Estimating real-world energy savings of an electric city bus with in-wheel motors versus central drive configuration

EVS 35, Oslo - June 13th 2022

Fontys Lectorate Future Powertrain

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Source: https://www.vdlbuscoach.com/en/products/citea/citea-slf-slfa-electric

Background

- RET: *Rotterdamse Electrische Tram*
  - Public transport organisation
  - Founded in 1927
  - In 2022: 97 zero emission city buses

Source: https://corporate.ret.nl/over-ret/historie

Claim from an E-driveline supplier:

"Application of in-wheel motors reduces the energy consumption by 15%"

The problem

Problem statement:

- Can the claim be confirmed without running tests?
- We also like to better understand the origin of the energy savings.

Problem approach:

- Execution of a drive line energy consumption comparison by means of 1D software Simcenter AMESim

Source: https://www.tech-story.net

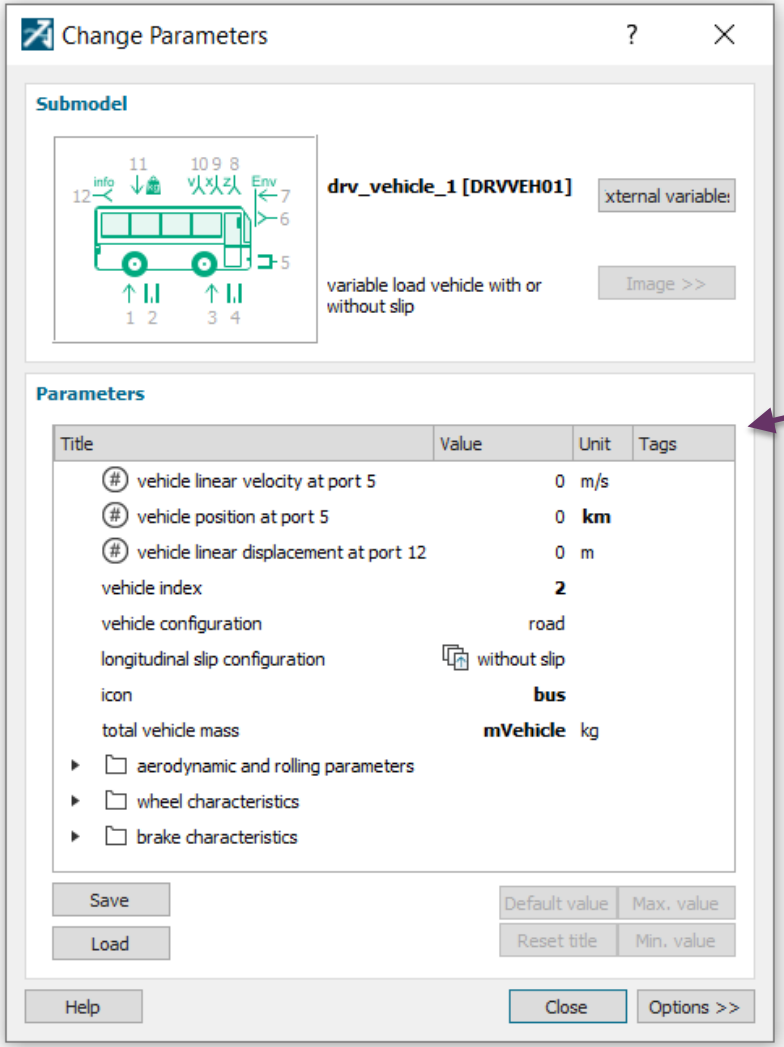
Claim from an E-driveline supplier:

"Application of in-wheel motors reduces the energy consumption by 15%"

The modeling approach

Focus on the **largest road load related energy losses**, and with **a sufficient level of detail** by making use of commercially available **1D software**.

