COMPARING AND PARAMETERIZING THE ELECTRICAL ENERGY CONSUMPTION MODELS IN SUMO

YUN-PANG FLÖTTERÖD, MICHAEL BEHRISCH, PETER WAGNER

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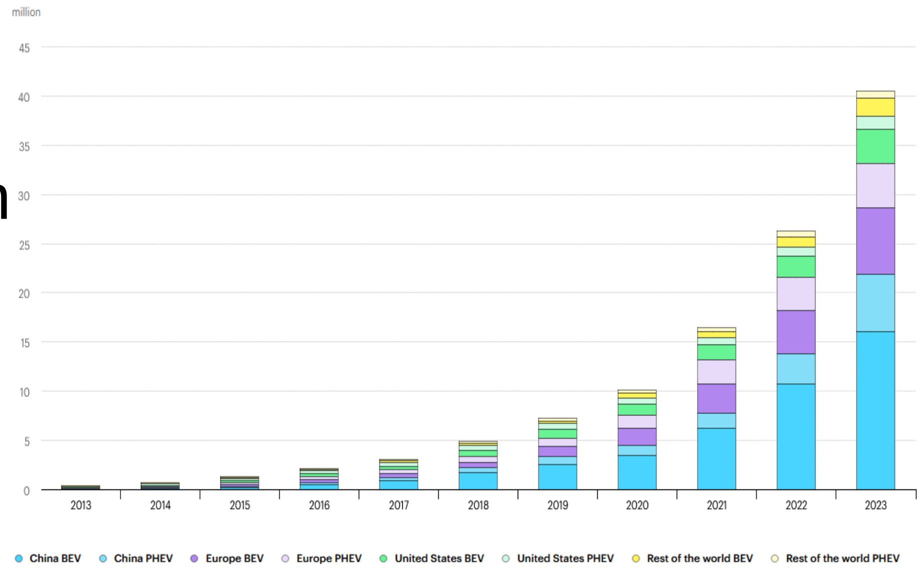
Motivation

- The popularity of electric vehicles (EVs) is increasing rapidly worldwide.
- EV facilities need to be enhanced to meet the increasing demands of EVs.
- Electric energy consumption models can facilitate strategy evaluations together with traffic simulation and emission models.
- 4 Models in SUMO
  - how well can these models reflect real-world battery consumption?
  - which model would be suitable for which conditions?
  - What possible difference in battery consumption would there be between these models?



https://www.iea.org/reports/global-ev-outlook-2024/trends-in-electric-cars

Electric energy consumption models in SUMO

Characteristics	HBEFA	PHEMlight	EVM	MMPEVEM
Data source	data across Europe and from PHEM	PHEM	individual vehicle data	individual vehicle data
Required input	vehicle categories	vehicle categories	12 parameters per vehicle type	16 parameters per vehicle type
Method	polynomial curve fitting	Calculation of energy consumed by vehicle movement and on-board systems		
Versions	HBEFA2, HBEFA3, HBEFA4	PHEMLight, PHEMlight5	EVM	MMPEVEM
BEVs	HBEFA4+ / 5 categories (12 classes)	4 categories (6 classes)	x (unlimited)	x (unlimited)
HEVs	x (HBEFA4+)	x	-	-
Fuel consumption	CO_2, CO, NO_x, PM_x, HC	CO_2, CO, NO_x, PM_x, HC	-	-
Separable auxiliary consumption	-	x	x	x
Licence required	no	yes (2 free classes)	no	no

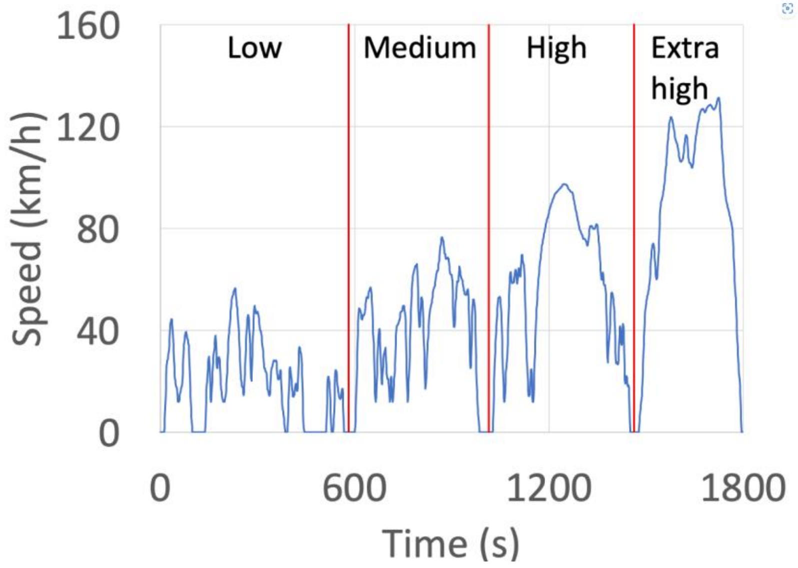
Parameterization extension of PHEMlight

- Purpose:
  - increase the flexibility to deal with different vehicle types and loading situations
  - enable a fair model comparison

Parameter	Defintion
maximumPower	the maximum power which the vehicle can achieve.
frontSurfaceArea	the front surface area of the vehicle
airDragCoefficient	the air resistance coefficient of the vehicle
rollDragCoefficient:	the rolling resistance coefficient of the vehicle
constantPowerIntake	the constant power consumption
wheelRadius	the wheel radius of the vehicle
mass	the curb weight of the vehicle with standard equipment
loading	additional loading, that the vehicle has, e.g. passengers, goods
rotatingMass	the mass during vehicle rotation, which corresponds to the mass of the internal rotating elements

World harmonized Light vehicle Test Procedure (WLTP)

