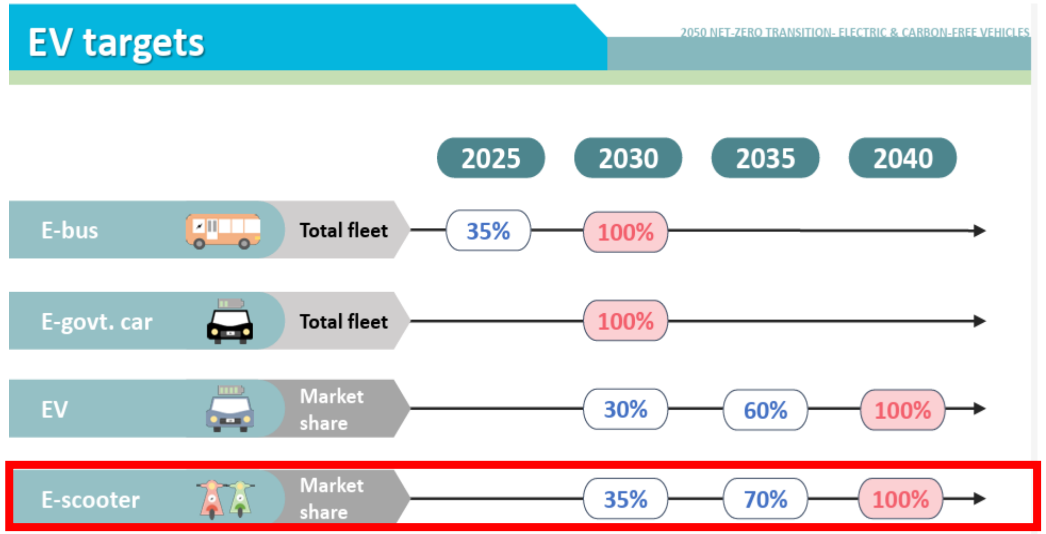
- With global climate change intensifying, the low-carbon transformation of the transport sector has become a key strategy for achieving carbon neutrality. (Figenbaum et al., 2020；IEA, 2021)
- Among all vehicle types, electric two-wheelers (E2Ws) are particularly effective for city carbon reduction due to their high energy efficiency and low emissions (IEA, 2021).



3| Introduction_2

- In Asia, motorcycles are widely used for daily transport—Taiwan leads the world with 620 motorcycles per 1,000 people (as of October 2023).
- Taiwan plans to ban the sale of fuel-powered motorcycles by 2040 and is promoting E2Ws through subsidies, R&D, and localized supply chains to achieve both environmental and industrial transformation.





4| Literature Review_1

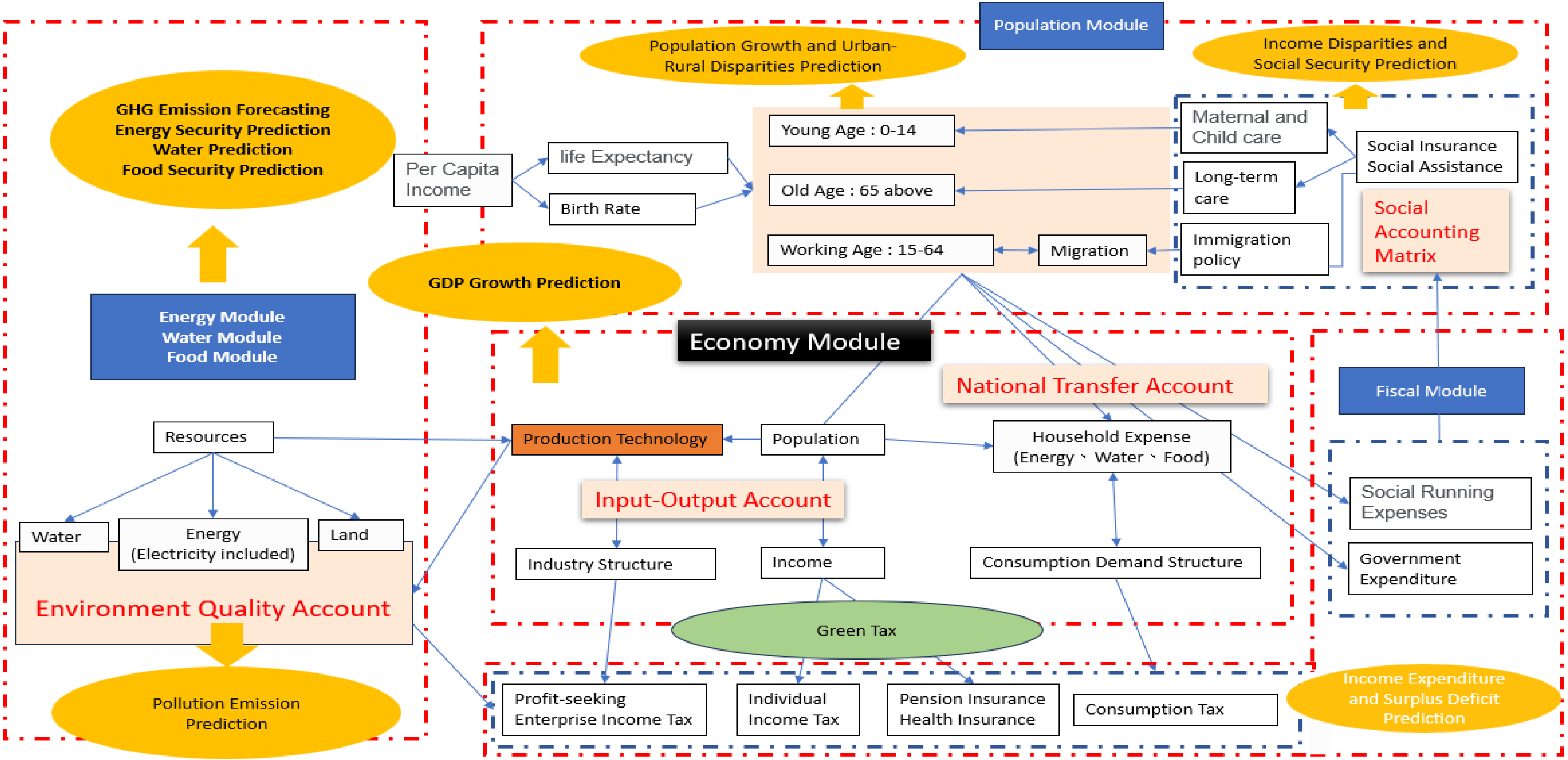
- In markets like Vietnam, **oil prices** and **technology commercialization** significantly influence E2W penetration rate (Jones et al., 2013).
- Price trends differ across regions—**policy incentives in China** led to a 30% price drop from 1999 to 2005, while Europe saw stable prices (Weiss et al., 2015).
- Norway's experience shows that **tax incentives and infrastructure** can effectively boost EV adoption and reduce emissions (Figenbaum et al., 2020).
- China rapidly expanded EV adoption after launching **new energy vehicle subsidies** (Zhang et al., 2020).
- **Charging infrastructure and renewable energy development** are seen as critical success factors (Bakker & Vassilakopoulou, 2017).
- Taiwan began R&D of E2Ws in 1995; early studies confirmed lower per-unit carbon emissions than fuel motorcycles (Tsai, 1996).

