



Forward. For all.

„BEV truck efficiency optimization with focus
on vehicle thermal and energy management“

Julian Bodory – Lead Engineer H2 & Thermal Systems

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Introduction

- The heavy-duty transportation sector is a significant contributor to global CO₂ emissions and is still experiencing a growing trend.
 - Electrification of commercial vehicles can contribute to lower GHG emissions and to meet EU and US emission targets.
 - First BEV trucks are available but see many challenges.
 - Technology challenges of BEV-Trucks:
 - Vehicle range
 - Driving efficiency
 - Total costs of ownership
 - Charging time
- ➔ Vehicle Thermal & Energy Management
- Payload
 - Infrastructure
 - Reliability & flexibility

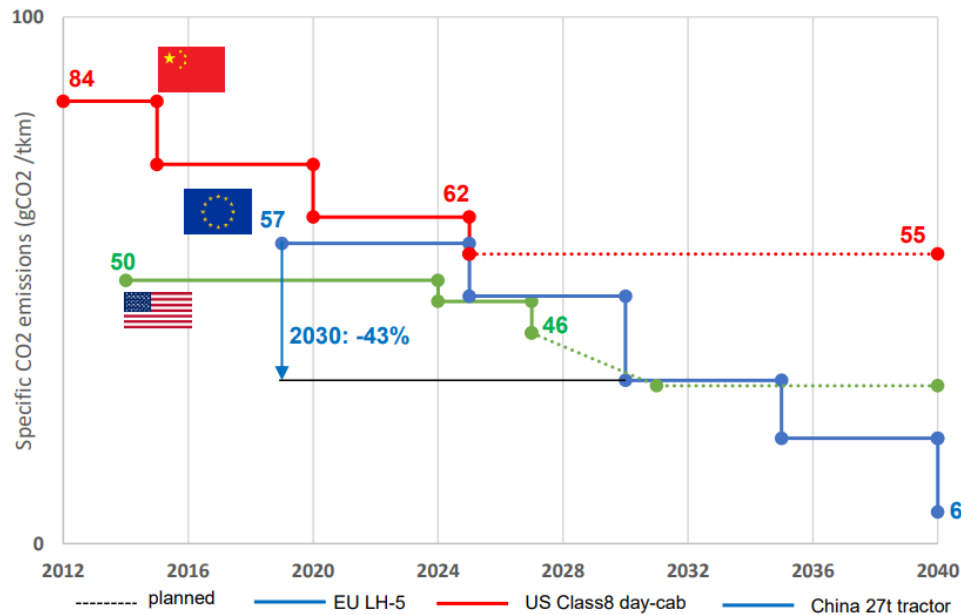


Global CO2 reduction targets for HD

Worldwide CO2 reduction targets defined / planned

- EU CO2 fleet target 2030 -43%*
- CO2 target refers to tailpipe emissions
- CO2 neutral fuels not considered yet
- EU with most stringent targets
- Regulatory worldwide enforces electrification

Global CO2 reduction forecast truck fleets



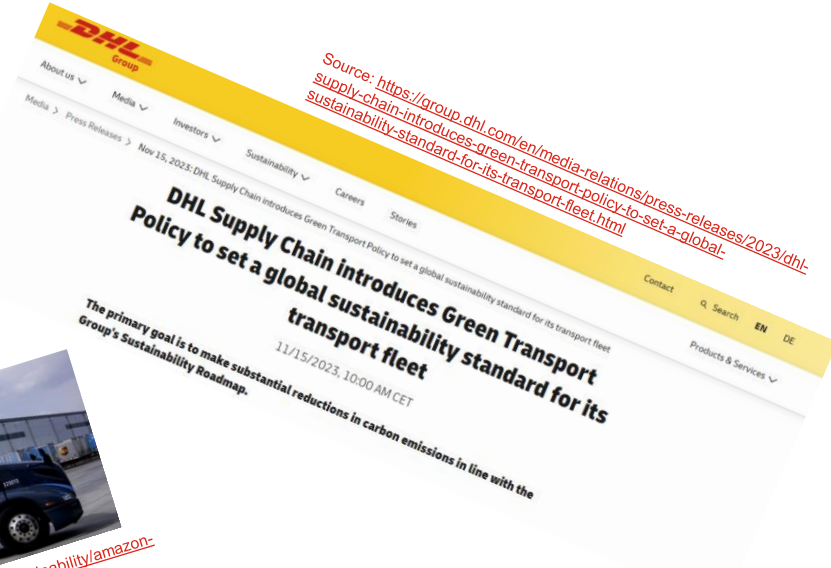
Source:
https://ec.europa.eu/commission/presscorner/detail/en/23_762
<https://www.epa.gov/system/files/documents/2024-04/42024018.pdf>

*Baseline 2019 fleet values

Exploring Customer Interest: Is the Market Real?



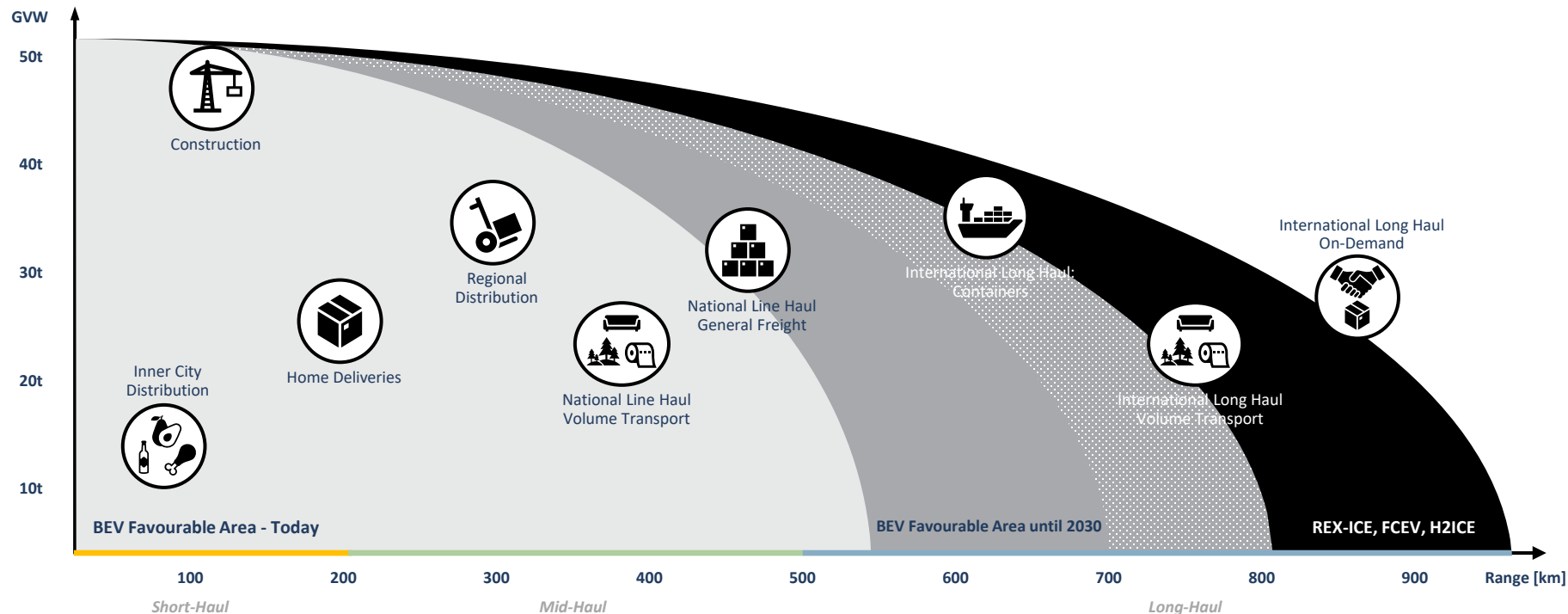
Sustainable Transportation
Transportation is a key part of our plan to meet net-zero carbon by 2040. We are committed to optimizing and transforming our transportation network through innovations in electrification, efficiency enhancements, and alternative delivery methods.