- World harmonized Light vehicle Test Cycle (WLTC)
  - Replace the New European Driving Cycle (NEDC)
  - Provide more realistic assessments for measuring standardized energy consumption and pollutant emissions from vehicles
  - is designed with a more demanding test procedure and driving profile for being able to provide figures closer to real-world driving behaviour
- Setup:
  - 5 types of vehicles in the MMPEVEM paper by Koch et al
  - WLTC dataset class 3b
  - All constant power consumption: 360 W
  - The SUMO tool emissionsDrivingCycle



source: transportpolicy.net

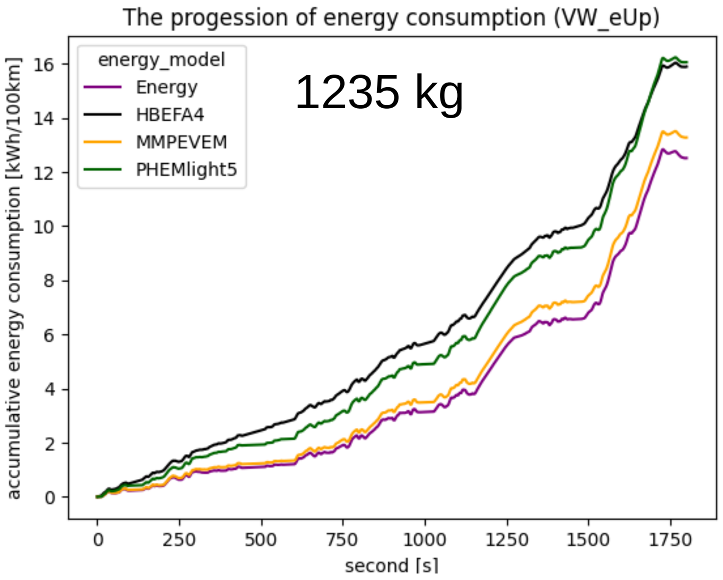
WLTC - overall result

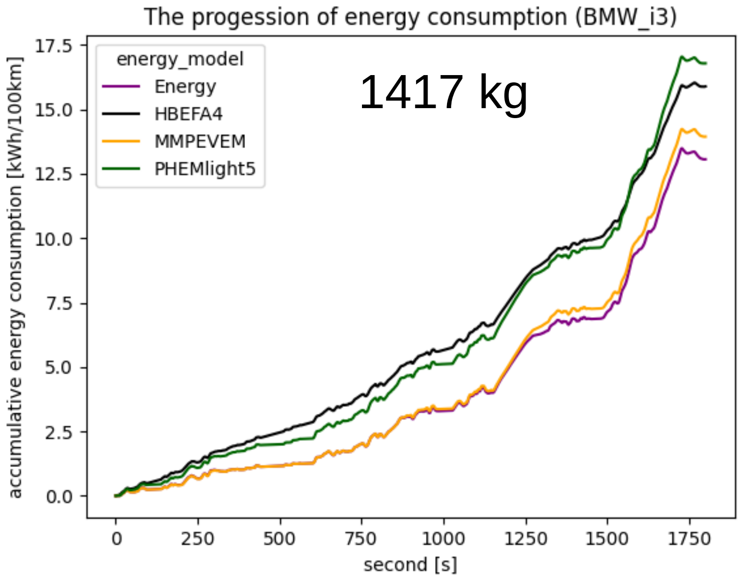
- All values of HBEFA4 are the same at a certain charging loss
- At a 10 % charging loss
  - MMPEVEM’s estimates highly correspond to the manufacturers’ data
  - PHEMlight5 tends to overestimate.
  - EVM tends to underestimate, but close to MMPEVEM’s estimates.
- Consumption ranking:
  - All the same except HBEFA4
- Default setting in SUMO
  - Different model uses represent different vehicle types.