5| Literature Review_2

Limitations of LCA and Role of CGE Modeling

- LCA studies show lower emissions during use but highlight issues like **end-of-life solid waste** and **stage-shifting of pollution** (Lee & Pan, 2003; Lin et al., 2008).
- LCA is static and **cannot reflect economic structural changes** or product heterogeneity (Neves et al., 2024).
- CGE models can provide insights on **intersectoral adjustments**, **supply chain effects**, **energy substitution**, and **emission prediction** under different policy scenarios (Guo et al., 2021).
- CGE studies in Asia indicate that **electrification policies** can reduce emissions but may also create **short-term GDP losses**, highlighting the potential of **environment–economy trade-off** (Jiang et al., 2020; Khamphilavanh & Masui, 2020).

Framework of GEMTEE model



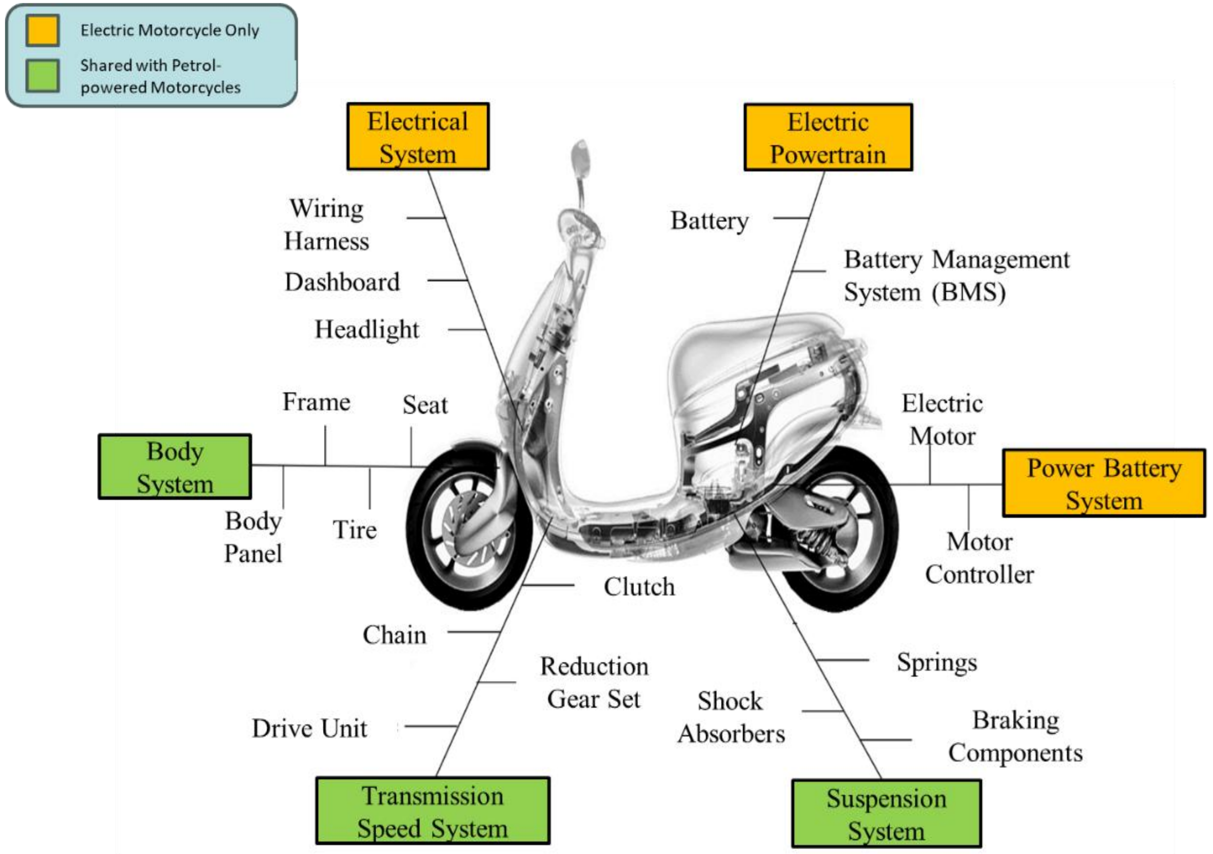
7| Data Updating of GHG Emission Account

