Development of Energy Management Strategy for Range Extended Hybrid Scooter with HiL Validation and Well-to-Wheel CO2 Emissions Evaluation

CHENG-CHIH LEE

Advisor : Jung-Ho Cheng, Ph.D.

APRDC, NTU, July 2021

doi:10.6342/NTU202102024

Introduction

This project presents the research and development of the Energy Management Strategy (EMS) for a scooter series Range-Extended Hybrid System (REHS). We first built a Range-Extended Hybrid System with an 8kW traction motor, a 4 Ah battery system and a 4-stroke gasoline Internal Combustion Engine (ICE) generator for verification.

After considering subsystem specification and efficiency, an Integrated Rule-Based Energy Management Strategy is developed through Simulink simulation. Then as for the EMS is applied through a prototype VCU (Vehicle Control Unit), a CiL (Controller-in-Loop) test is executed to confirm the accuracy and stability. Finally, the verification is completed through HiL (Hardware-in-Loop) test with AVL BME Dyno and dSPACE RTI computer.

This project at the end took Well-to-Wheel (WtW) CO2 emission calculation and obtained thorough conclusion over the application of REHS on Scooter.

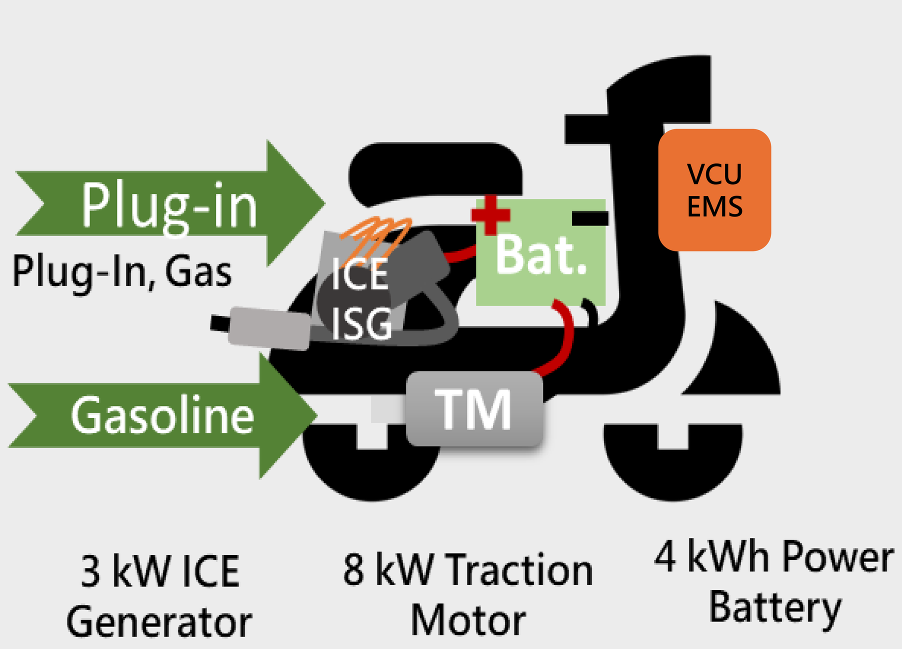
Procedure and Approach

This project focuses on the development process and benefit evaluation of an energy management strategy for hybrid electric power systems applied to two-wheeled vehicles. The target system of this research is a plug-in series hybrid electric drive system, which consists of a traction motor, an Internal Combustion Engine-Generator set, and a lithium battery pack that can be charged.