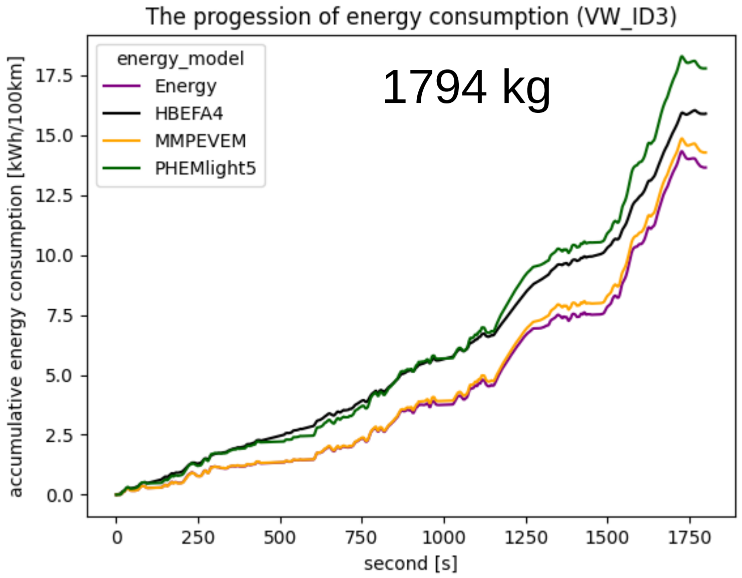
Unit: kWh/100 km

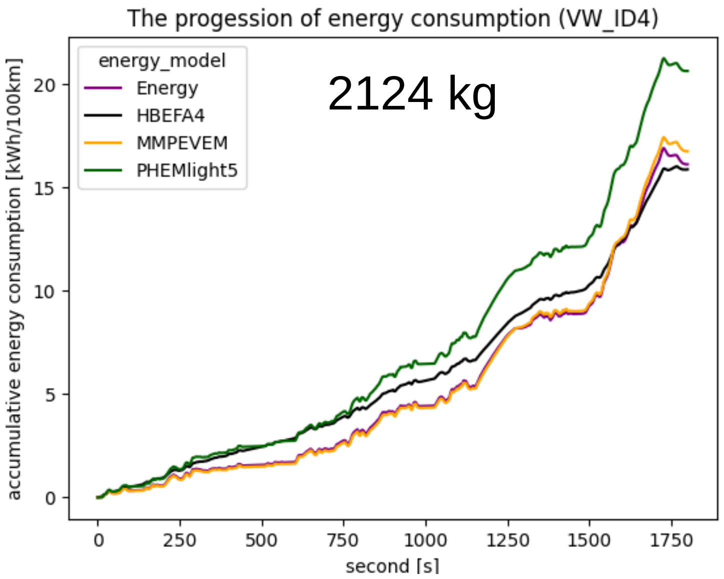
Vehicle type (mass)	HBEFA4	PHEMlight5	EVM	MMPEVEM	MMPEVEM [7]	Data from the manu-facturers [7]
BMW (1417 kg)	15.89(0%) 16.73(5%) 17.66(10%)	16.79(0%) 17.67(5%) 18.65(10%)	13.06(0%) 13.75(5%) 14.51(10%)	13.94(0%) 14.68(5%) 15.49(10%)	- - 15.5(10%)	15.3 - 16.3
VW e-Up (1235 kg)	15.89(0%) 16.73(5%) 17.66(10%)	16.05(0%) 16.90(5%) 17.84(10%)	12.51(0%) 13.17(5%) 13.90(10%)	13.27(0%) 13.97(5%) 14.75(10%)	- - 14.8(10%)	14.5 - 14.9
VW ID.3 (1794 kg)	15.89(0%) 16.73(5%) 17.66(10%)	17.78(0%) 18.72(5%) 19.76(10%)	13.65(0%) 14.36(5%) 15.16(10%)	14.27(0%) 15.02(5%) 15.86(10%)	- - 15.9(10%)	15.4 - 15.9
VW ID.4 (2124 kg)	15.89(0%) 16.73(5%) 17.66(10%)	20.66(0%) 21.75(5%) 22.95(10%)	16.14(0%) 16.99(5%) 17.93(10%)	16.77(0%) 17.65(5%) 18.64(10%)	- - 18.6(10%)	18.2 - 18.5
SUV (2100 kg)	15.89(0%) 16.73(5%) 17.66(10%)	24.46(0%) 25.75(5%) 27.18(10%)	19.96(0%) 21.01(5%) 22.18(10%)	21.34(0%) 22.46(5%) 23.71(10%)	- - 23.71(10%)	-
SUMO default (1500 kg)	15.89(0%) 16.73(5%) 17.66(10%)	24.15(0%) 25.42(5%) 26.84(10%)	13.58(0%) 14.30(5%) 15.09(10%)	13.25(0%) 13.94(5%) 14.72(10%)	- - -	-