Major transportation sustainability initiatives → need of BET Trucks

Technological Limitations

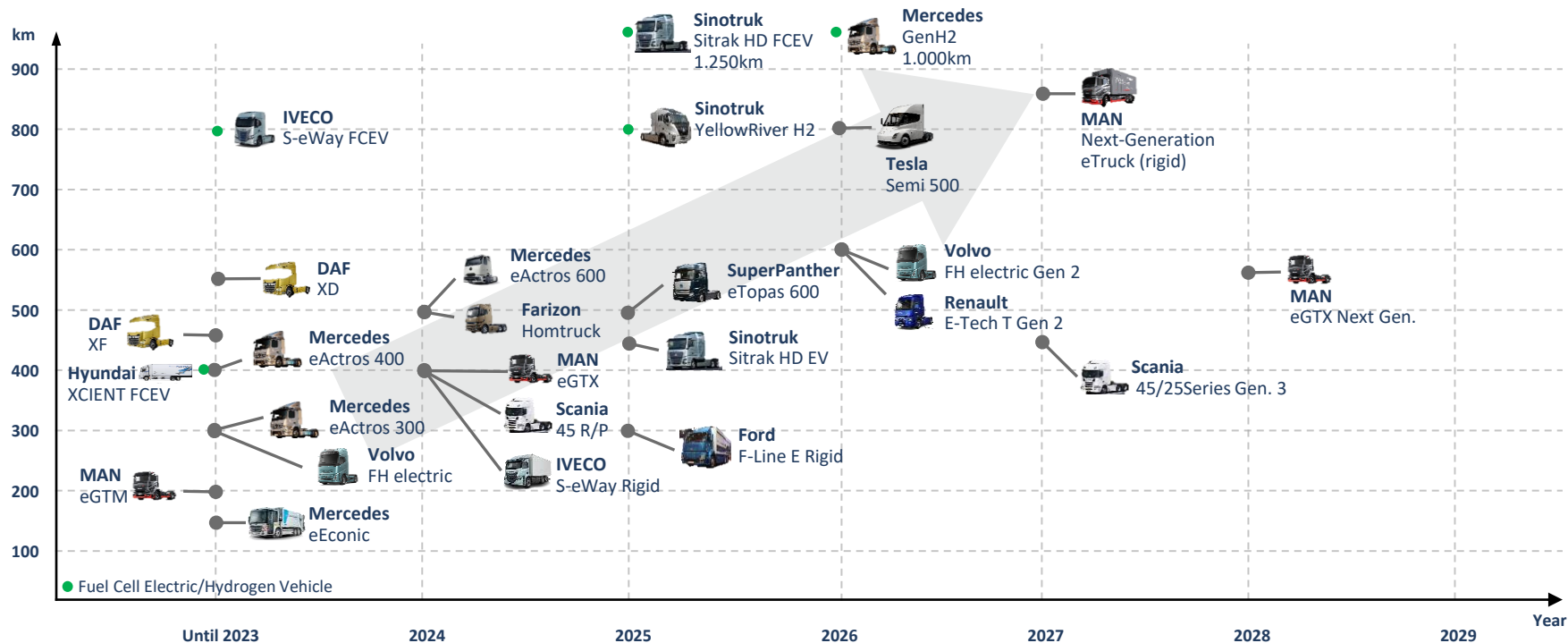
Range and payload are limited by the propulsion technology* – thus the right technology must be chosen for each use case



*schematic depiction of propulsion capability

BET Truck Launch Strategy

In the short- and mid-haul segment there are already many BET options available – in the long-haul segment options will increase over the next years



Question:

Can a class 8 BEV truck run 500 miles?

Can a BEV truck run 500 miles?

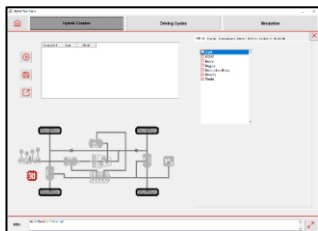
- Tesla Semi Delivery Event on December 2nd, 2023
- Tesla announced that the Semi Truck can run 500 miles with a single battery charge
- Elon Musk: “There are people out there they say it can’t be done – we did it”



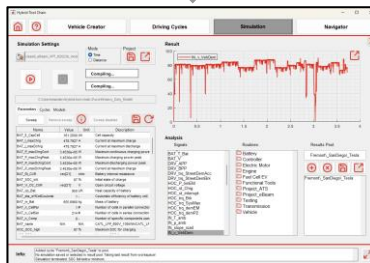
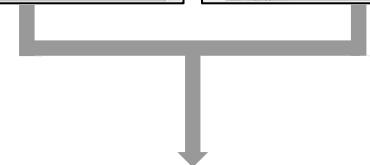
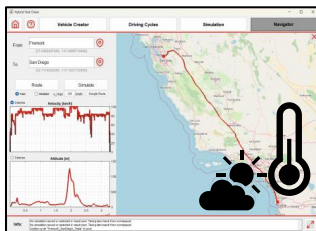
Complete vehicle simulation environment

Virtual Product Development

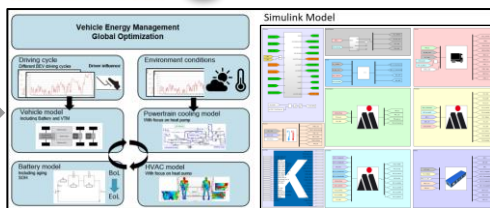
Vehicle & powertrain architecture



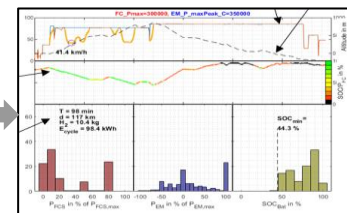
Mission profiles & environment conditions



Matlab Simulink



Simulation model



Result interpretation



Simulation environment for vehicle analysis



Consideration of **various driving cycles** – navigator based, library incl. worst case cycles



Interface between **KULI SW & Matlab Simulink**



Consideration of **various environment conditions**



Analysis of **different system architectures**



Analysis of **operation strategy**



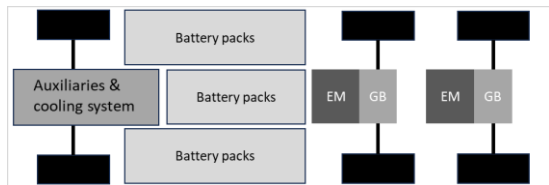
Simulation **results interpretation** and analysis of complete **vehicle target fulfillment**

Vehicle and powertrain architecture

Assumptions:

Component	Parameter	Class 8 6x4
Battery	Capacity	900 kWh
	Voltage	800 V
Electric motor	Max. torque	2x735 Nm peak
	Max. power	2x216 kW cont.
Resistance	Drag cd	0.36
	Frontal area	9.7 m ²
	Rolling cr	0.0048
Weight	Full load	82000 lbs

Class 8 Truck PT architecture:



Example of class 8 truck:



Source: Magna design study

Mission profile & environment conditions

Investigated Route:

Tesla Plant in Fremont → Tesla Plant in San Diego

Open Street Map:

Route: Fremont → San Diego:

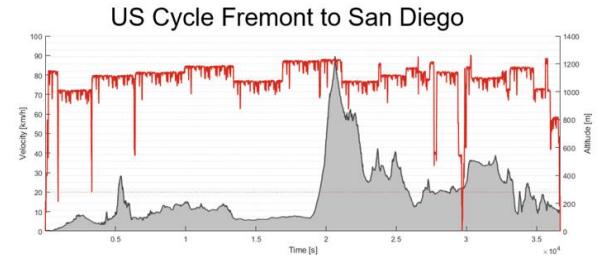


Source:
https://www.openstreetmap.org/directions?engine=fossgis_osrm_car&route=37.5483%2C-121.9886%3B32.7174%2C-117.1628#map=5/38.100/-95.581

Magna driving cycle generator:

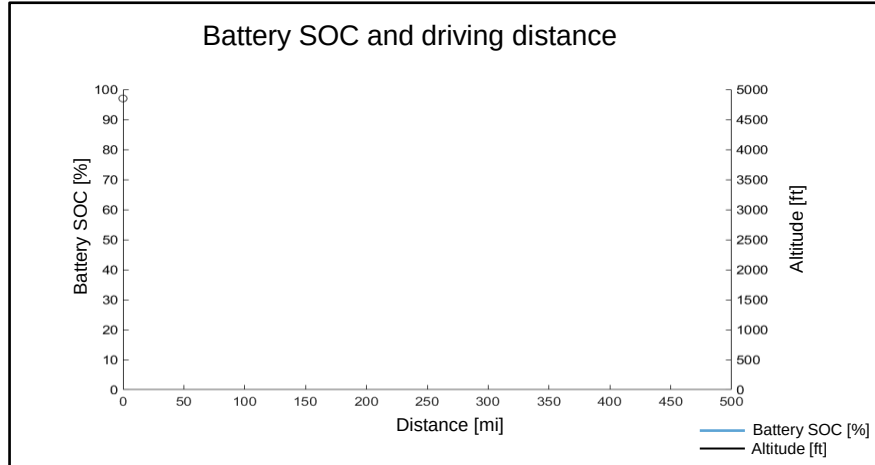


Tesla driving cycle:



Can a truck run 500 miles?

Magna simulation results:



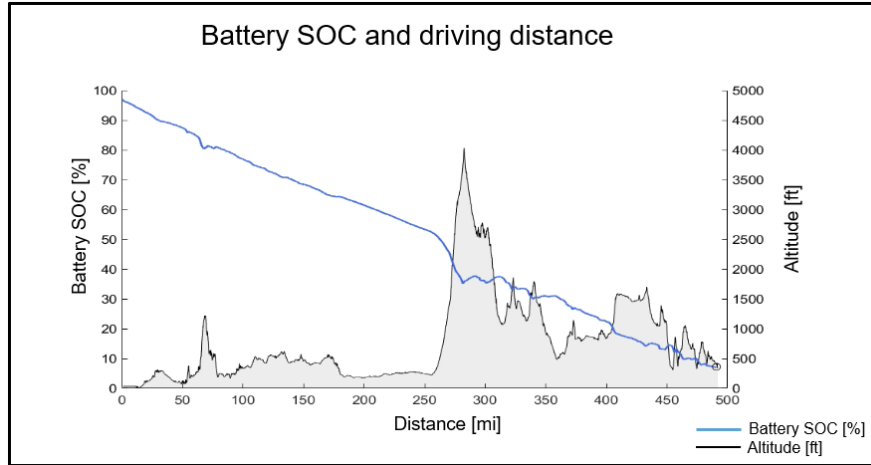
Source: <https://www.tesla.com/semi>



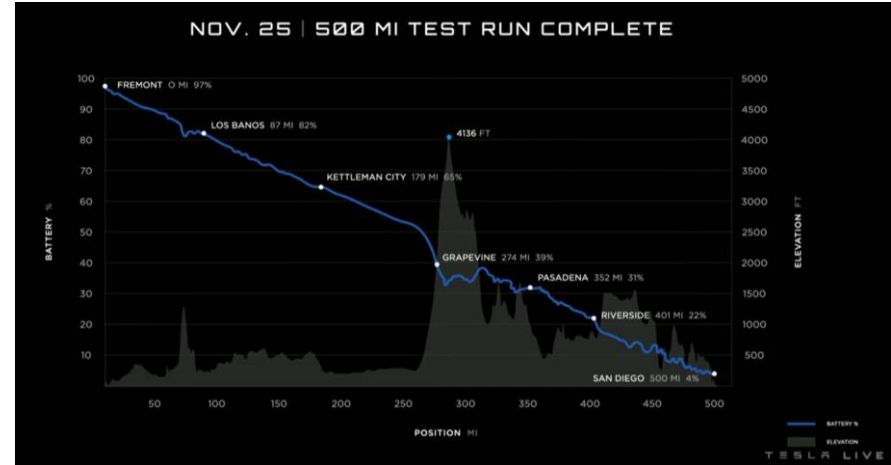
Based on simulation this truck can run 500 miles

Can a truck run 500 miles?

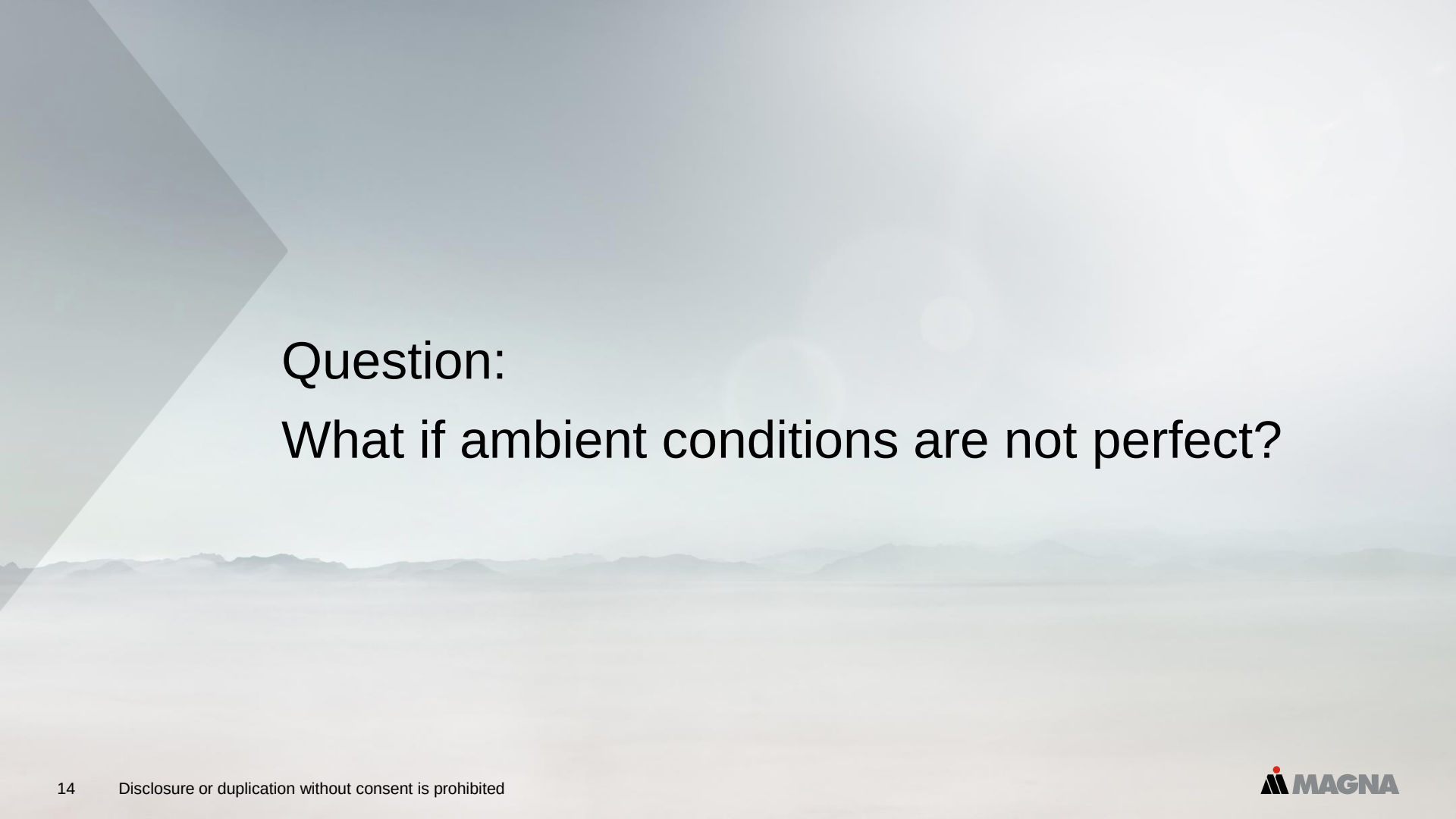
Comparison of Magna simulation results & data presented by Tesla