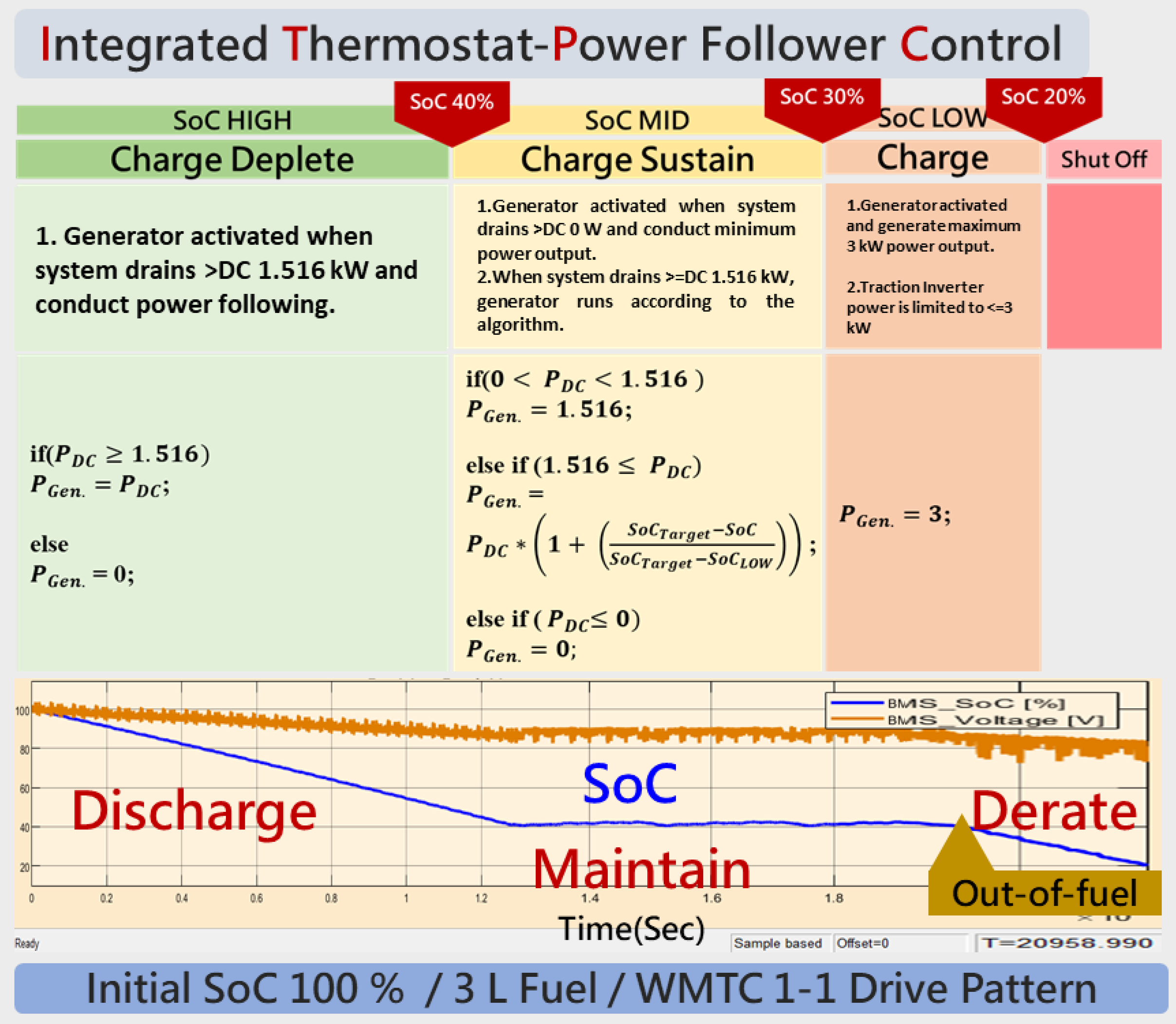
The process includes an investigation of the system's performance, limitations, and operating conditions, followed by the establishment of a forward mathematical model for simulation and analysis.

Based on this model, an energy management strategy is designed and implemented on a physical controller. The strategy is then evaluated through Controller-in-the-Loop (CiL) testing using an RTI (Real-Time Interface) computer and the mathematical model and finally validated through Hardware-in-the-Loop (HiL) testing to verify the simulation results and control design.