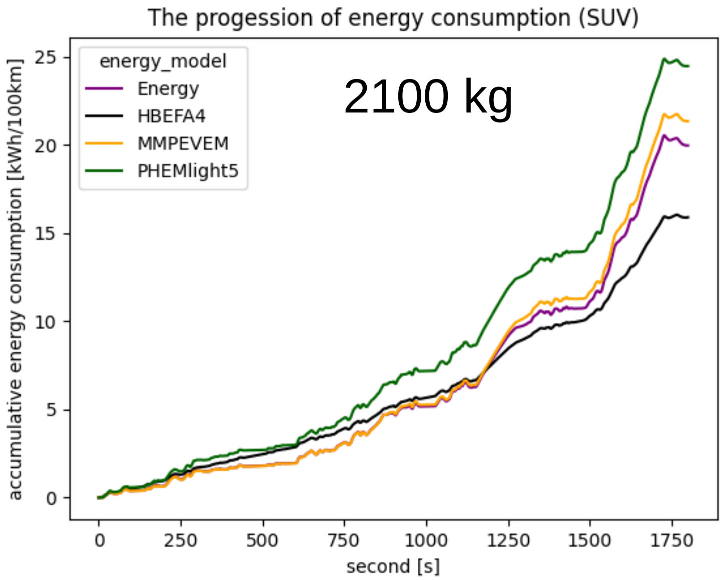
WLTC - cumulative result





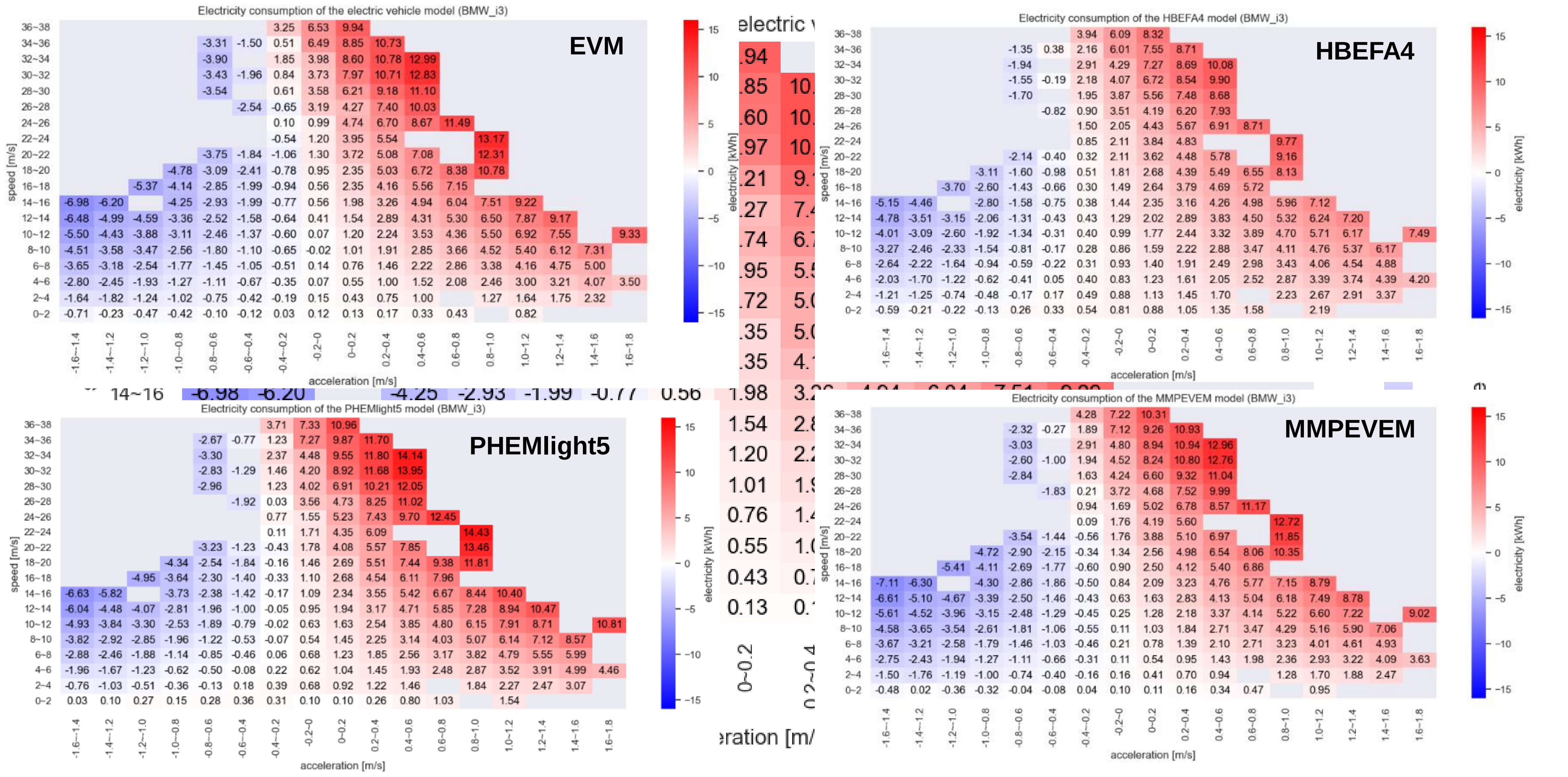






Yun-Pang Flötteröd, Institute of Transportation Systems, 2024.05.14

WLTC – relationship between speed, acceleration and energy consumption (BMW i3 - EVM) (1/2)



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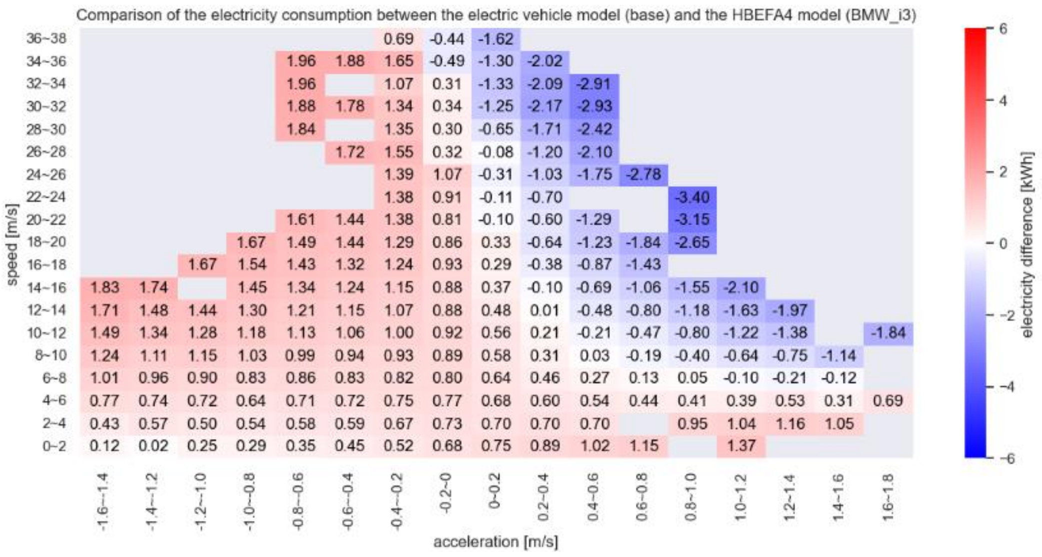
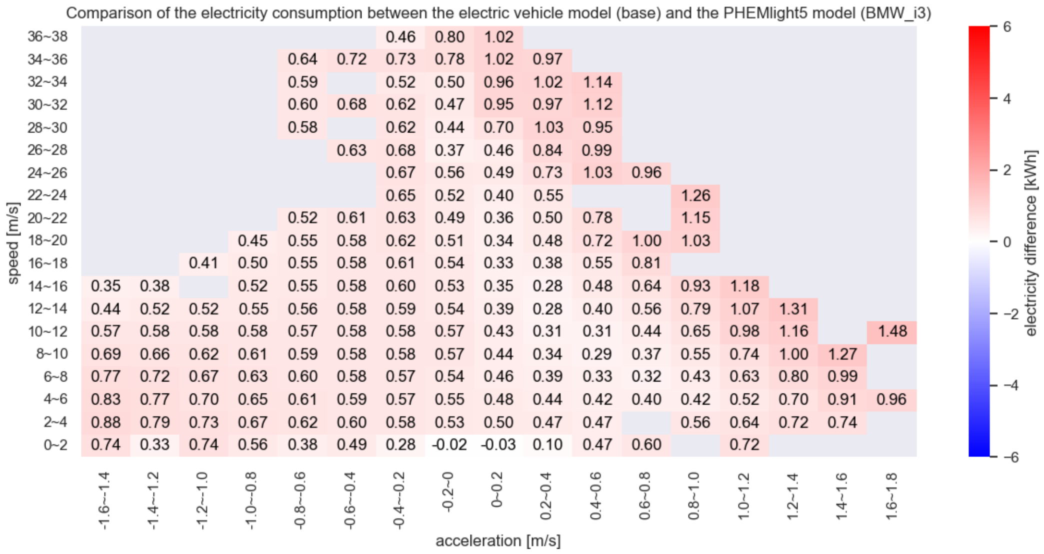
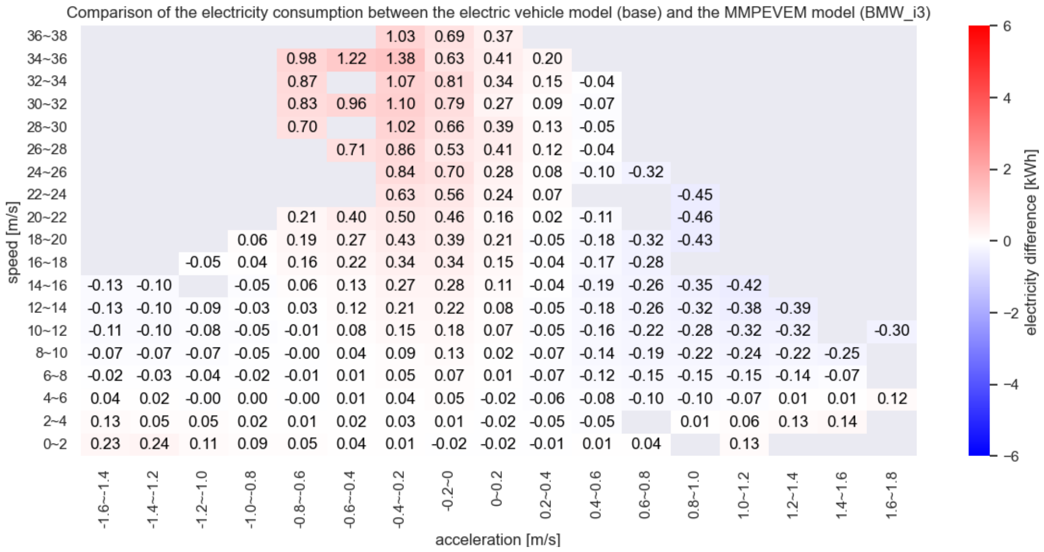


