

<The 69th session of the EVE IWG>

Use of Simulations for Driving Ranges of BEVs

The-K Hotel Seoul, Seoul, South Korea

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National Institute of
Environmental Research



HANYANG UNIVERSITY

Driving Range Regulations for Battery Electric Vehicles in South Korea

- An Overall Process of Driving Range Certification for BEVs
 - Driving range certification process controlled by NIER

NIER: National Institute of Environmental Research
 MOE: Ministry Of Environment

OEMs who own certified testing facilities

<BEV Manufacturer>



✓ **Testing** BEVs driving range by OEM

Submitting Certification Documents

- OEM Self-test results
- BEVs information
- Test information

<MOE, NIER>



- ✓ Review
- ✓ Screen

Utilize Simulation

Qualified

Disqualified

<MOE, NIER>



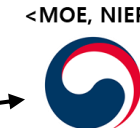
✓ Issue a certificate



Qualified

✓ **Testing** BEVs driving range by Agency

Disqualified



✓ Issue a certificate



- ✓ Request supplement
- ✓ Reject certification

<Market>



OEMs who do not own appropriate testing facilities

<BEV Manufacturer>



Submitting Certification Documents

- BEVs information

<MOE, NIER>



✓ **Testing** BEVs driving range by Agency

<MOE, NIER>



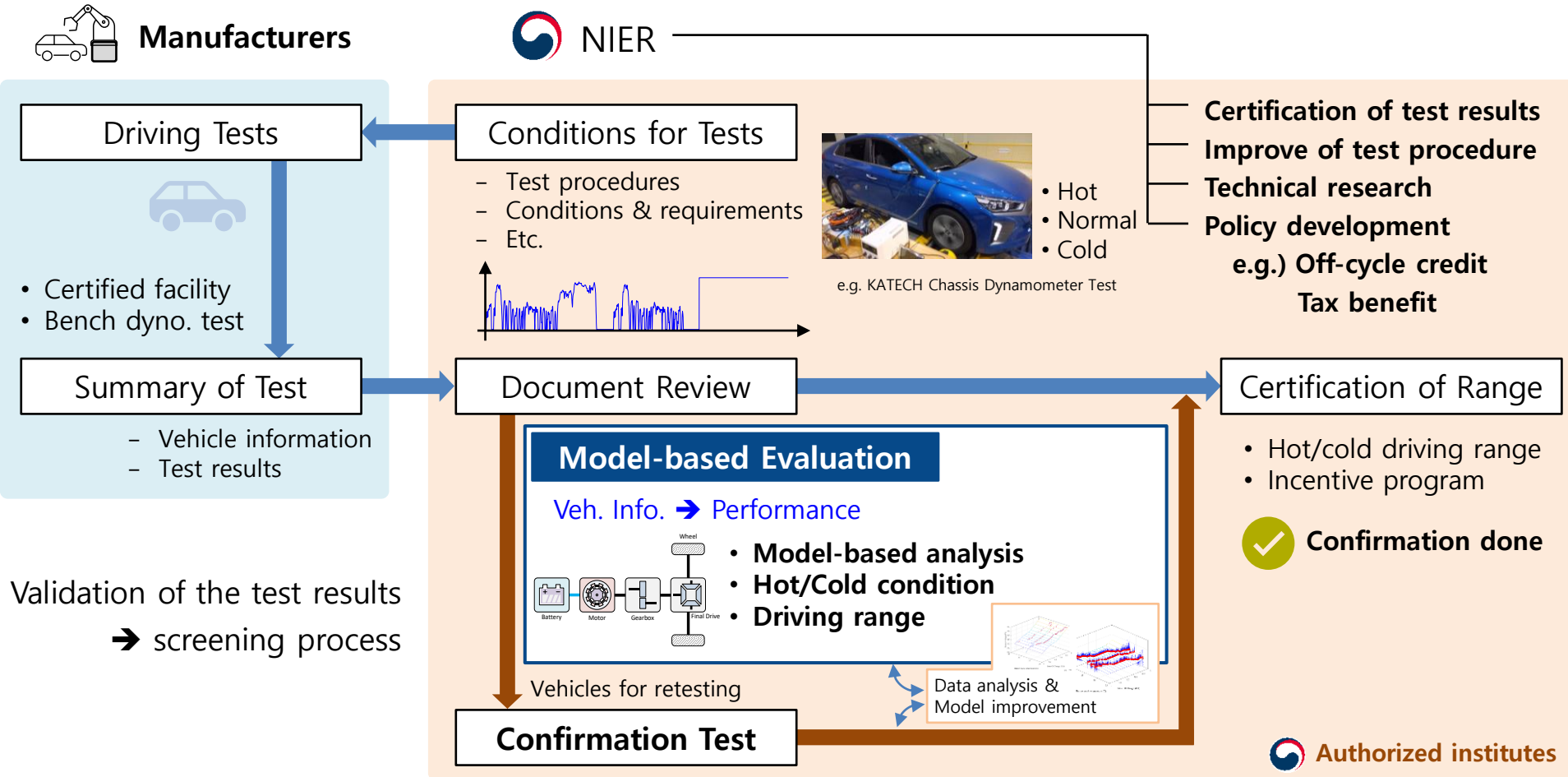
✓ Issue a certificate

<Market>



Driving Range Regulations for Battery Electric Vehicles in South Korea

- An Overall Process of Driving Range Certification for BEVs
 - Results validation based on simulation techniques for supporting the BEV Certification



Speed profiles: MCT

MCT driving test

BEV Energy Flow

Electrical Aux Energy (kWh) → HVAC Output Energy (kWh) → Motor Loss + Mechanical Loss