Target Vehicle System Architecture

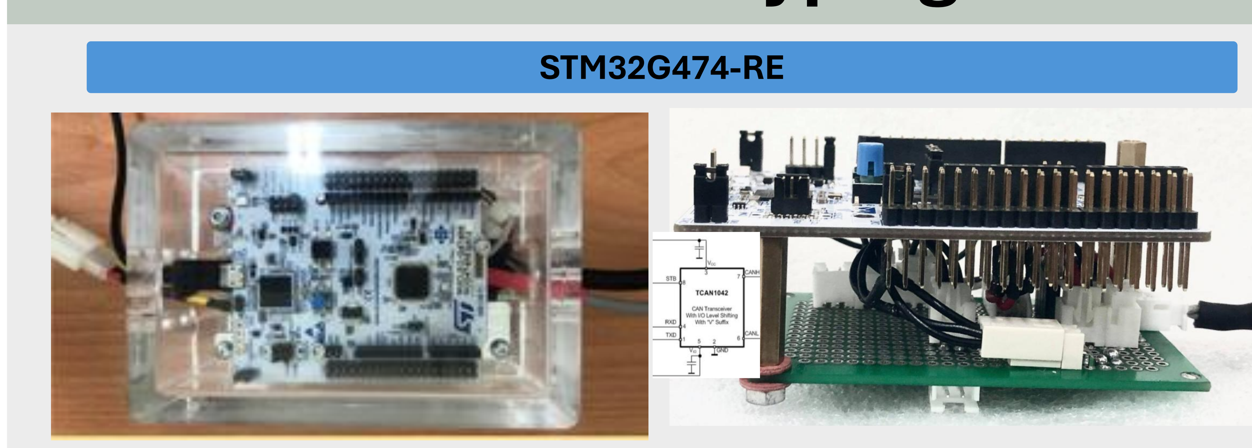


Energy Management Strategy (EMS)