Source: <https://www.tesla.com/semi>



Source: <https://www.tesla.com/semi>



Question:

What if ambient conditions are not perfect?

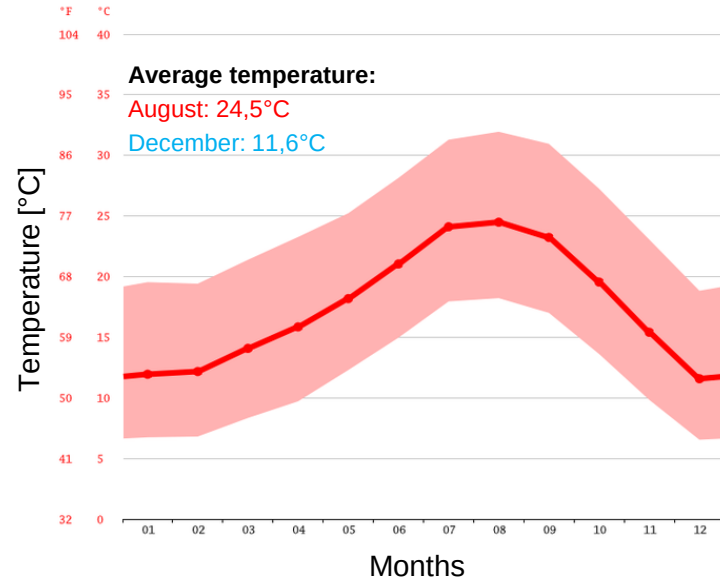
California

The environment temperatures in California provide almost perfect conditions for a BEV Truck...



Source: Microsoft PowerPoint Picogramme

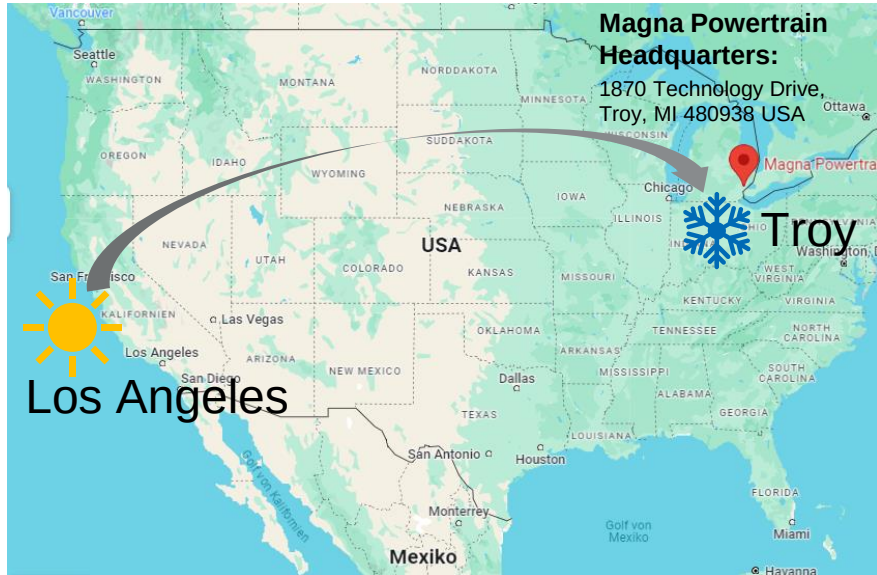
Temperature diagram Los Angeles:



How about Michigan?

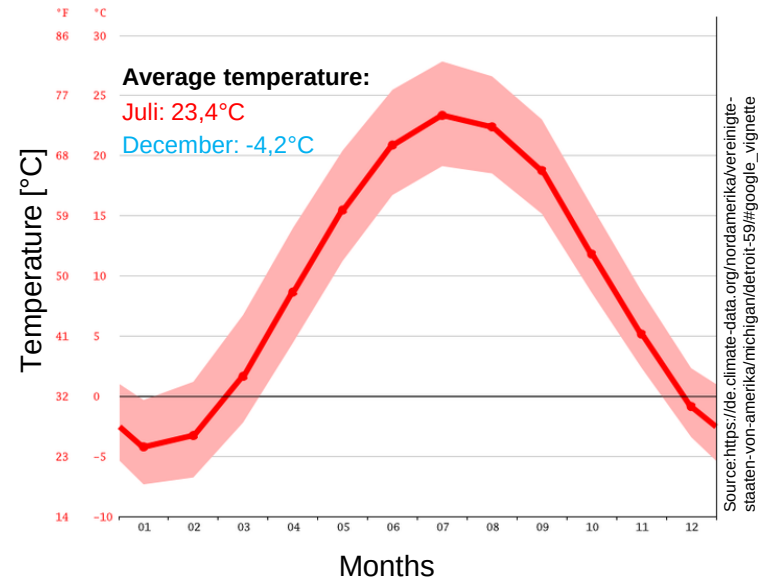
Magna Powertrain headquarter is located in Michigan

Trucks are operated globally in all kind of use cases and climatic conditions



Source: <https://www.google.at/maps>

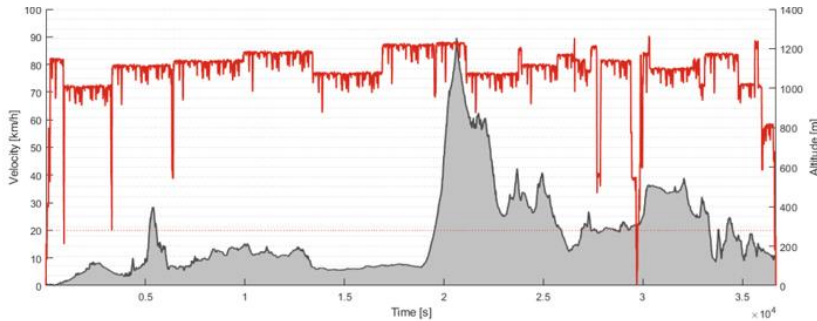
Temperature diagram of Troy:



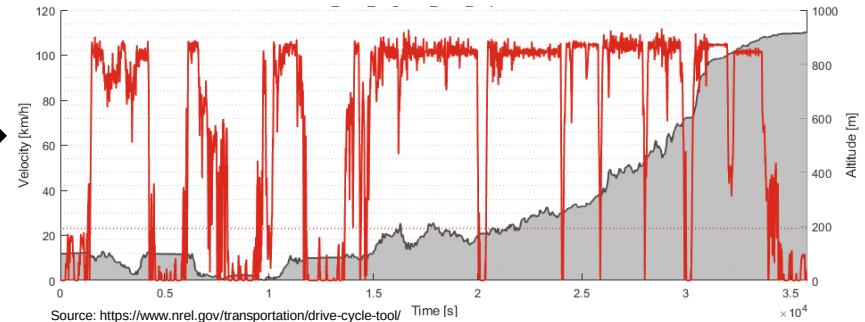
How about representative US driving cycle?