Battery Output Energy (kWh) → Inverter Input Energy (kWh) → Dyno Input Energy (kWh)

Comparative study: test vs. simu.

Specification	Motor	Battery	Reduction Gear	Wheel	Vehicle	Heating	LDC
Motor Max Torque	Motor Efficiency Map	Battery Capacity	Mechanical Efficiency	Transfer Efficiency	Equivalent Inertia Weight	HVAC Power	Electrical AUX Power
Motor Efficiency Map	Battery Capacity	Mechanical Efficiency	Transfer Efficiency	Equivalent Inertia Weight	HVAC Power	Electrical AUX Power	Electrical AUX Power
Battery Capacity	Internal Resistance	Mechanical Efficiency	Transfer Efficiency	Equivalent Inertia Weight	HVAC Power	Electrical AUX Power	Electrical AUX Power
Internal Resistance	SOC Range	Mechanical Efficiency	Transfer Efficiency	Equivalent Inertia Weight	HVAC Power	Electrical AUX Power	Electrical AUX Power
SOC Range	Wheel Radius	Mechanical Efficiency	Transfer Efficiency	Equivalent Inertia Weight	HVAC Power	Electrical AUX Power	Electrical AUX Power
Wheel Radius	Equivalent Inertia Weight	Mechanical Efficiency	Transfer Efficiency	Equivalent Inertia Weight	HVAC Power	Electrical AUX Power	Electrical AUX Power
Equivalent Inertia Weight	Road Load Coefficient	Mechanical Efficiency	Transfer Efficiency	Equivalent Inertia Weight	HVAC Power	Electrical AUX Power	Electrical AUX Power
Road Load Coefficient	HVAC Power	Mechanical Efficiency	Transfer Efficiency	Equivalent Inertia Weight	HVAC Power	Electrical AUX Power	Electrical AUX Power
HVAC Power	Electrical AUX Power	Mechanical Efficiency	Transfer Efficiency	Equivalent Inertia Weight	HVAC Power	Electrical AUX Power	Electrical AUX Power
Electrical AUX Power		Mechanical Efficiency	Transfer Efficiency	Equivalent Inertia Weight	HVAC Power	Electrical AUX Power	Electrical AUX Power