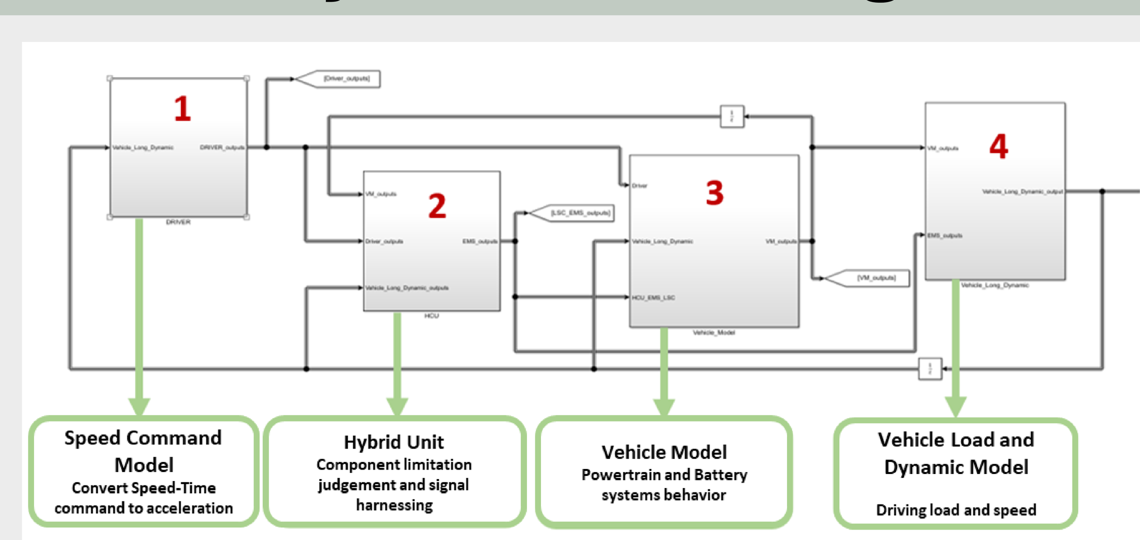


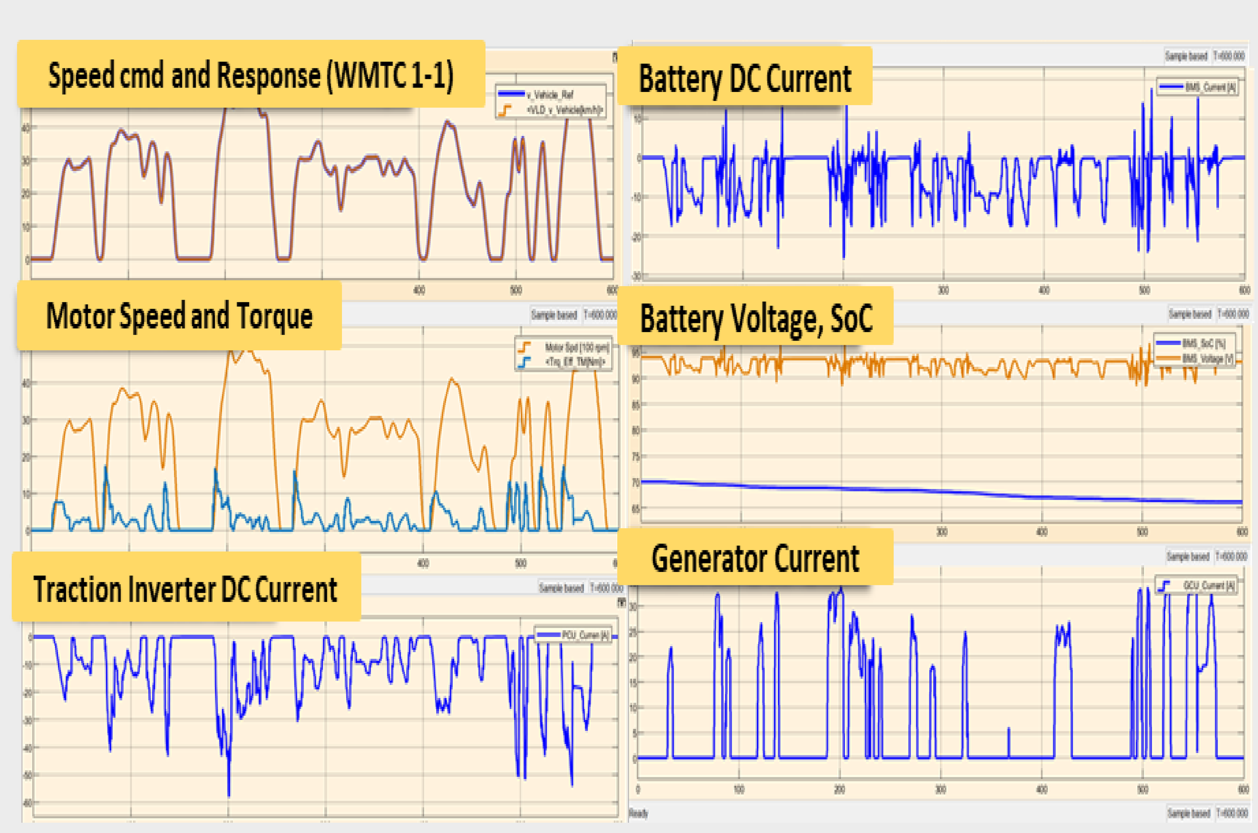
VCU Prototyping

STM32 CubeIDE

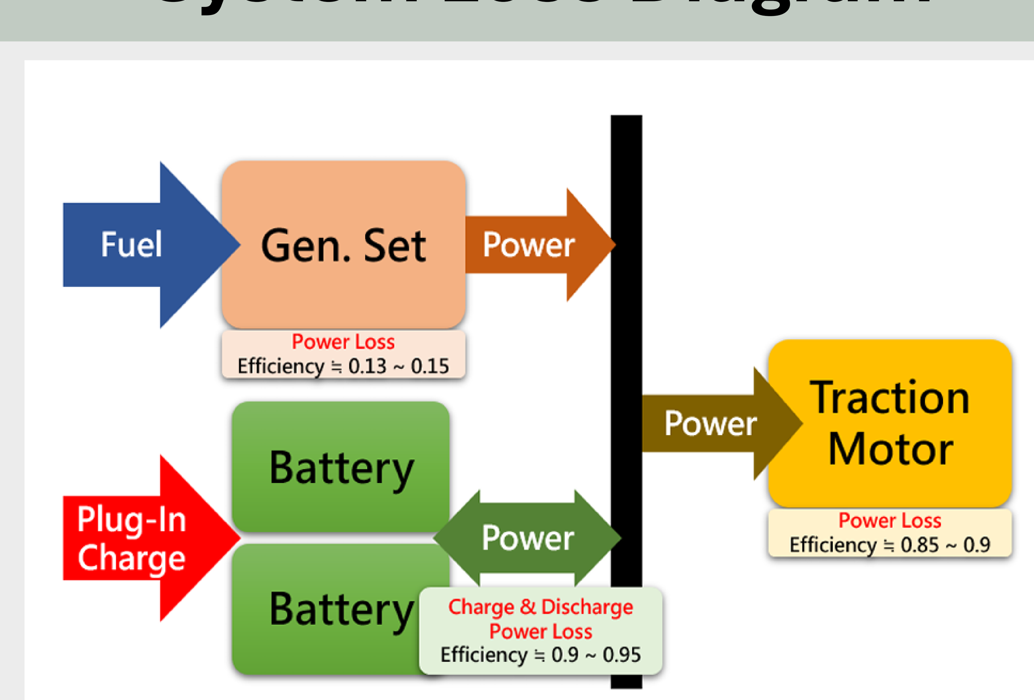


System Modeling

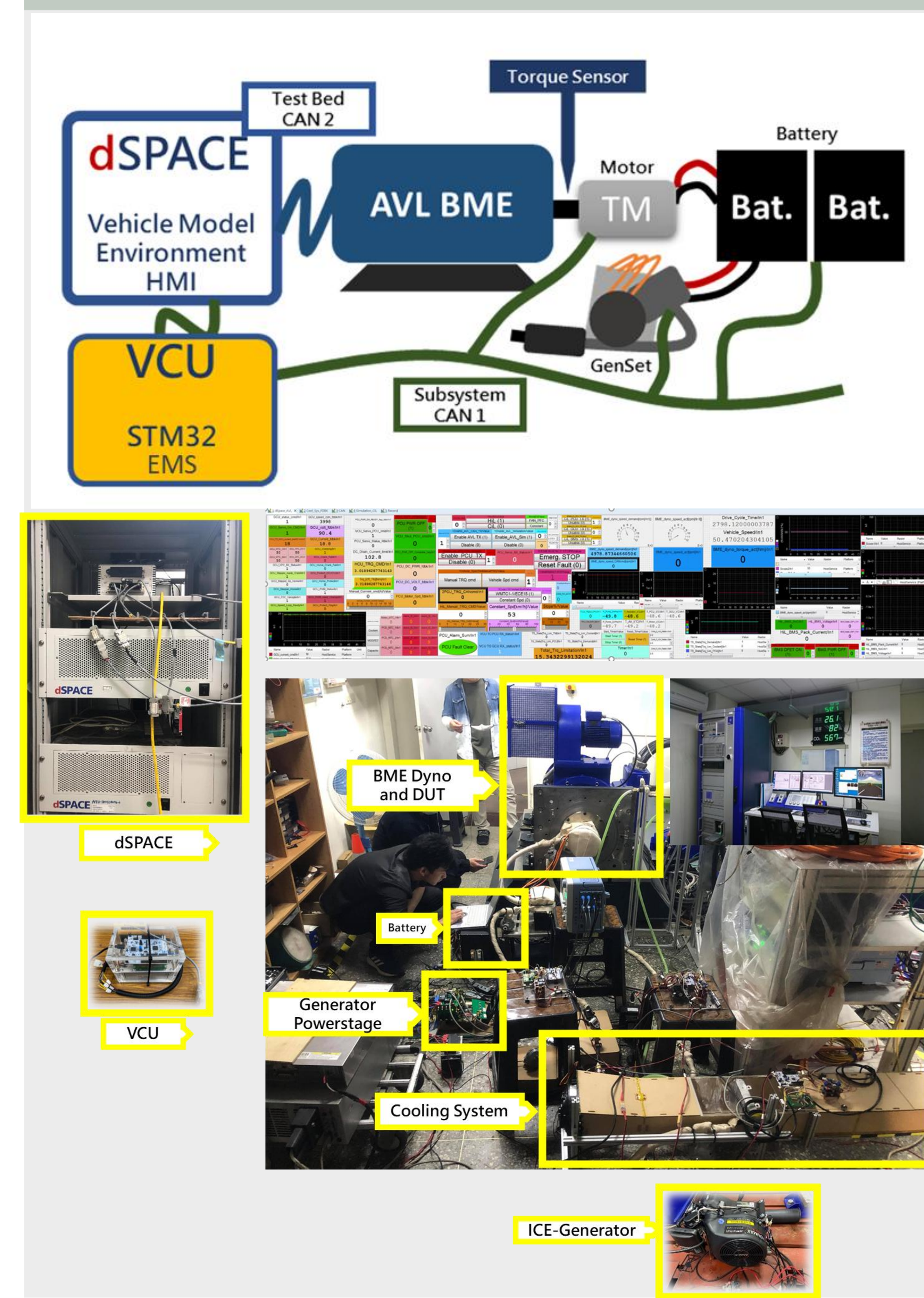




System Loss Diagram

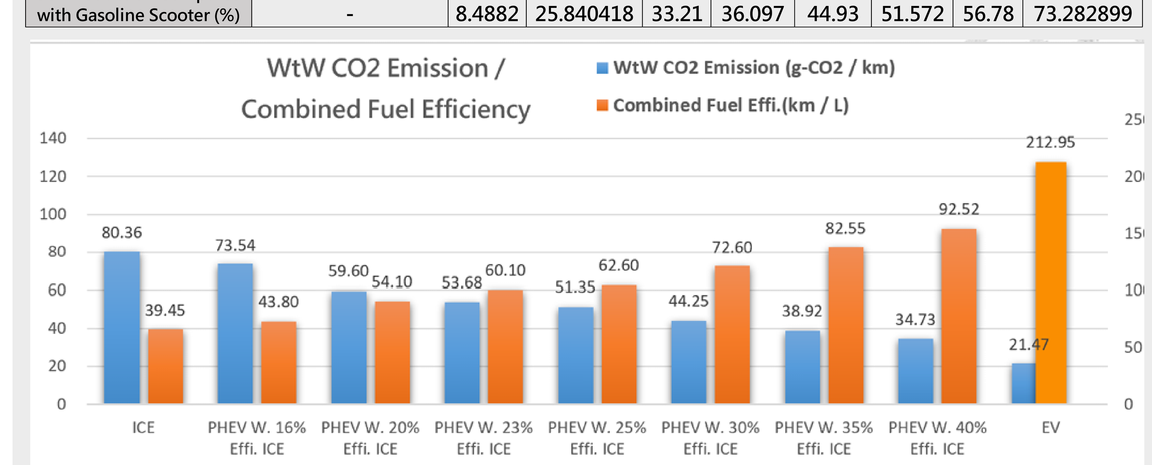


Test Bench Setup



Efficiency Analysis Results

	Conventional Gasoline Scooter (Commercial Model)	Series-Range-Extended Hybrid Electric Scooter							Commercial Electric Scooter
Engine Efficiency(%)	-	16.23	20	23	25	30	35	40	-
Overall Fuel Efficiency(km / L)	39.45	43.8	54.1	60.1	62.6	72.6	82.55	92.52	212.95
Fuel Efficiency Improvement over Gasoline Scooter (%)	-	11.027	37.135615	52.34	58.682	84.03	109.25	134.5	0