Data Sources:

- **National Greenhouse Gas Inventory (2025)**
  - ✓ Emissions are listed comprehensively from various sources.
  - ✓ Separate emission sources into **combustion** and **non-combustion**.
- **Input-Output Tables (2021) with 163 sectors**
  - ✓ Data about the expenditure on intermediate inputs used by each sector for production and the expenditure on final use of goods by end-use sectors.

➡ Obtain the **distribution structure** of each product across industries.

8| Decomposition of EV from motorcycle sector



Source: ARTC(2018), Ho(2020)

Input item	Cost item	Percentage
Intermediate input	Power battery system	33.89%
	Electric powertrain	18.09%
	Suspension system	6.37%
	Transmission system	11.93%
	Body system	6.29%
Original input	Labor	9.91%
	Capital	13.52%
Total		100%

Components	EV	Fuel-Motorcycle
Electronic Parts & Components	8.79%	1.50%
Non-Electronic Parts	57.71%	58.48%
Service Sector	10.07%	17.14%
Primary Input	23.43%	22.88%

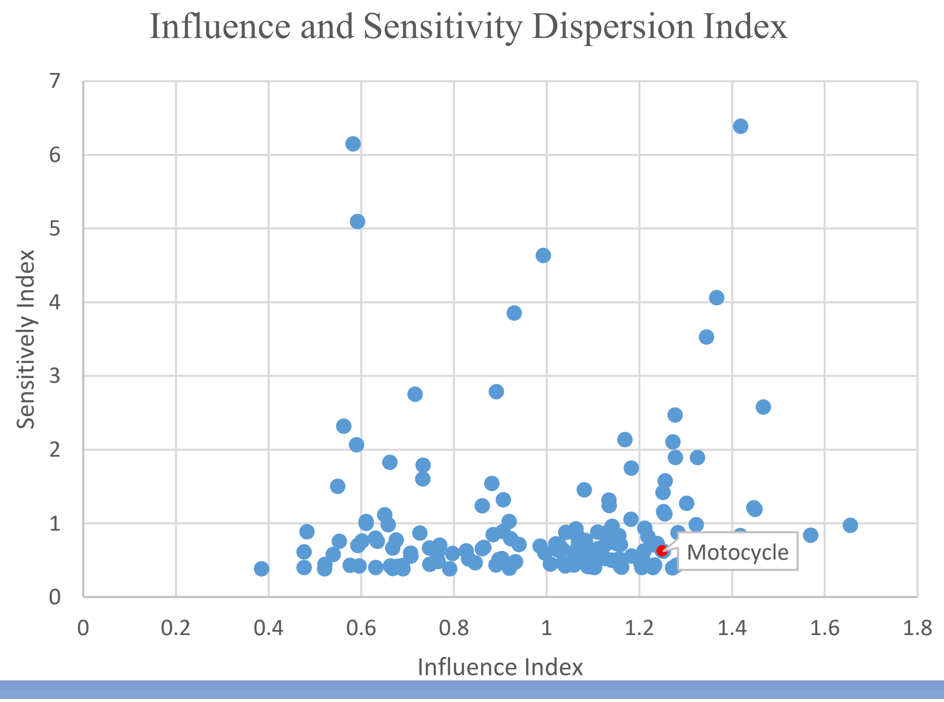
9| Decomposition of EV from motorcycle sector (#99) in IO table