For further investigation, following cycle developed by NREL was used

Driving cycle Fremont → San Diego



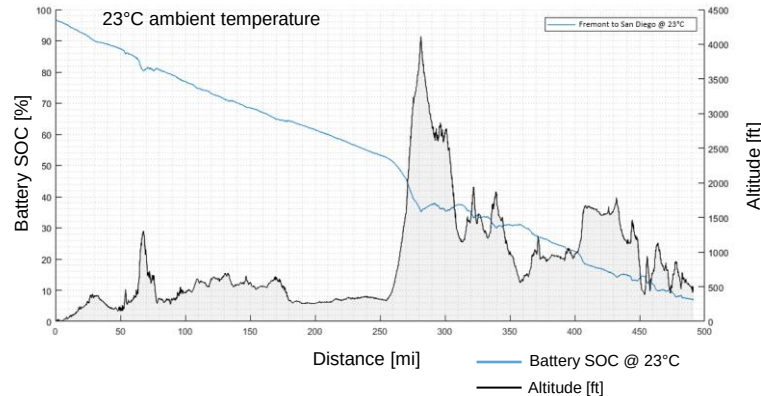
Fleet DNA Regional Haul Representative Cycle



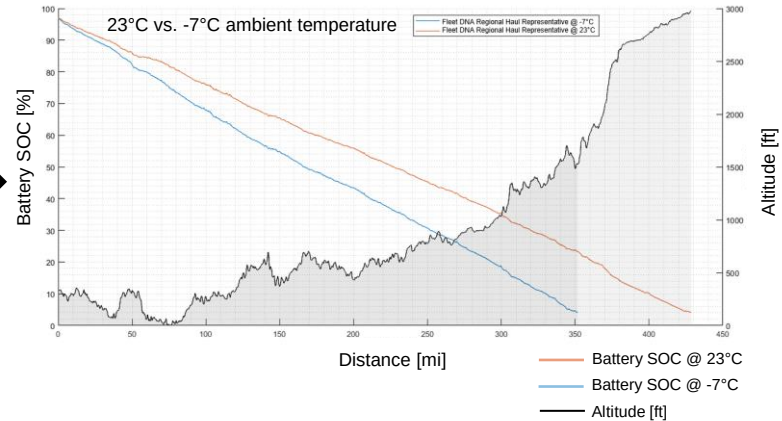
Simulation Result

Tesla cycle compared to Regional Haul Representative Cycle
23°C ambient temperature compared to -7°C ambient temperature

Driving cycle Fremont to San Diego

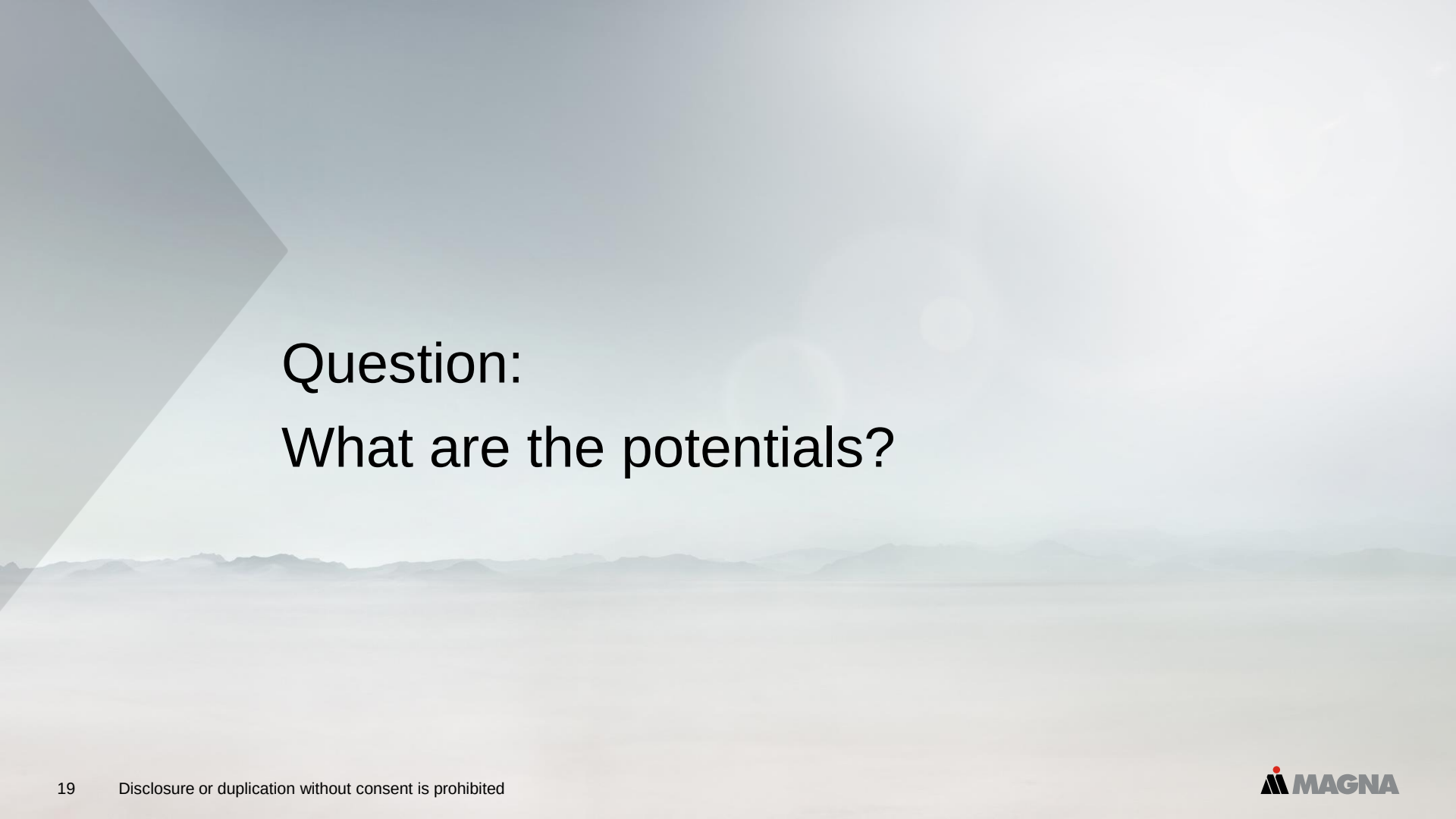


Fleet DNA Regional Haul Representative Cycle



Simulation results:

- Maximum range is reduced from 500mi (Tesla Cycle) to 428mi (Regional Haul Cycle) at 23°C ambient temperature
- Winter conditions (-7°C) further reduce the range by around 18%
- Maximum winter range is limited to 352 miles at Fleet DNA Regional Representative Haul Cycle
- Range reduction mainly caused by limited recuperation and heating