EVM vs. HBEFA4

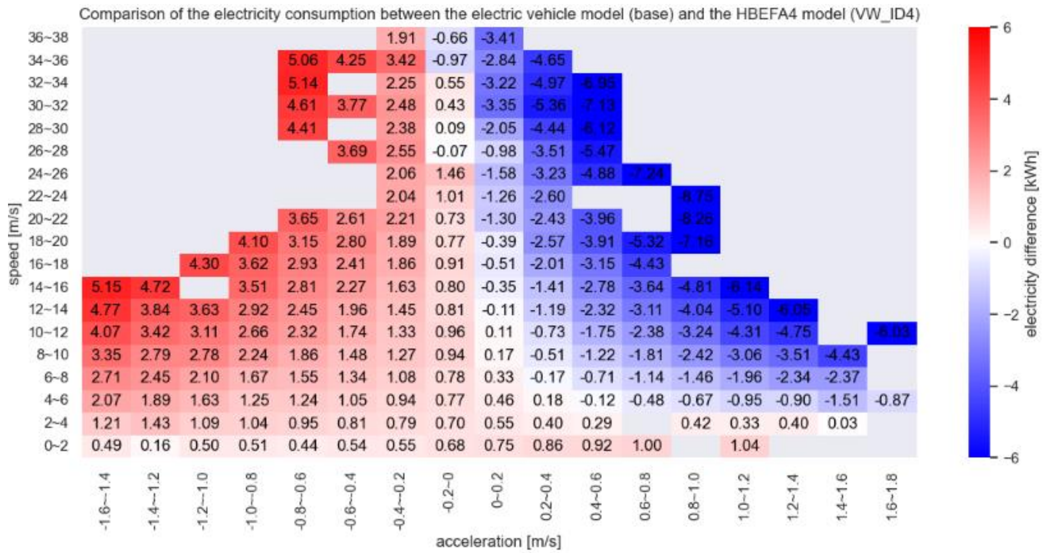


EVM vs. PHEMlight5

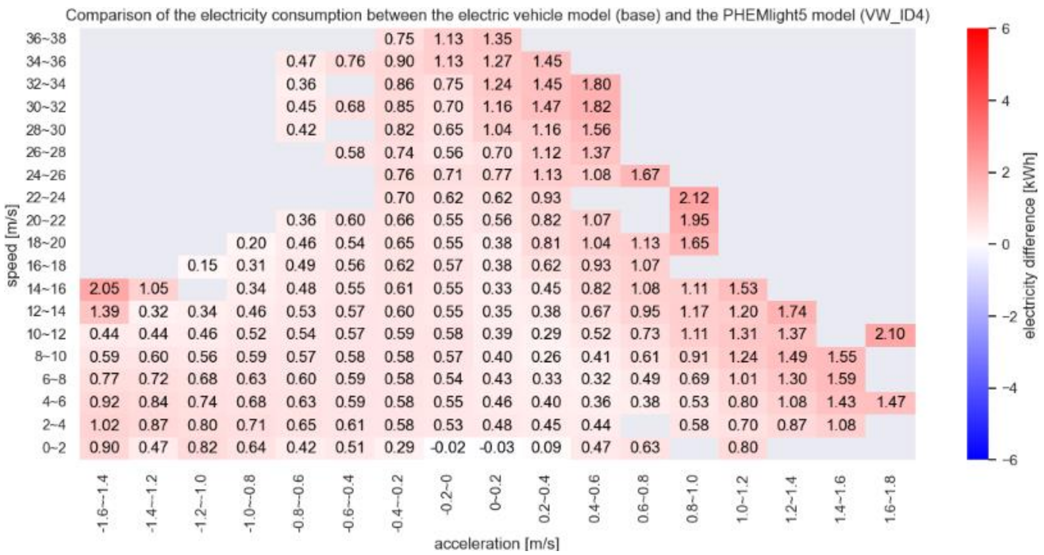


EVM vs. MMPEVEM

WLTC – relationship between speed, acceleration and energy consumption (VW ID.4 - EVM)