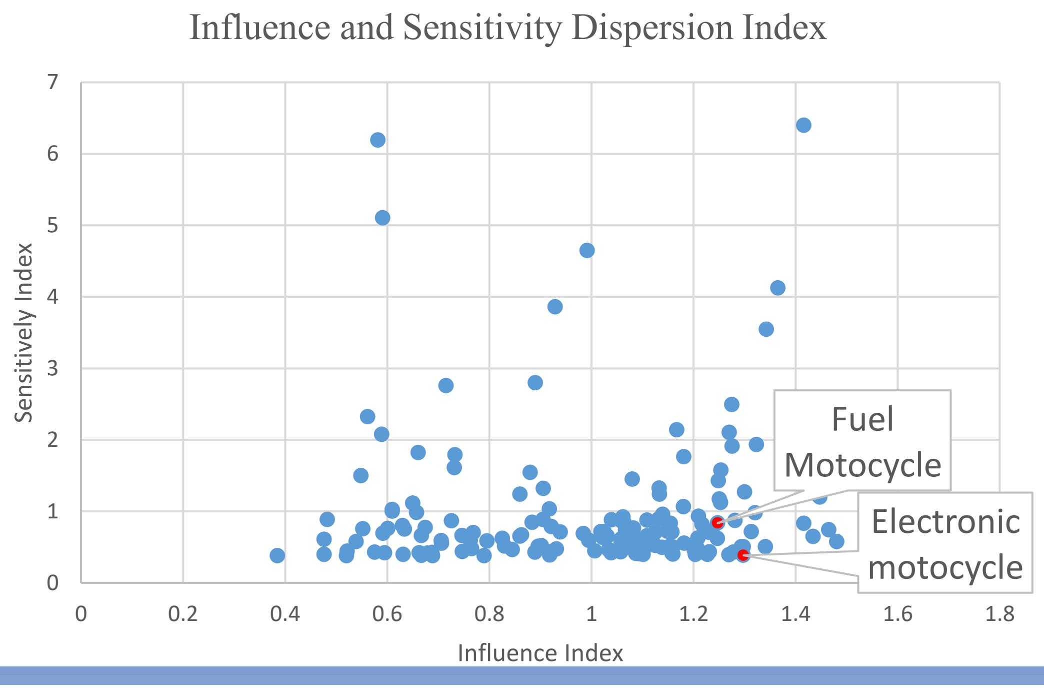
I-O Table		Intermediate Demand			Final Demand		Output
		Sector 1	Motorcycle	Sector n	Consumption	Investment	
Intermediate Input	Sector 1	x_1^1	x_1^m	x_1^n	C_1	I_1	X_1
	Motorcycle	x_m^1	x_m^m	x_m^n	C_m	I_m	X_m
	Sector n	x_n^1	x_n^m	x_n^n	C_n	I_n	X_n
Original Input	Labor	L_1	L_m	L_n			
	Capital	K_1	K_m	K_n			
Input		X_1	X_m	X_n			

I-O Table		Intermediate Demand				Final Demand		Output
		Sector 1	Electric Motorcycle	Fuel Motorcycle	Sector n	Consumption	Investment	
Intermediate Input	Sector 1	x_1^1	x_1^{em}	x_1^{fm}	x_1^n	C_1	I_1	X_1
	Electric Motorcycle	x_{em}^1	x_{em}^{em}	x_{em}^{fm}	x_{em}^n	C_{em}	I_{em}	X_{em}
	Fuel Motorcycle	x_{fm}^1	x_{fm}^{em}	x_{fm}^{fn}	x_{fm}^n	C_{fm}	I_{fm}	X_{fm}
	Sector n	x_n^1	x_n^{em}	x_n^{fm}	x_n^n	C_n	I_n	X_n
Original Input	Labor	L_1	L_{em}	L_{fm}	L_n			
	Capital	K_1	K_{em}	K_{fm}	K_n			
Input		X_1	X_{em}	X_{fm}	X_n			

10| Influence and Sensitivity Index Dispersion_1

✓ Both of EV and fuel motorcycle are in the quadrant with High Influence and Low Sensitivity
  - **Strong driving force** across the supply chain
  - Low responsiveness to upstream price or supply shocks
  - **Suitable as core sectors for industrial transformation**





11| Influence and Sensitivity Index Dispersion_2

- Fuel Motorcycle (1.25, 0.84)
  - ✓Strong linkages with traditional supply chains (e.g., engines, exhaust systems, metal processing);
  - ✓Moderately sensitive to upstream price or supply fluctuations;
  - ✓Still with dominant market share and relatively high economic multiplier effects.
- Electric Motorcycle(1.29, 0.38)
  - ✓Sensitivity of dispersion ≈ 0.38 (significantly lower than fuel motorcycle);
  - ✓Growing industrial influence, but supply chains remain underdeveloped;
  - ✓Lower dependency on conventional components results in lower economic responsiveness.

📌 A policy shift toward electrification may **impact traditional motorcycle sectors** and may need proactive transition strategies.

12| LCA Analysis_1

Environment Perspective: GHG Emissions of Electric and Fuel Motorcycles

$$\text{Monthly Emissions } (kgCO_2e) = \frac{\text{Daily Mileage}}{\text{Energy Efficientcy}} \times \text{Emission Factor} \times 30$$

Vehicle Type	Daily Mileage(km)	Energy Efficiency	Emission Factor	Monthly Emissions ($kgCO_2e$)
Fuel Motorcycle	13.3	49.05 (km/l)	2.4 ($kgCO_2e$/l)	19.52
Electric Motorcycle	19.1	23.92 (km/kWh)	0.509 ($kgCO_2e$/ kWh)	12.20

13| LCA Analysis_2

- By incorporating the Life Cycle Assessment (LCA) approach, emissions are categorized into two stages: material acquisition & manufacturing and use. The results show that electric motorcycles produce lower emissions than fuel-powered motorcycles in both stages.
- Notably, the emission gap is most significant during the use phase. As the electricity carbon emission factor continues to decline in the future, this difference is expected to become even more pronounced.