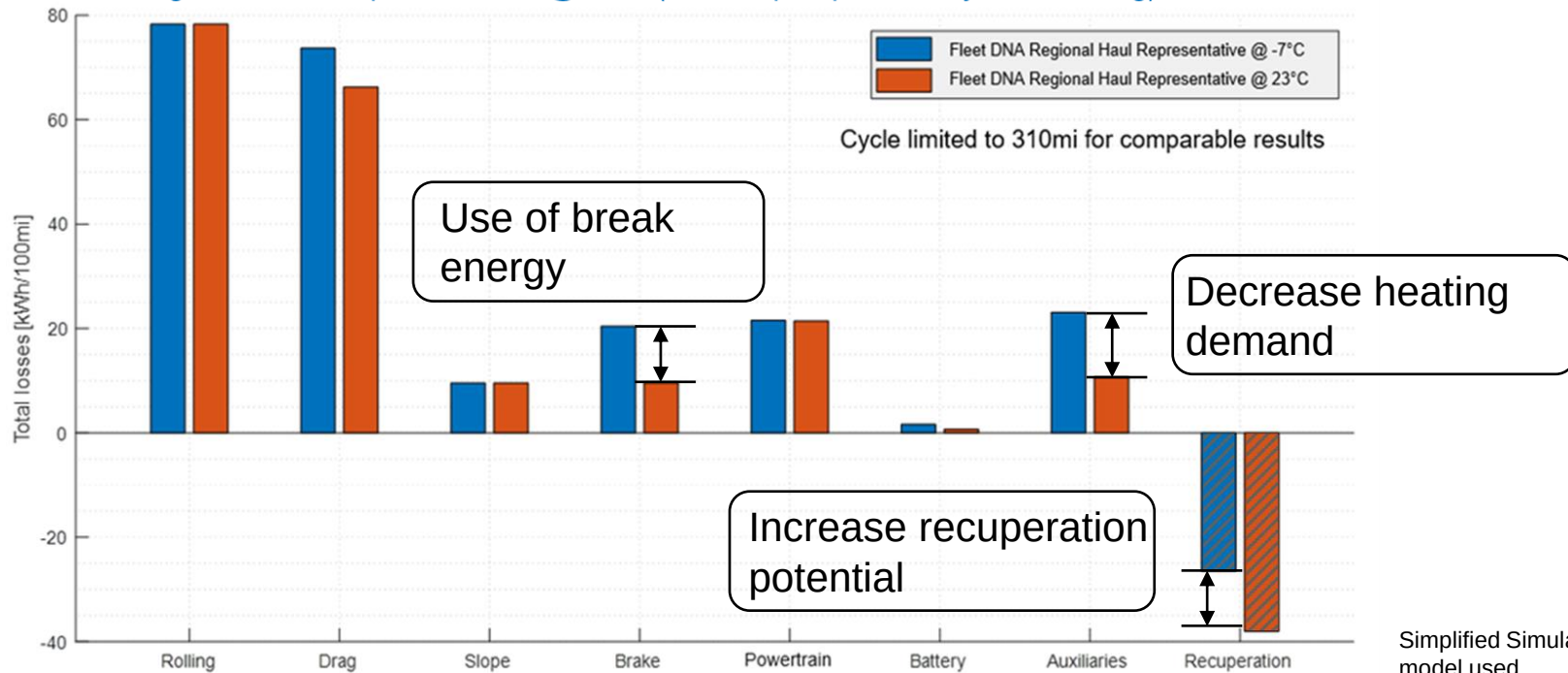
Question:
What are the potentials?

What are the potentials during winter?

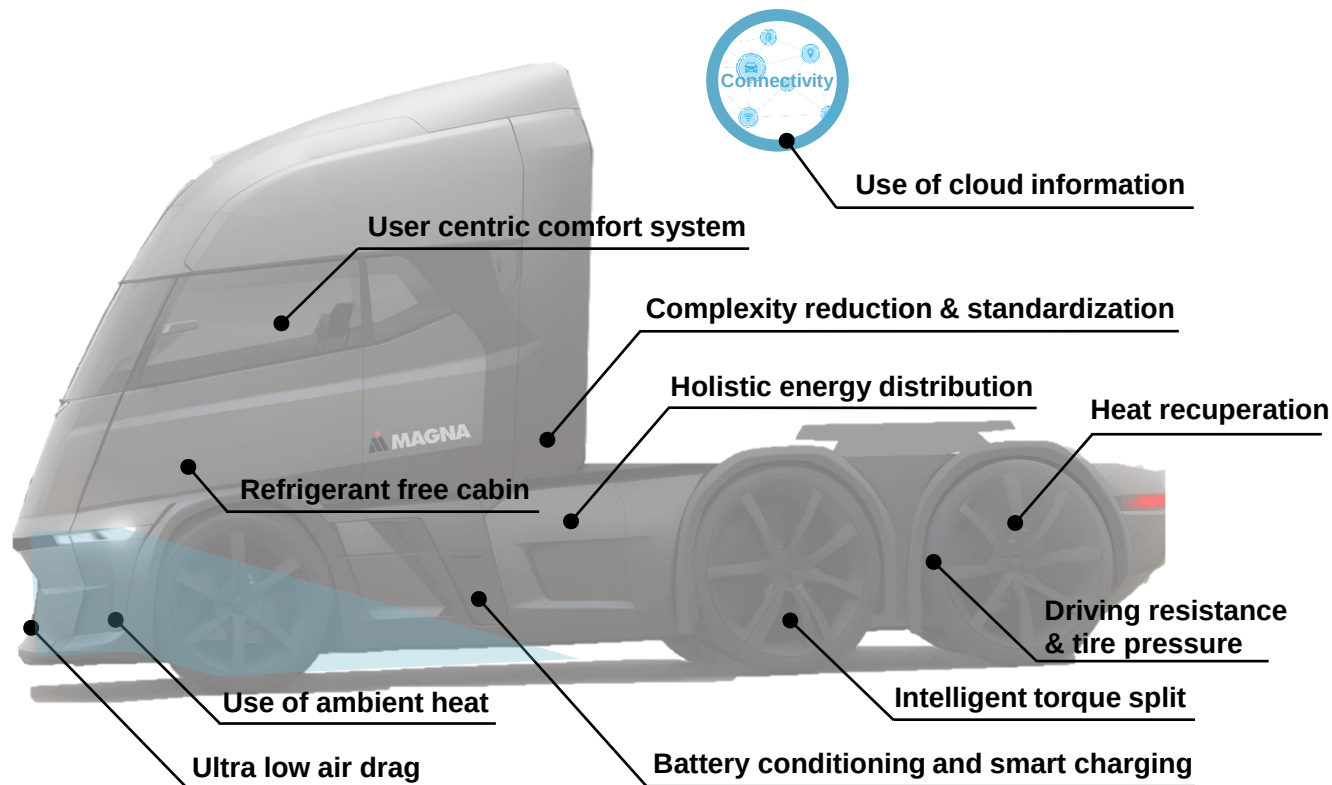
Energy split class 8 truck @ Feet DNA Regional Haul Cycle:

Fleet DNA Regional Haul Representative @ 23°C

Fleet DNA Regional Haul Representative @ -7°C (w/ heat pump & battery conditioning)



Optimization potentials overview



Investigated in this presentation:

- Reduction of energy demand for heating
- Thermal system architectures for heat management
- Recuperation potential in cold environments