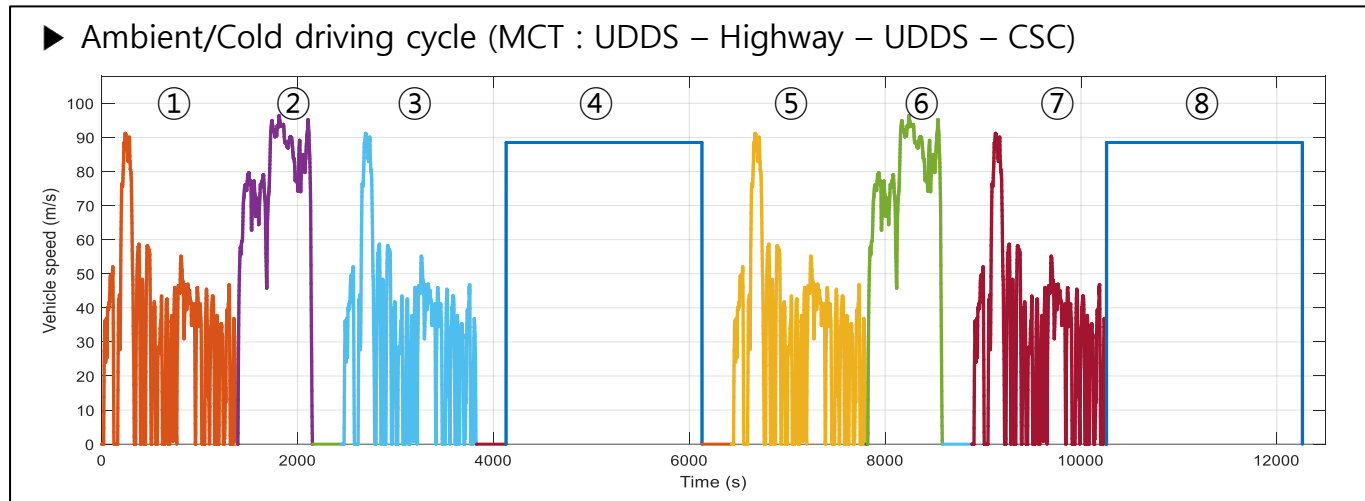
Vehicle Spec.

Estimated Range

Driving Range Regulations for Battery Electric Vehicles in South Korea

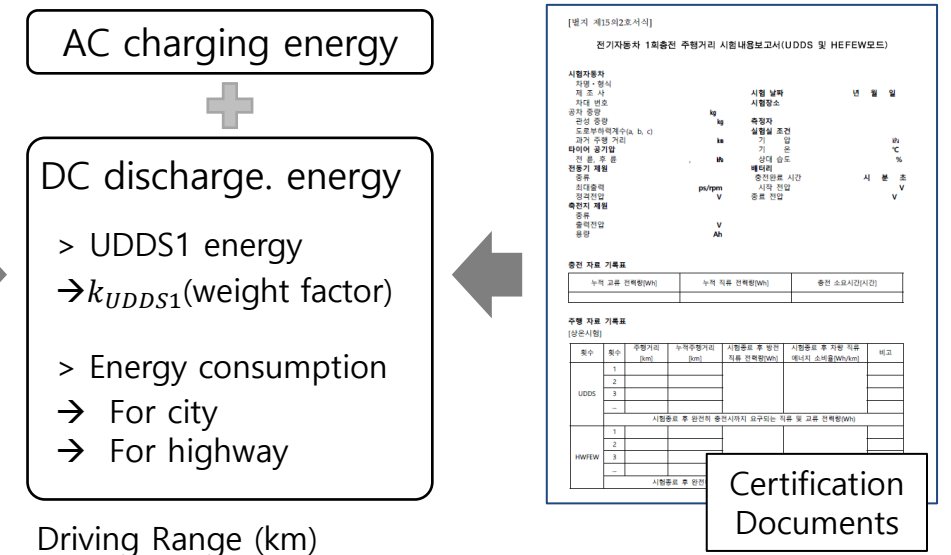
- An Overall Process of Driving Range Certification for BEVs
 - MCT-based BEV testing certification for City/Highway/Combined driving range