	LCA	GHG Emissions (ton CO2e)	Total Emissions (ton CO_2e)
Electric Motorcycles	Material Acquisition & Manufacturing	2.150	3.614
	Use Phase	1.464	
Fuel Motorcycles	Material Acquisition & Manufacturing	1.899	4.241
	Use Phase	2.342	

14| Scenario Design

1. **Baseline (2025-2040):**

GEMTEE will be calibrated using historical simulation (2021-2024) to estimate industrial production technologies. This calibrated framework is then used to simulate future growth in the number of electric and fuel-powered motorcycles.

2. **Policy Target Scenario** (S1):

This scenario reflects Taiwan's 2040 target for transport electrification, with projections for electric and fuel motorcycle fleets. The number of vehicles is exogenously specified in the model.

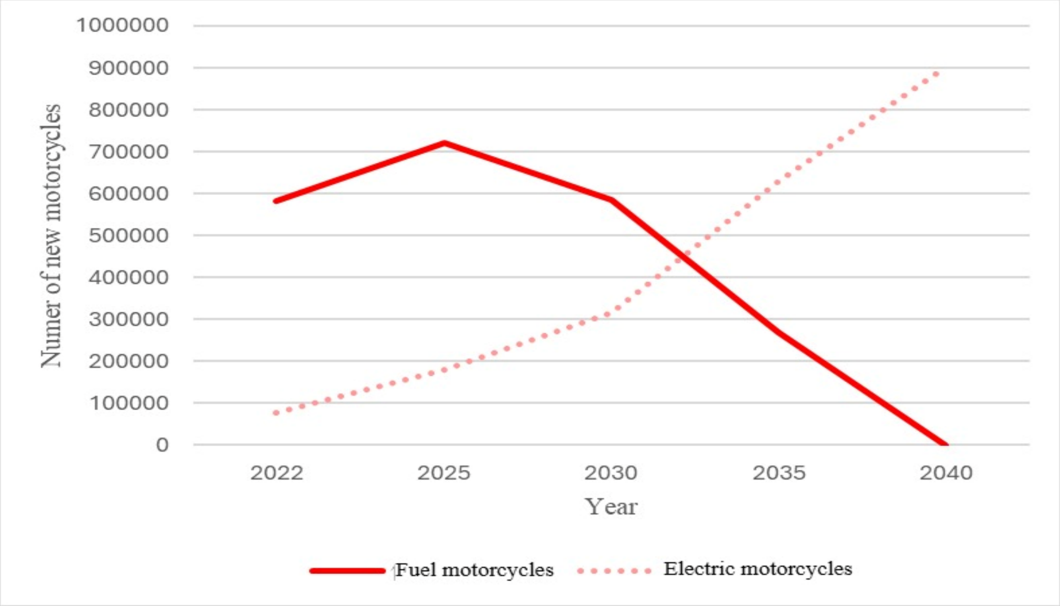
3. **High Oil Price Scenario** (S2):

This scenario simulates a sharp increase in international oil price, assuming an annual growth rate of 5%.

EV status and targets

2050 NET-ZERO TRANSITION- ELECTRIC & CARBON-FREE VEHICLES

Vehicle type	Target item	Now	Target			
		2022	2025	2030	2035	2040
E-bus	% in fleet	10%	35%	100%		
	NO. of registration	1,170	4,600	11,700		
EV	% of market share	4.4%	10%	30%	60%	100%
	% in fleet	0.5%	1.4%	7.3%	20.3%	43.2%
	Annual sales	16,106	38,000	114,000	228,000	380,000
	NO. of registration	34,160	101,365	519,365	1,431,365	3,027,365
E-scooter	% of market share	11.9%	20%	35%	70%	100%
	% in fleet	4.4%	7.9%	16.7%	34.7%	63.3%
	Annual sales	87,690	180,000	315,000	630,000	900,000
	NO. of registration	630,223	1,131,438	2,376,138	4,896,138	8,856,138



15| Results of CGE Simulation_1

1. GDP Impact:

GDP in S1 still grows 4.14% in 2025–2030, but turns slightly negative (–0.73%) by 2036–2040

→Under the EV policy scenario (S1), GDP grew by 4.14% in 2025–2030, outperforming the baseline (3.71%), which **differ from most literature stating a short-term economic decline** during electrification period.

Possible Explanation

- **2025–2030:** EV adoption increases steadily, while fuel motorcycle decline remains moderate → **Net new vehicle demand expands**, boosting GDP.
- **2031–2040:** EV growth accelerates and fuel motorcycles plummet → Traditional industries with higher multipliers shrink, while EV-related sectors contribute less → **GDP starts to decline**.
- **Extended interpretation:** The GDP drop **does not occur immediately** but emerges **once policy-driven structural substitution becomes dominant**.