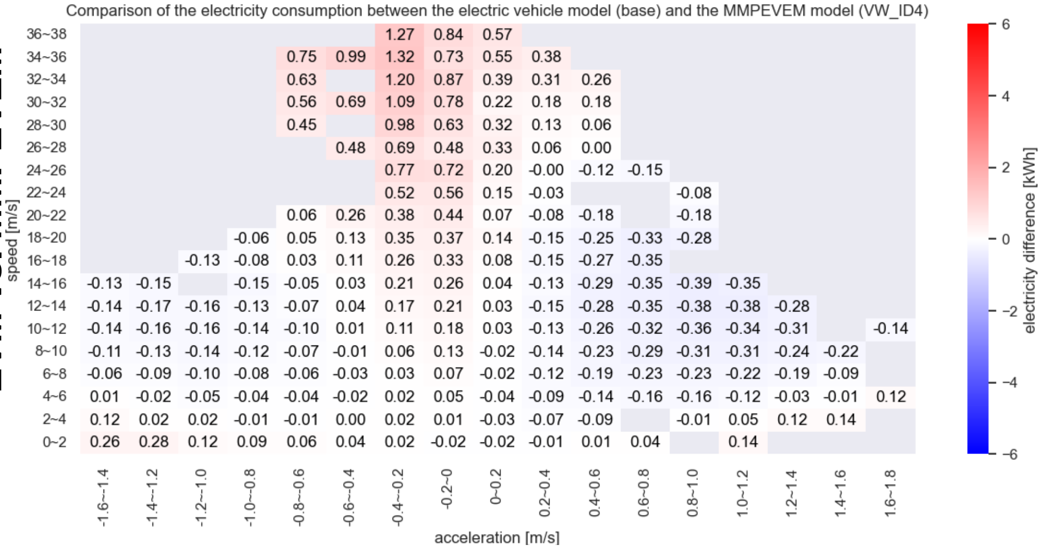


EVM vs. HBEFA4

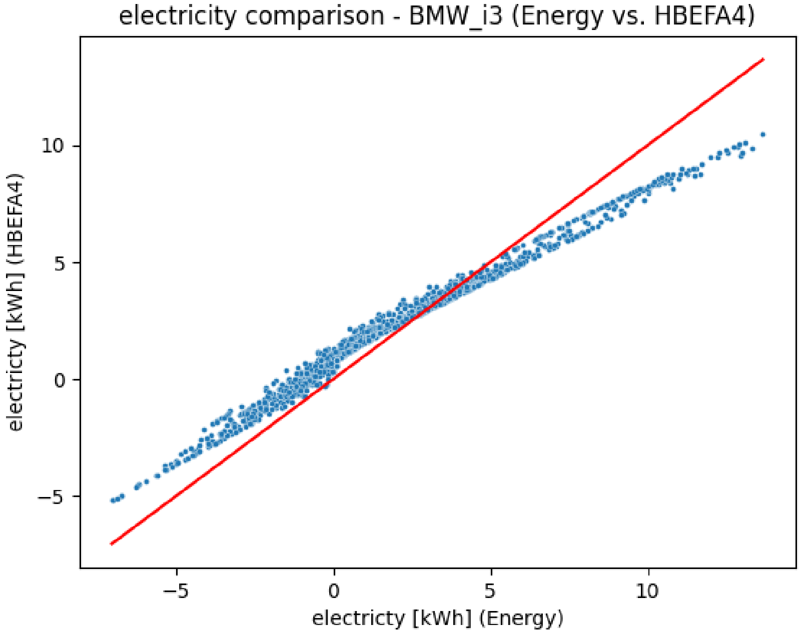


EVM vs. PHEMlight5

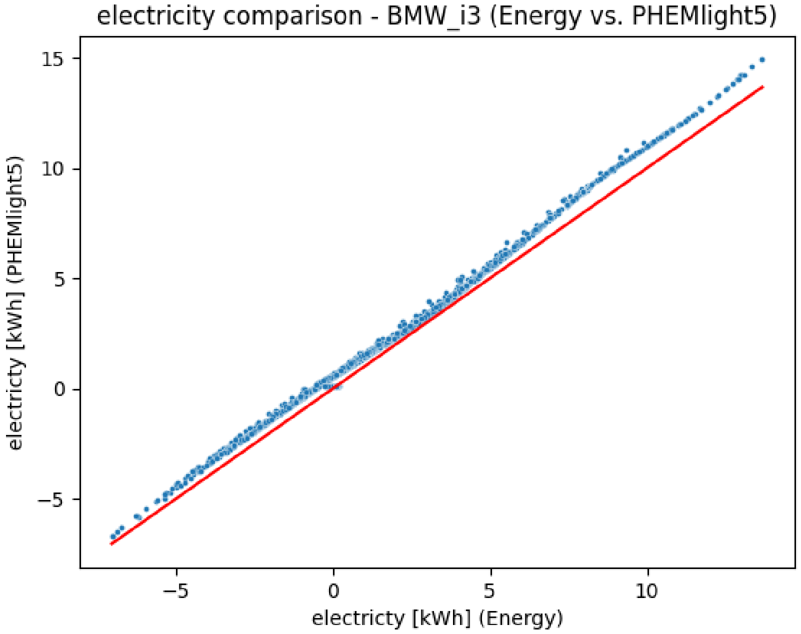
EVM vs. MMPEVEM



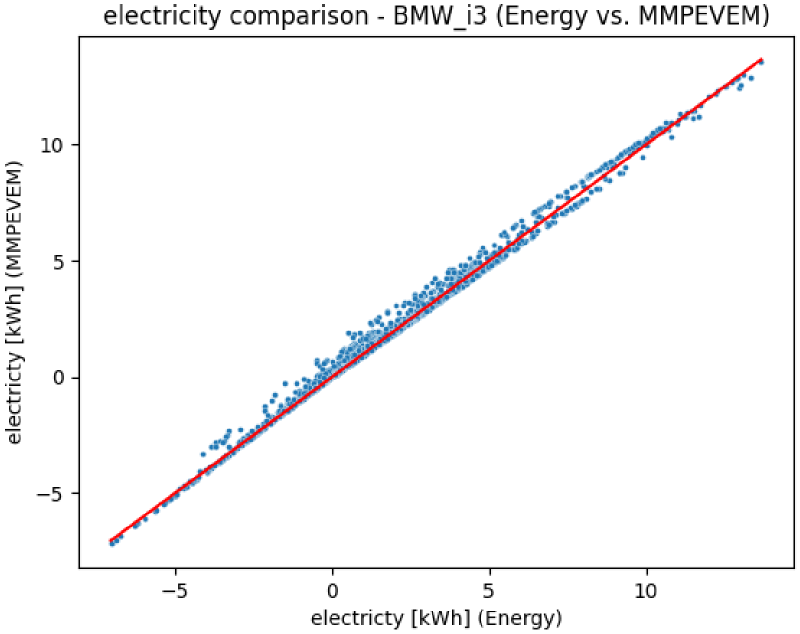
WLTC – fitness check (BMW i3)