Multi-Cycle Test Procedure for BEV Driving Range



Mode	UDDS1	HWFET1	UDDS2	CSCm	UDDS3	HWFET2	UDDS4	CSCe
Range								
Energy								
	EC_city	EC_highway	FE_city	FE_highway	FE_combined	Range_city	Range_highway	Range_combined
Ordinary	0.2554	0.3757	2.3184	1.5764	1.9132	152.7317	103.8506	130.7352
Cold	0.3346	0.4376	2.6238	2.0067	2.3049	166.1319	127.0590	148.5491

Driving Range Calculation



$$= \frac{\text{Usable Battery Energy [kWh]}}{\text{Each cycle DC discharge energy consump. [kWh/km]}}$$

National Institute of Environmental Research



Certification of Driving Ranges (including cold test)

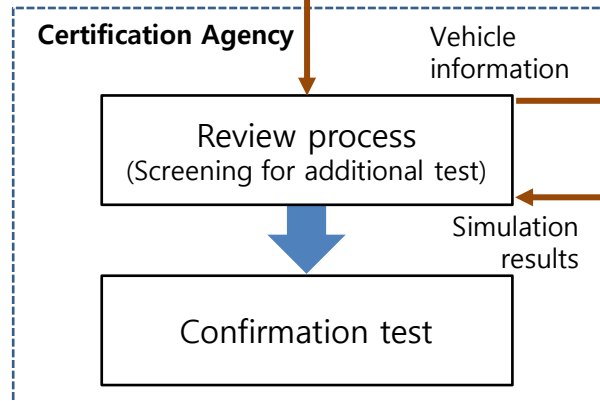
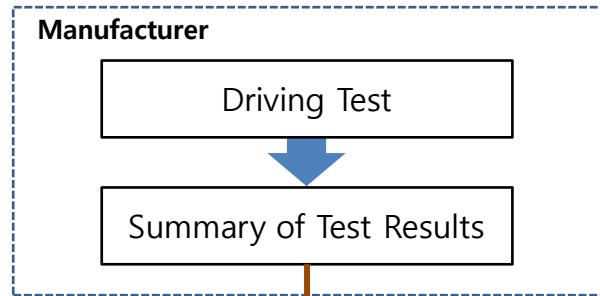


Incentive program by the government

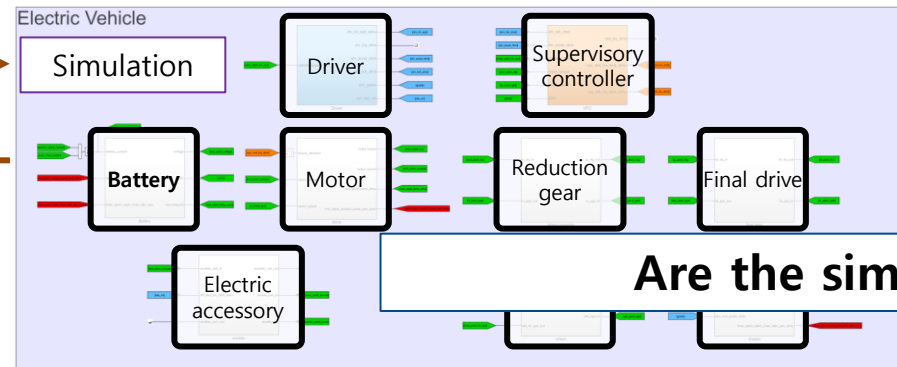
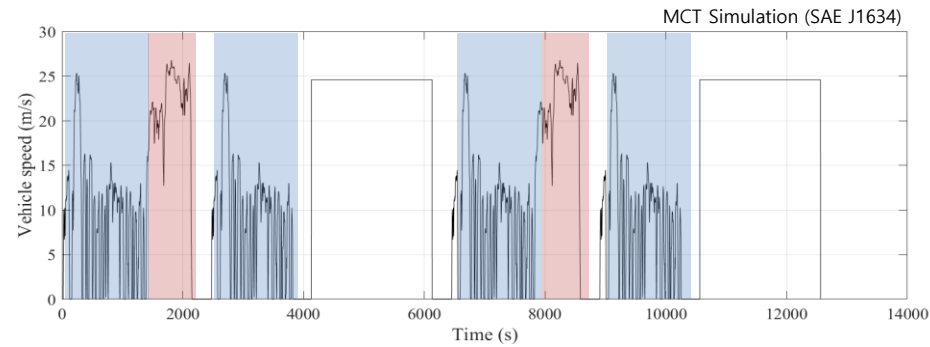
Simulation Tool Development for Driving Range Evaluations

- A Simulation Tool for Driving Range Analysis of BEVs
 - Overview of BEVs driving range simulation process

Certification Process



Driving Range Test Simulation



Are the simulation good enough?