Macro Indices	Scenario	2025-2030	2031-2035	2036-2040
GDP	Baseline	3.71	0.49	1.25
	S1	4.14	1.06	-0.73
	S2	2.22	-0.52	-0.93

16| Results of CGE Simulation_2

2. Investment:

Investment in S1 rebounds clearly after 2036 (2.18%), indicating growing capital formation in battery and energy-related sectors.

→Results show that EV rely less on conventional materials and more on emerging tech, meaning the production shock is more concentrated in legacy sectors.

3. Consumption:

Consumption in S1 slows in the early stage but recovers notably after 2036, reflecting reduced costs and improved consumer confidence.

Macro Indices	Scenario	2025-2030	2031-2035	2036-2040
Investment	Baseline	-4.05	-0.50	0.62
	S1	-1.54	0.22	2.18
	S2	-7.61	-4.06	-2.10
Consumption	Baseline	4.14	2.51	1.85
	S1	4.68	2.14	1.24
	S2	1.17	-1.41	-1.81
Import	Baseline	2.05	1.50	1.36
	S1	2.61	1.89	1.89
	S2	-4.27	-4.73	-3.97
Export	Baseline	5.06	1.54	0.55
	S1	4.75	0.47	-2.86
	S2	2.11	-2.02	-2.18

Results of CGE Simulation_3

4. Import:

S1 increases slightly, reflecting reliance on imported components like batteries and motor systems during early electrification.
S2 declines significantly suggesting reduced industrial activity and energy-related imports.
→Strengthening local supply chain resilience and domestic R&D is crucial to reduce import dependence and vulnerability to energy price shocks.

5. Export:

Decline in S1 is due to contraction in legacy fuel-powered vehicle exports, while electric vehicle supply chains have not yet fully integrated into global markets.

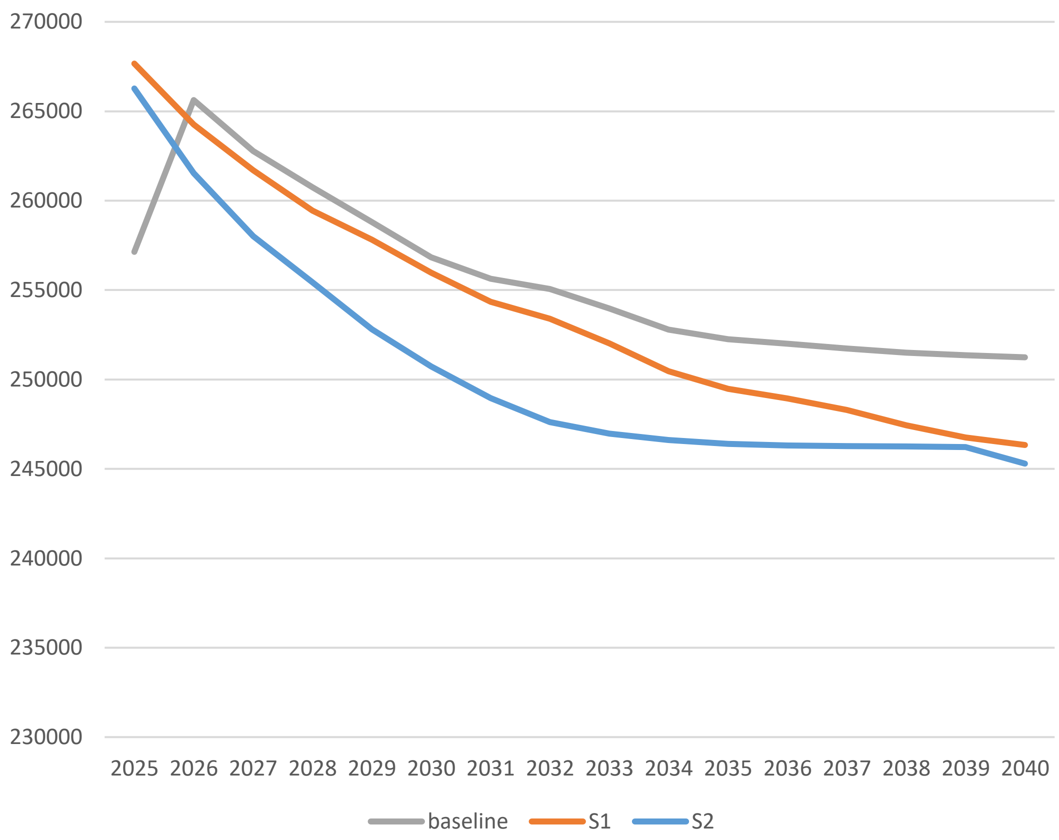
→Proactive development of export-oriented components like batteries and power systems is essential.

→Strategic export promotion and technological upgrading are needed to maintain export momentum during the electrification transition.