Model setup


Change Parameters
Submodel
drv_vehicle_1 [DRVVEH01]
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Parameters
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vehicle linear velocity at port 5
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vehicle position at port 5
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vehicle linear displacement at port 12
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vehicle index
2
vehicle configuration
road
longitudinal slip configuration
without slip
icon
bus
total vehicle mass
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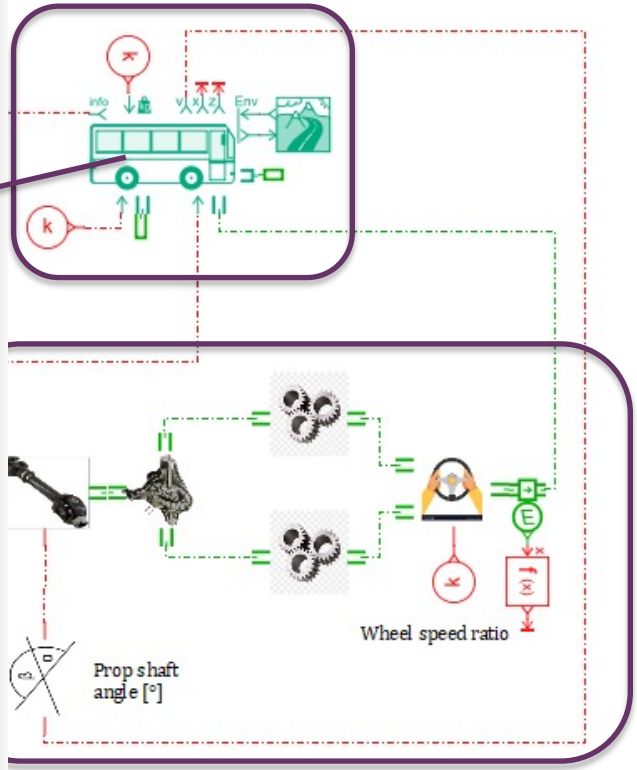
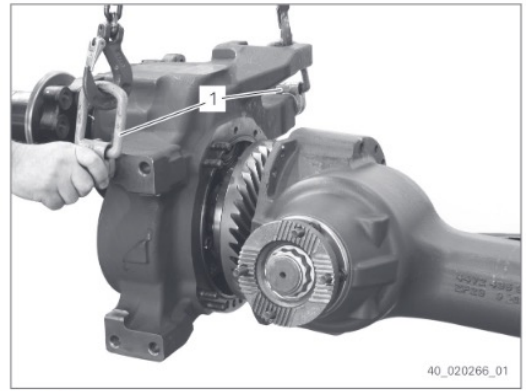
Options >>


Wheel speed ratio
Prop shaft angle [°]

Model input

- Publicly accessible information
- Literature



Typical road load characteristics

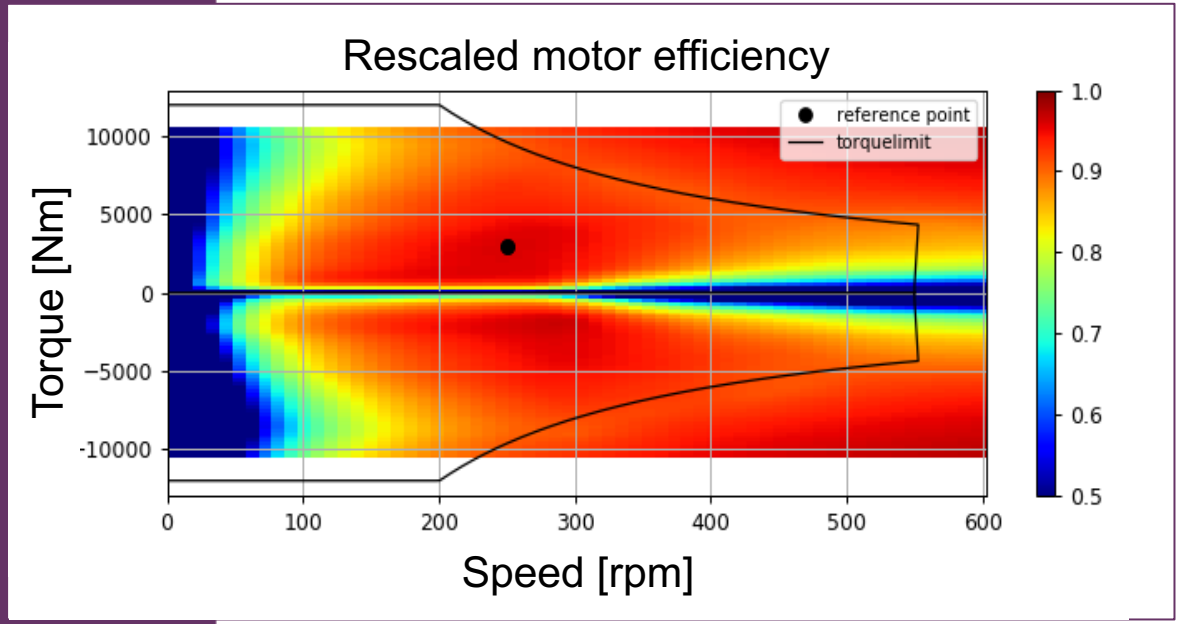
	12 m urban bus
Frontal area [m^2]	8,4
Vehicle mass, empty [kg]	13250
Vehicle mass in calculations [kg]	14500
Air drag resistance coefficient Cd [-]	0,7
Number of gears	Fixed ratio
Rolling losses resistance coefficient Crr [-]	0,006
Tyre type	275/70R22,5

Source: https://www.vdlbuscoach.com/en/products/citea/citea-slf-slfa-electric
The coefficient values are estimated and have not been supplied by VDL