App Development & Deployment



Simulation Tool Development for Driving Range Evaluations

- Model Validation by Analyzing Results Obtained by Real-world Driving Tests
 - Develop and validate models based on MCT time-series test data

Vehicle Specification



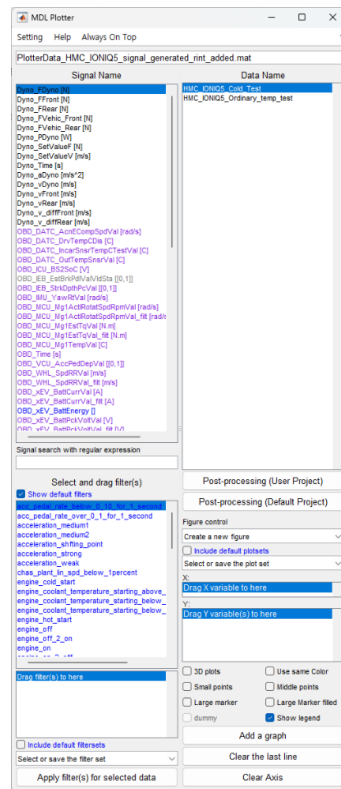
Hyundai IONIQ5 MY21

Battery	Lithium-ion Polymer 111.2 Ah, 72.6 kWh 180 cells, 653 V
Motor	PMSM 350 Nm, 168 kW
AER	300 miles (482 km)
Gear	10.65
FE (EPA)	132/98 MPGe (city/hwy)
0-60mph	7.4 s

Test Cycle

UDDS, HWFET, MCT

Driving Range & Analysis Study



Test data analysis procedure

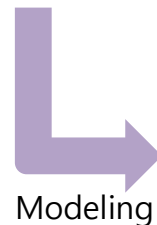
Performance analysis

$$\eta_{mot} = \left(\frac{P_{mech}}{P_{elec}} \right)^{-k}$$

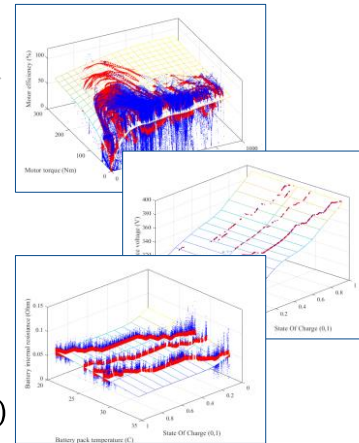
$$R_i = f(SOC, T_{bat})$$

$$V_{OC} = f(SOC, T_{bat})$$

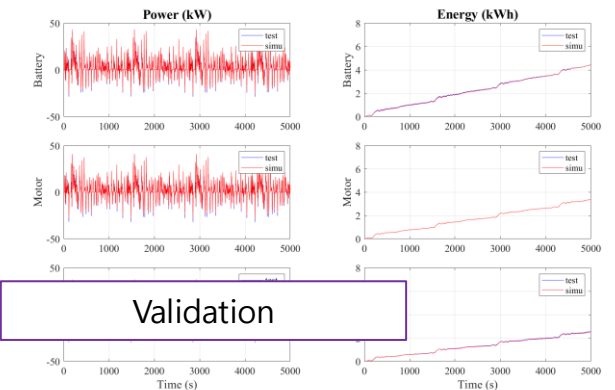
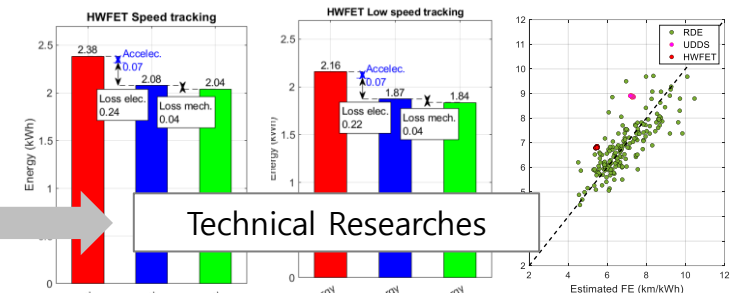
Parameter estimation