Macro Indices	Scenario	2025-2030	2031-2035	2036-2040
Investment	Baseline	-4.05	-0.50	0.62
	S1	-1.54	0.22	2.18
	S2	-7.61	-4.06	-2.10
Consumption	Baseline	4.14	2.51	1.85
	S1	4.68	2.14	1.24
	S2	1.17	-1.41	-1.81
Import	Baseline	2.05	1.50	1.36
	S1	2.61	1.89	1.89
	S2	-4.27	-4.73	-3.97
Export	Baseline	5.06	1.54	0.55
	S1	4.75	0.47	-2.86
	S2	2.11	-2.02	-2.18

18| Results of CGE Simulation (CO2 emission)_4

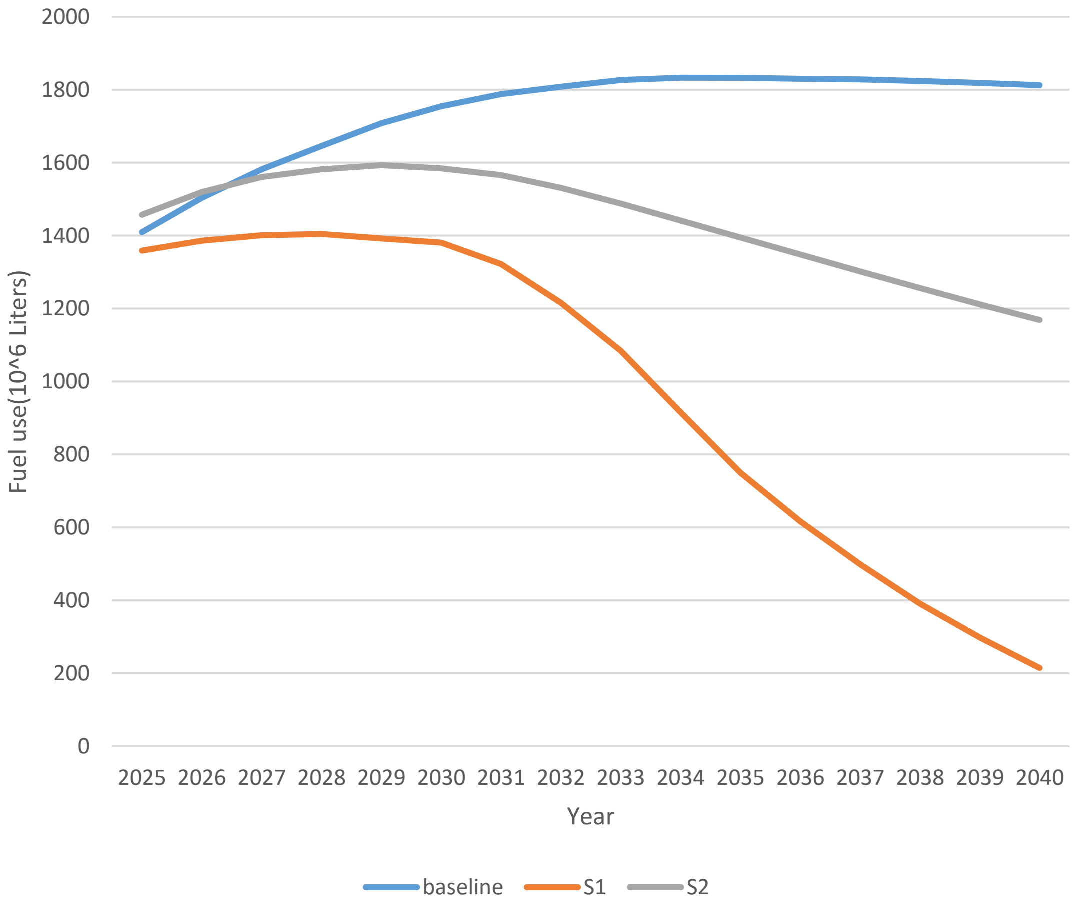
- **Baseline**: Emissions peak in 2026 (265 $MtCO_2e$), then slowly decline, staying above 252 $MtCO_2e$ by 2040.
- **S1**: Emissions decline steadily after 2026 due to electric motorcycle adoption, staying below baseline.
- **S2**: Shows the dramatic drop, reaching 245 $MtCO_2e$ by 2040 under sustained high oil prices.
- **Insights**: Policy and price signals are key to achieving GHG reduction targets.



19| Results of CGE Simulation (Fuel use)_5

Energy Substitution effect : Fuel Use (10^6 Liters)

- **Baseline (blue):** Fuel use steadily increases, reaching 18.5 million liters by 2040.
- **S1 (orange, policy scenario):** Sharp decline after 2029 due to electric motorcycle adoption; drops below 3 million liters by 2040.
- **S2 (gray, high oil price):** Gradual decline driven by market forces, reaching 12 million liters by 2040.