Source: Maintenance instruction AV133
http://shop.pwt.ca/DRT/Vendors%20Manuals/04000%20Axles%20-%20ZF/4472.758.101b%20Operating%20Instructions%20AV-110%20&%20AV-133.pdf

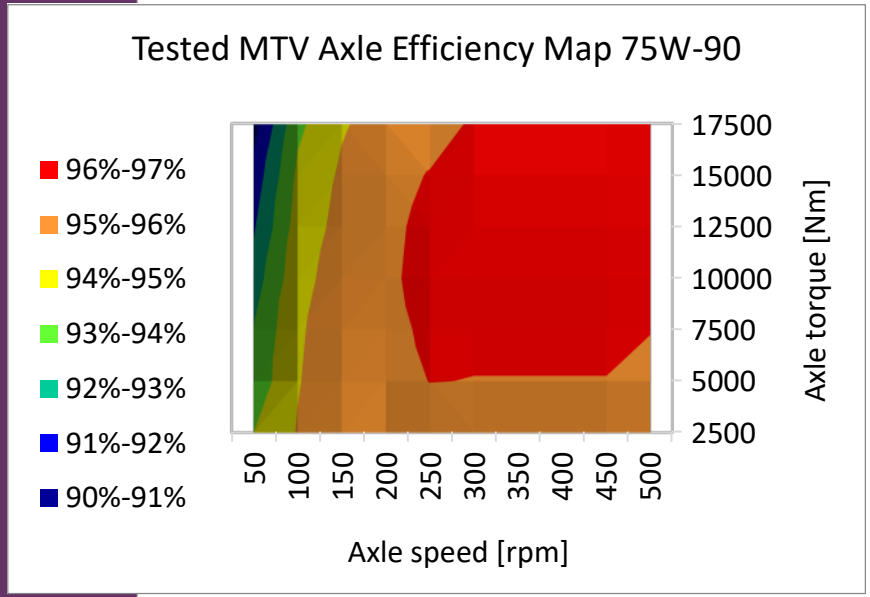
Assumptions

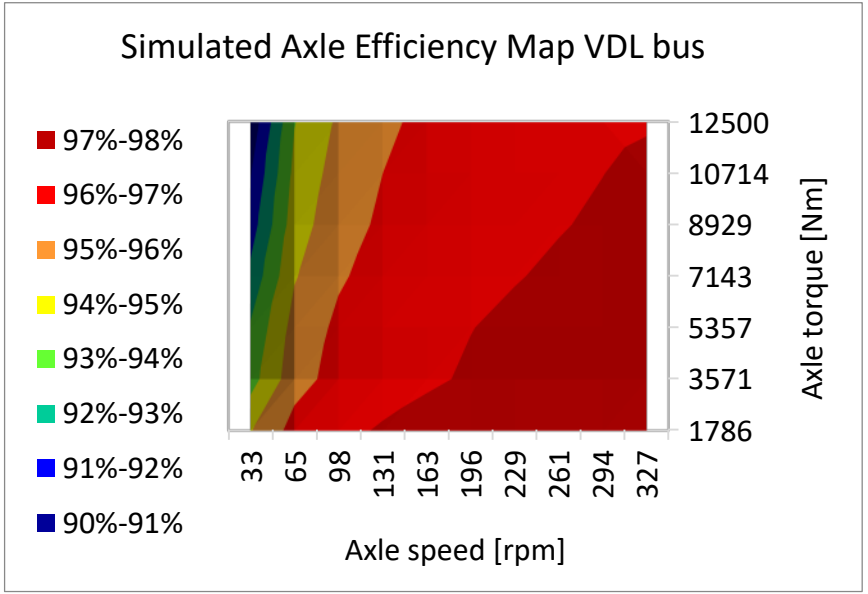
- The current motor + inverter efficiency map is unknown, so a default map from AMESim is taken, with the reference point estimated for this application



- The in-wheel motor efficiency map lies 3% lower than the central drive one

Model validation





Comparison between measured efficiency from literature [10] (left)
and simulated Central Drive line (CDR) efficiency (right)