Modeling



Model Validation & Database



Simulation Tool Development for Driving Range Evaluations

- Comparative Study: Results of Driving Range By Tests vs. Simulations
 - The development is in-progress by considering additional impacts on the driving ranges.

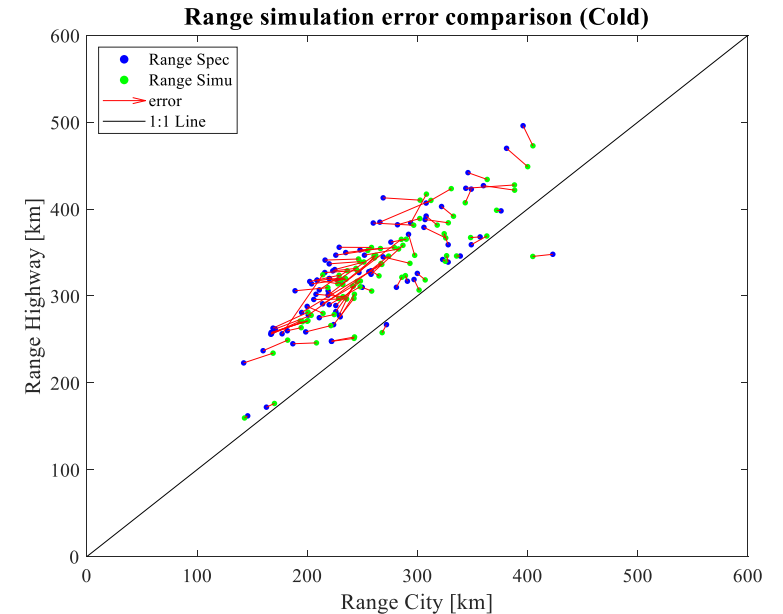
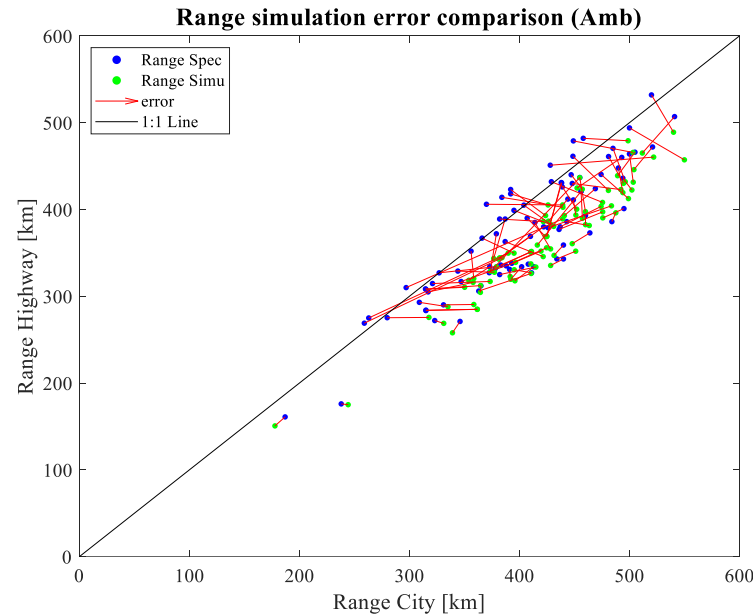
BEVs Specifications

BEVs Specifications provided by the manufacturer

Vehicle information (spec.)

Simulation

Simulation



Cases that deviates from the trends → Confirmation tests

Thank you!

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