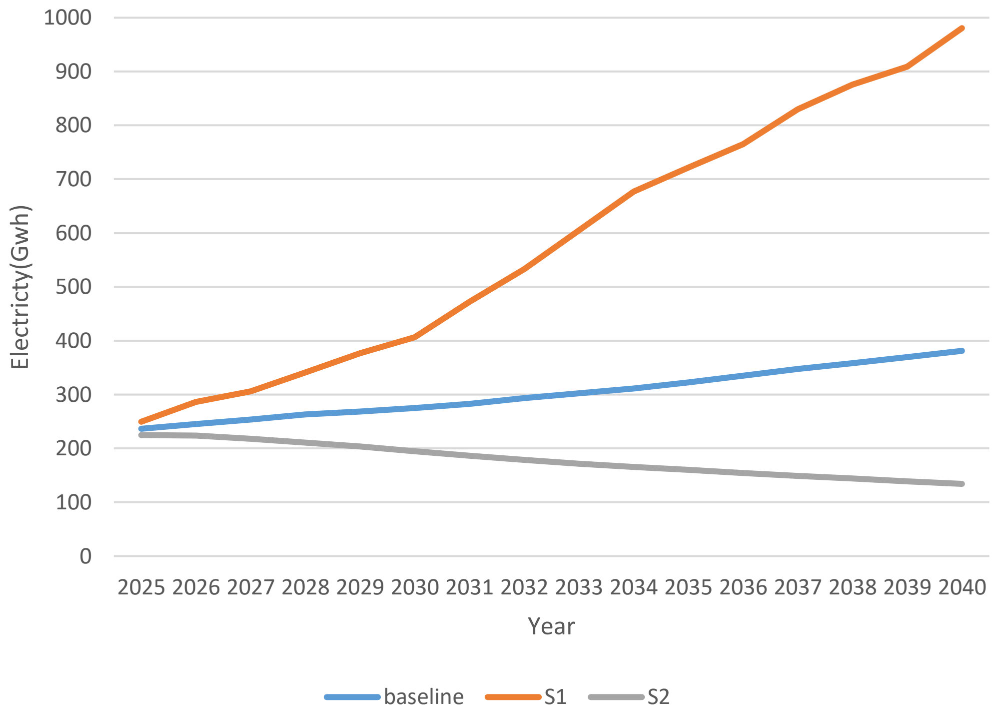
20| Results of CGE Simulation (Electricity use)_6

Energy Substitution effect : Electricity Use (Gwh)

- **Baseline (blue):** Moderate increase in electricity demand with slow EV growth.
- **S1 (orange, policy scenario):** Significant rise in electricity demand, surpassing 980 GWh by 2040.
- **S2 (gray, high oil price):** Limited electrification response to oil prices; electricity use remains much lower than S1.

📌 **Insights:**

- **S1** shows the strongest fuel-to-electricity transition.
- **S2** shows moderate shifts.
- **Baseline** reflects minimal structural change.



Concluding Remarks_1

- Comparing with fuel motorcycles, E-motorcycles emit less GHG during use phase, though slightly more in production. Lifecycle emissions of electric motorcycle are **15%** lower and advantage expected to grow with more renewable energy (e.g., low-carbon electricity)
- Using a CGE model we provide impact assessment of Taiwan's electric motorcycle policy aiming for 100% market share by 2040 from economic, environmental, and energy (3E) perspectives.

22| Concluding Remarks_2

- **Economic**:
  - Contrary to previous studies suggesting a short-term GDP decline from electric vehicle (EV) promotion, our simulation shows that GDP continues to grow in the short term (2025-2030).
  - This may be due to the **asymmetric trends in vehicle numbers**—electric motorcycles grow faster than the decline in fuel motorcycles. However, in the later stages (2031-2040), as fuel motorcycles are gradually phased out, the economic impact becomes more significant.
- **Environmental**:
  EVs reduce long-term emissions effectively. Use-phase emissions are much lower than fuel motorcycles and will improve further with a greener power grid.
- **Energy**:
  With rapid EV deployment in the later period, electricity demand increases substantially, while fuel consumption declines significantly.

Policy Recommendations

1. **Decarbonize the Power Grid with Motorcycle Electrification**
   - The effectiveness of electrification in reducing emissions depends on simultaneous **power sector decarbonization**.
   - Accelerate the integration of renewable energy and enhance grid resilience to prevent indirect emissions from rising due to increased electricity demand
2. **Balance Battery Production Localization with Environmental Sustainability**
   - Another key focus of motorcycle electrification policy is the localization of lithium-ion battery production. However, LCA results show that EVs have higher emissions in the production phase than conventional vehicles. Therefore, future policies may emphasize **low-carbon manufacturing processes**, **material recycling**, and **environmental monitoring**.

Many Thanks
for Your Listening.
Comments are Welcome.

Appendix

Emission intensity of six major sectors and emission of electric motorcycle

- $x = (\frac{z_{ij}}{x_j})x + y = Ax + y$
- $x = (I - A)^{-1}y$
- $E = \varepsilon x = \varepsilon(I - A)^{-1}\hat{y}$

Sector	Fuel combustion ($MtCO_2e$)	Non-fuel combustion ($MtCO_2e$)	Electricity-Related Emissions ($MtCO_2e$)	Total Emissions ($MtCO_2e$)	Output Value (NT$ million)	Emission Intensity (tCO_2e / NT$ million)
Energy	19.13	0.33	18.06	37.51	2,949,453	12.72
Manufacturing	35.68	22.14	99.50	157.31	31,150,725	5.05
Transportation	34.64	0.00	0.79	35.43	1,146,851	30.89
Residential & Commercial	7.94	0.00	49.88	57.82	19,597,754	2.95
Agriculture	1.33	3.28	1.68	6.29	796,688	7.90
Environment	0.00	2.84	0.00	2.84	211,987	13.40