Trendwise comparison confirms the modeling approach

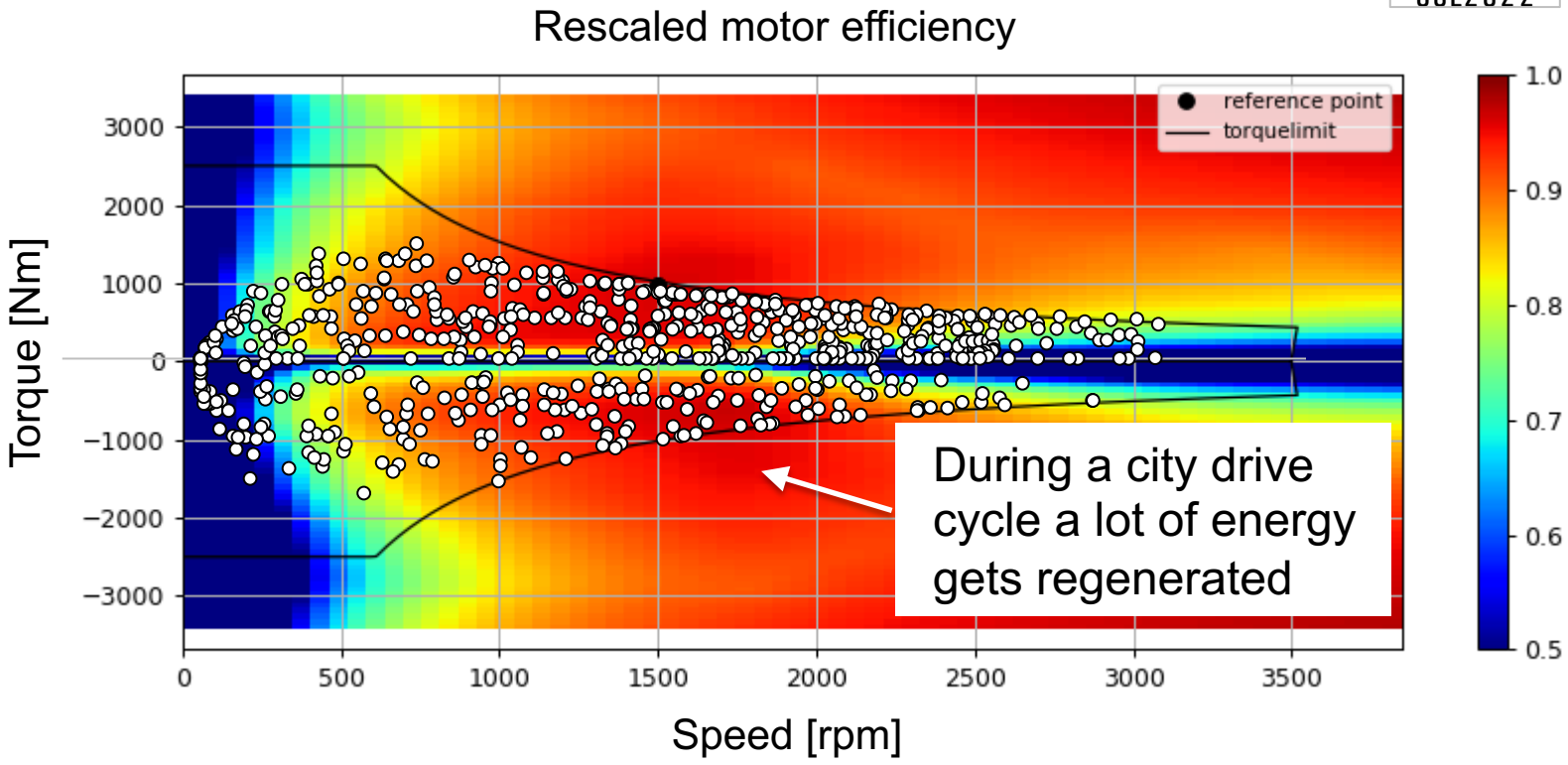
Simulation results

Table 3: Cycle energy consumption for different driveline configurations			
Cycle energy consumption [kWh/km]	Central drive (CDR)	In-wheel (IW)	IW compared to CDR
Dutch Urban Bus cycle [11]	1.04	0.93	-11%
Braunschweig cycle [11]	1.00	0.90	-10%
SORT heavy urban cycle [12]	1.21	1.10	-9%
SORT suburban cycle [12]	1.21	1.12	-8%
Average	*1.12*	*1.02*	***-9%***

These results are based on the assumption that the In-Wheel motor and inverter together have even a 3% lower efficiency than the Central Drive ones.

It's a significant improvement. Why?

Simulation results



Drive line losses very negatively impact the drive range

Conclusions

Simulation results show 8 ~11% better efficiency for IW compared to CDR

- The 15% claim is somewhat optimistic
- This is based on non validated model simulation (i.e. indicative)

The choice of drive line configuration also depends on other criteria.

Source: https://www.vdlbuscoach.com/en/products/citea/citea-slf-slfa-electric

Thank you for your attention

Acknowledgement
The generic primary model building activity in this study were part of the RAAK PRO VETIS project, funded by the Dutch Taskforce for Applied Research SIA. The detailed drivetrain modelling activities and reporting were funded by the Automotive Center of Expertise (ACE). The authors wish to thank both funding organizations for their support.