Overall Electric Energy Efficiency(km / kWh)	-	-	-	-	-	-	-	-	23.95
Maximum Driving Range(km)	250	138.2	170.70537	189.5	197.31	228.7	259.8	291.3	76.666667
WtW CO2 (kg / km)	0.080363511	0.0735	0.0595972	0.054	0.0514	0.044	0.0389	0.035	0.0214708
CO2 Reduction Compared with Gasoline Scooter (%)	-	8.4882	25.840418	33.21	36.097	44.93	51.572	56.78	73.282899



Conclusion

This project developed an energy management strategy for a series range-extended hybrid power system applied to two-wheeled vehicles.
An Integrated Thermostat and Power Controller (ITPC) strategy was proposed, combining the concepts of Thermostat Control and Power Follower while considering system protection and optimal operating efficiency.

A mathematical model was established for simulation using MPGe-equivalent fuel consumption and official test cycles from Taiwan's Bureau of Energy. Despite the prototype's low generator efficiency (13%), it achieved a composite fuel economy of 42.17 km/L, surpassing most gasoline scooters in the same class.

Further analysis showed that improving generator efficiency to 25% and adding a simple regenerative braking strategy could boost fuel efficiency by 50% over conventional scooters.

A Well-to-Wheel (WtW) CO_2 emission analysis also indicated that the proposed system significantly reduces CO_2 emissions, doubles the driving range of pure electric vehicles, and eliminates range anxiety.