Reduction of energy demand for cabin heating

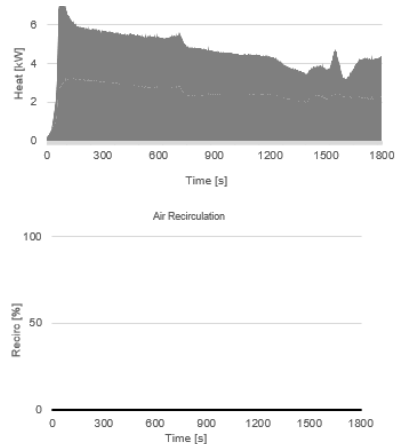
Advanced HVAC control

Example BEV vehicle:

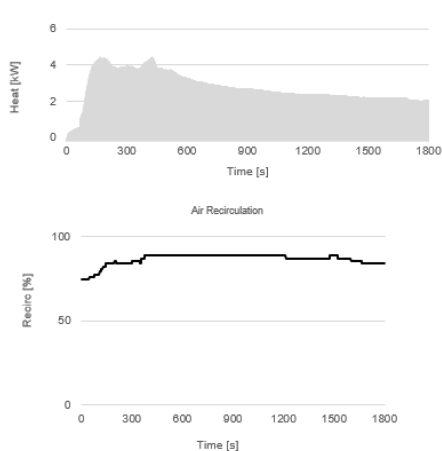
- Comparisons of 2 different HVAC control strategies during WLTC at -10°C
- Saving up to 40% possible by intelligent HVAC functions

Comparison of cabin heat demand @ WLTC -10°C

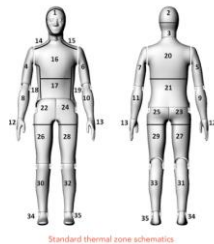
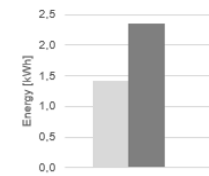
Vehicle 1
w/o advanced demisting control



Vehicle 2
With advanced demisting control



Energy consumption heat-up

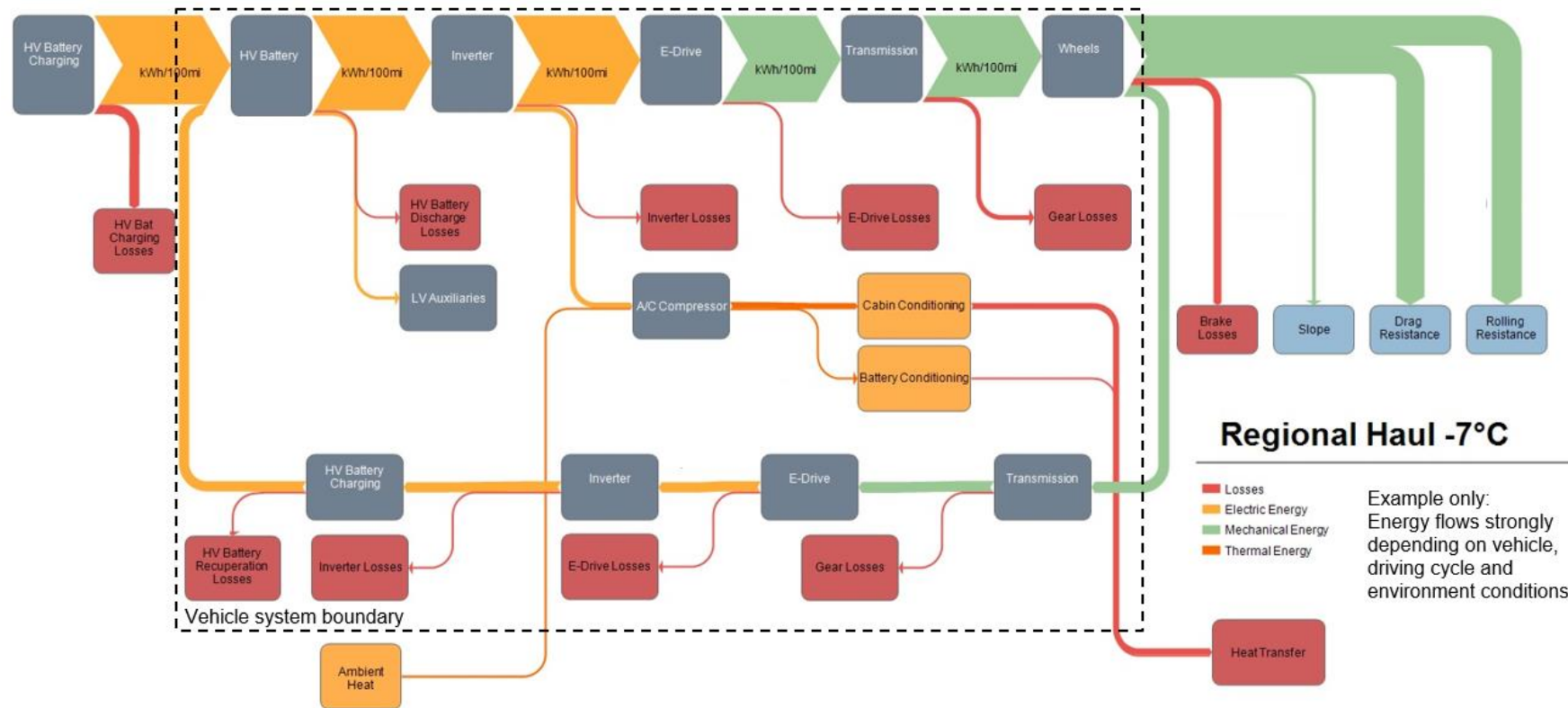


Thermal comfort validation with Manikin:



Potentials of Intelligent Energy Management

Energy flow of class 8 truck driving Feet DNA Regional Haul Cycle at -7°C

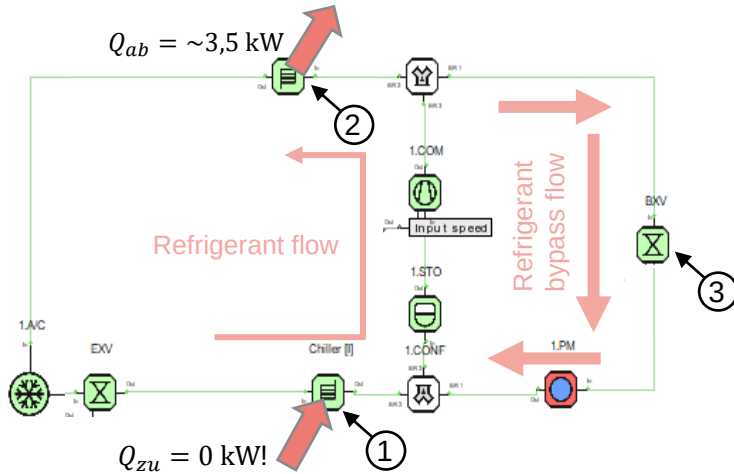


Simplification and cost reduction

Example: Heat pump system with hot gas bypass

- Cabin heating without HV PTC heater
- Simplification and reduction of components reduce costs of thermal system