EVM vs. HBEFA4

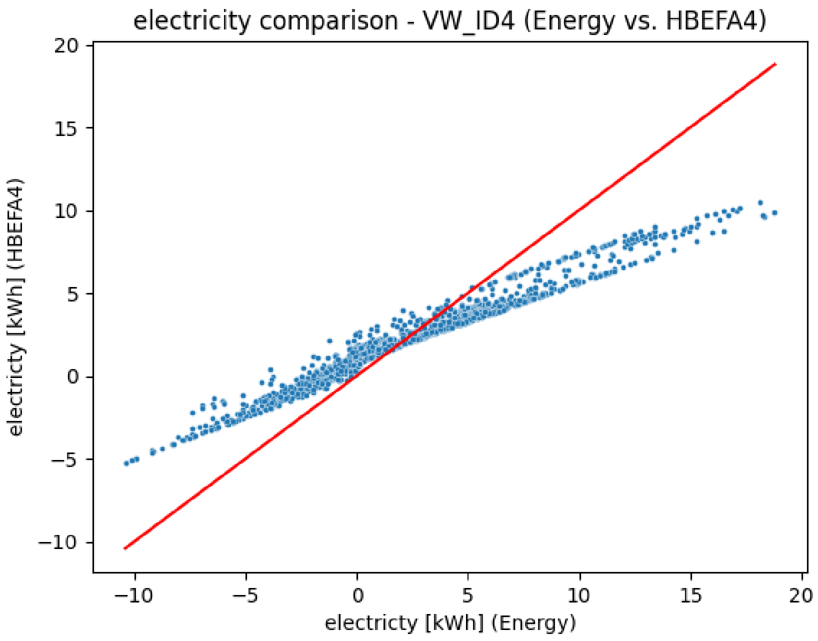


EVM vs. PHEMlight5

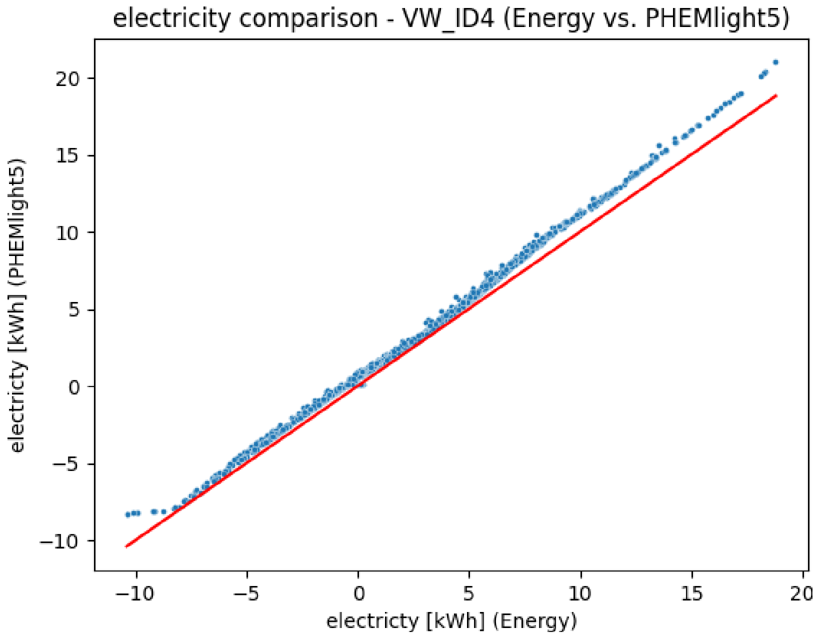


EVM vs. MMPEVEM

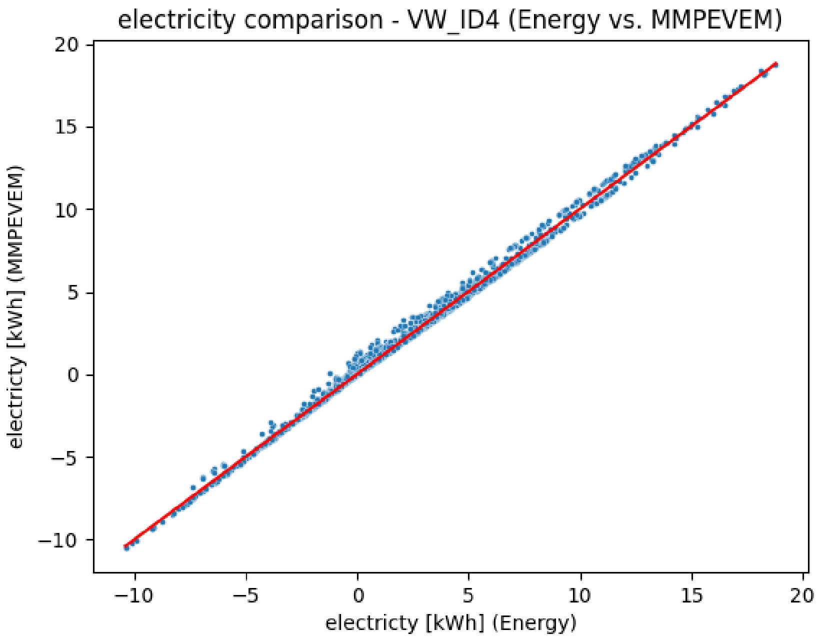
WLTC – fitness check (VW ID.4)



EVM vs. HBEFA4



EVM vs. PHEMlight5



EVM vs. MMPEVEM

Highway with constant travel speed

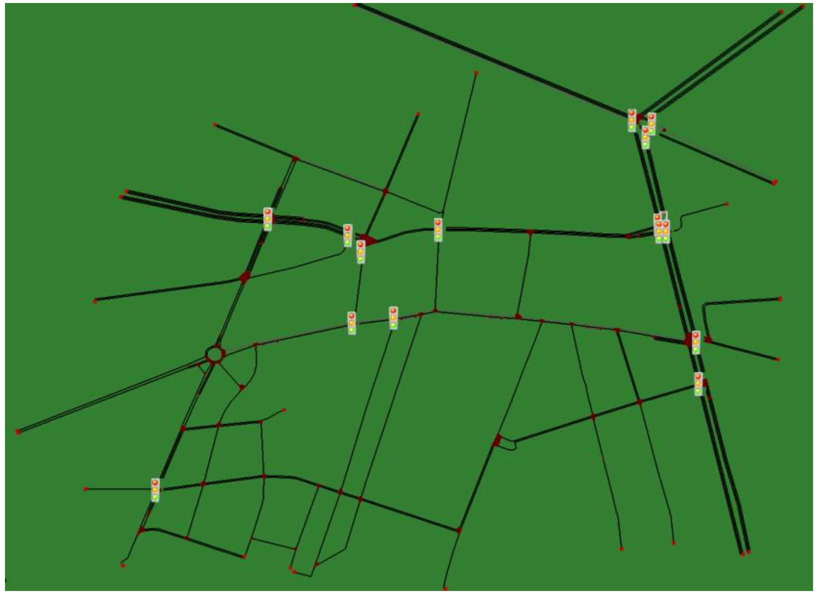
- Condition: constant speed 110 km/h in mild weather
- Simulation environment: 100 BEVs, maximum speed 110 km/h, no speed deviation, no speed factor, no driver imperfection

Unit: kWh/100 km

Vehicle type	HBEFA4	PHEMlight5	EVM	MMPEVEM	Data from the manufacturers
BMW i3	17.92 (-1%)	20.81 (15%)	18.71 (3%)	20.78 (15%)	17.6 – 18.1
VM e-Up	17.92 (2%)	19.96 (6%)	18.11 (-4%)	18.70 (-1%)	17.5 – 18.8
VW ID.3	17.92 (1%)	20.60 (13%)	18.07 (-1%)	18.89 (3%)	17.8 – 18.3
VW ID.4	17.92 (-7%)	24.52 (16%)	21.38 (1%)	23.24 (10%)	19.3 – 21.1
SUMO default	17.92	28.38	21.87	21.62	-

Scenario Acosta – setup

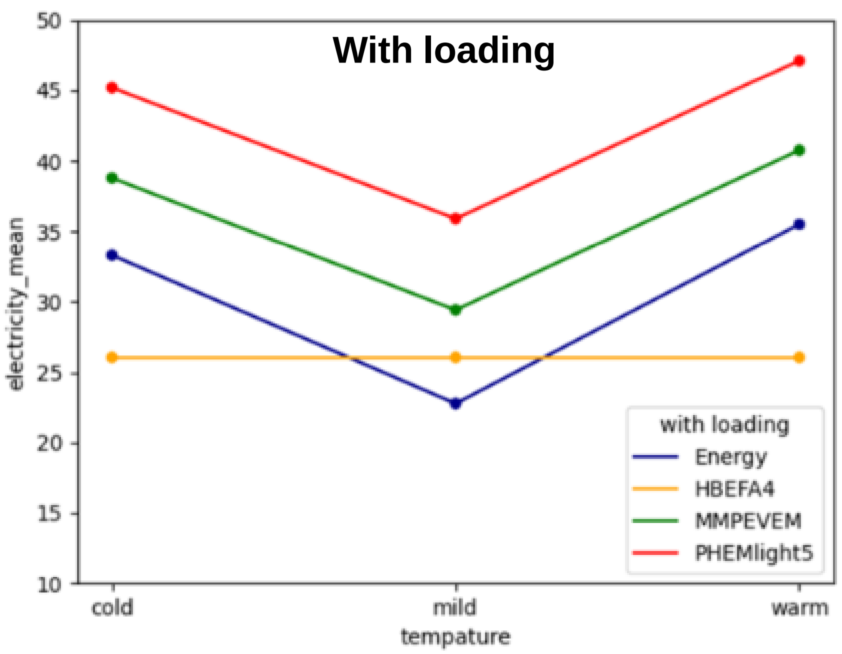
- Based on the published SUMO scenario Acosta
- Examine the effects of loads and constant consumption on energy consumption after PHEMlight's parameterization
- Simulation environment
  - Around 9000 vehicles and 160 busses
  - Roads with intersections with/without traffic signals
  - Five vehicle types:
    - BMW i3, VW e-Up, VW ID.3, VW ID.4, SUV
  - Two load conditions: 0 kg and 350 kg
  - Three situations of constant consumption:
    - 360 W (mild weather)
    - 2146 W (cold weather)
    - 2520 W (warm weather)

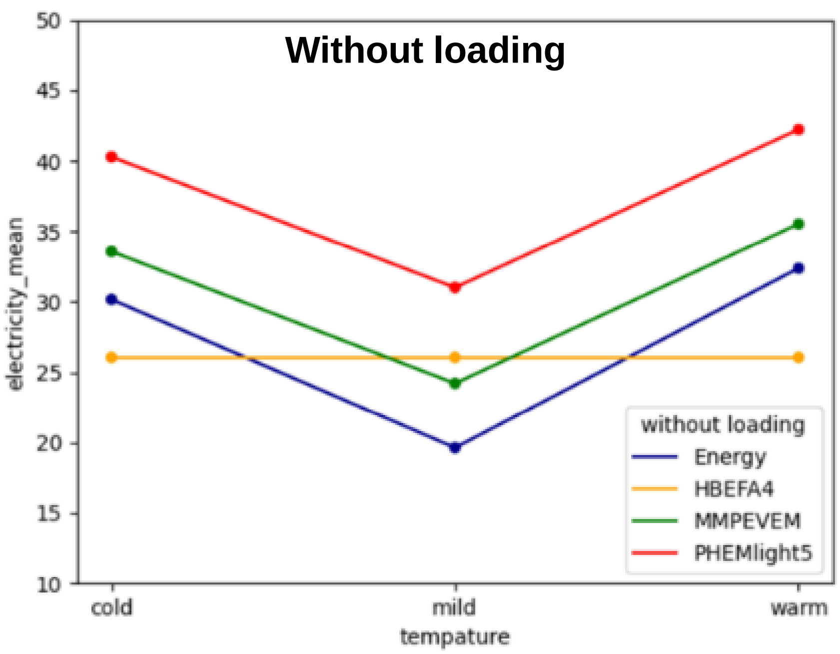


Scenario Acosta – result

Unit: kWh/100 km

Battery consumption in a mild weather condition (kWh/100 km)	HBEFA4	PHEMlight5	EVM	MMPEVEM
With loading	26.06	35.91	22.79	29.41
Without loading	26.06	31.01	19.64	24.21





Summary and next steps

- PHEMlight's advanced parameterization allows for more accurate estimation of electrical energy consumption.
- In general, PHEMlight tends to estimate higher energy consumption, while EVM is the opposite. Only small difference exists between all models’ estimates at very low acceleration and non-high speed.
- A compromise needs to be made between accuracy and effort for data collection and processing.
- A conversion mechanisms between the models‘ energy consumption could be developed if the relationship found in the fitness check can be further confirmed.
- Further analysis with different car-following models
- Further comparison and sensitive analysis of each energy consumption component between the models