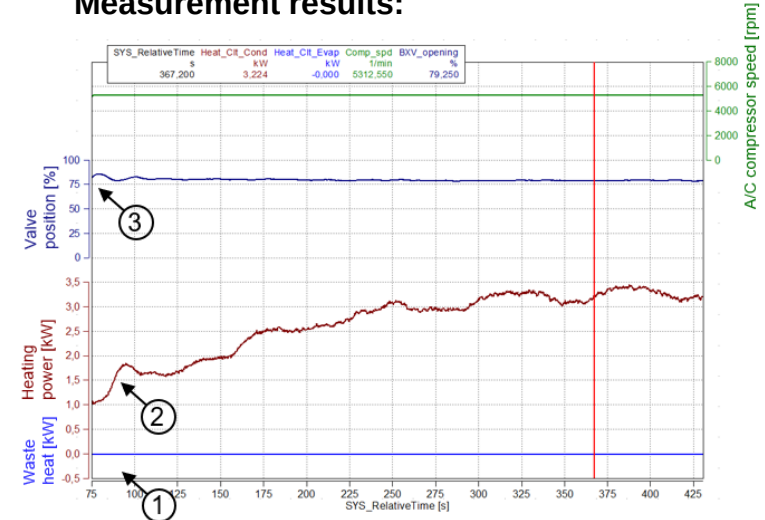
Test bench layout:



ECS thermal system test bench:



Measurement results:



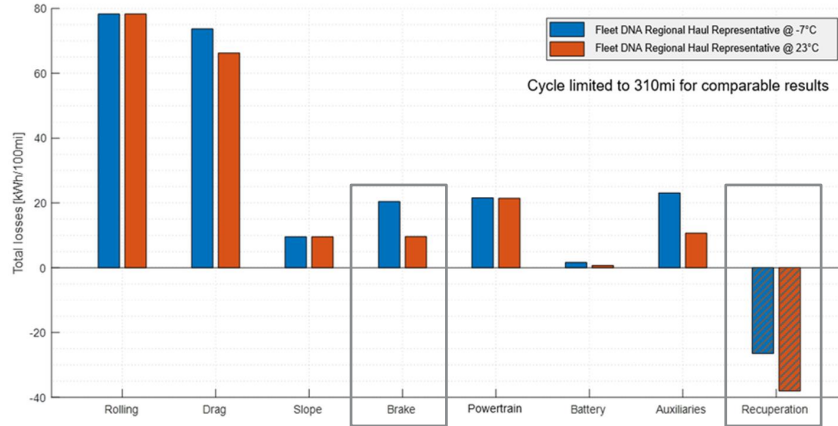
Cost saving by replacement of PTC heater

Recuperation potential in cold environments

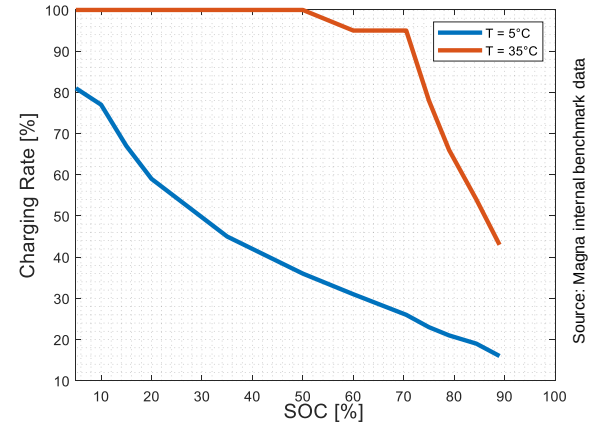
- Full recuperation potential needs to be ensured for best driving efficiency
- Battery charging currents are limited at low cell temperatures
- Depending on driving cycle and load case battery heating is required for best efficiency

Fleet DNA Regional Haul Representative @ 23°C

Fleet DNA Regional Haul Representative @ -7°C (w/ heat pump & battery conditioning)



Example charging current limitation:



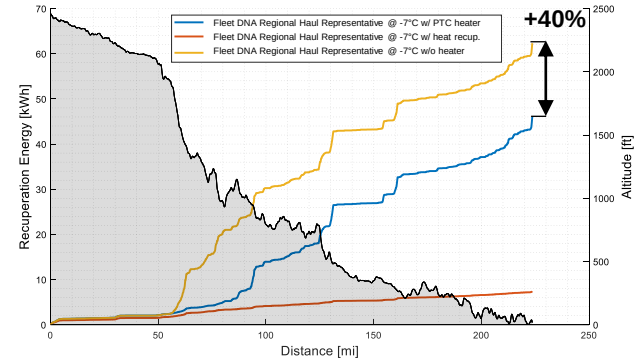
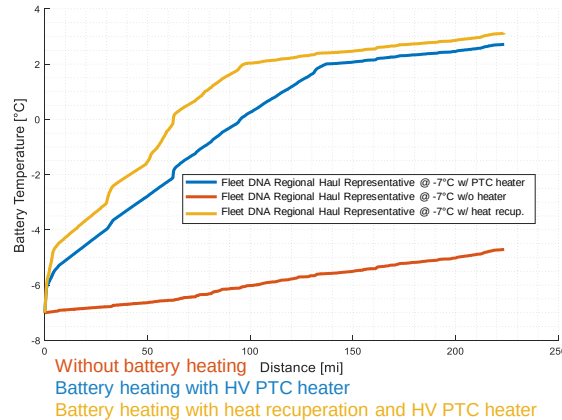
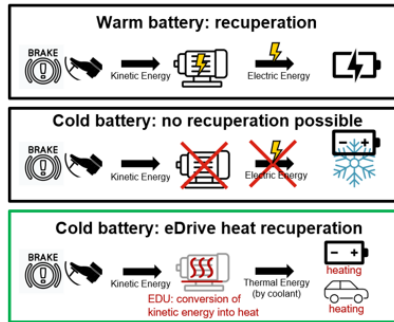
Source: Magna internal benchmark data

Potential of heat recuperation

Approach:

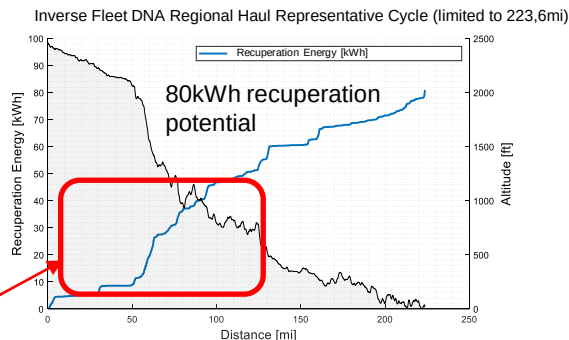
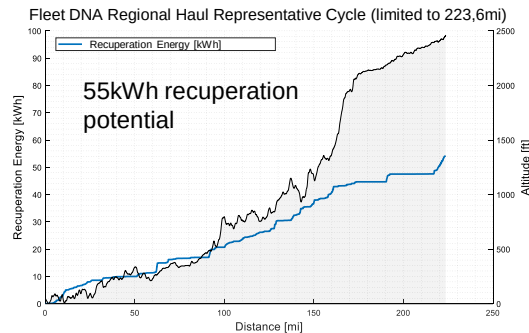
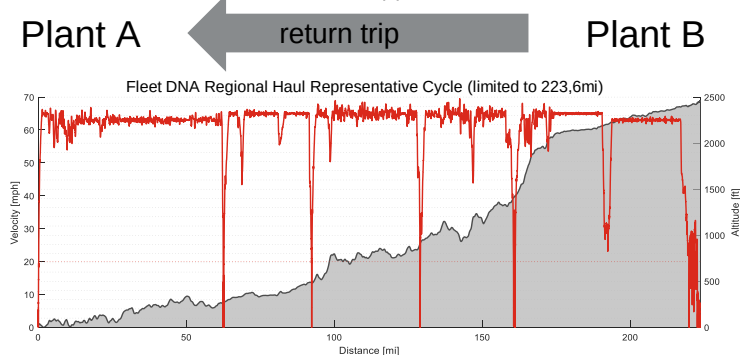
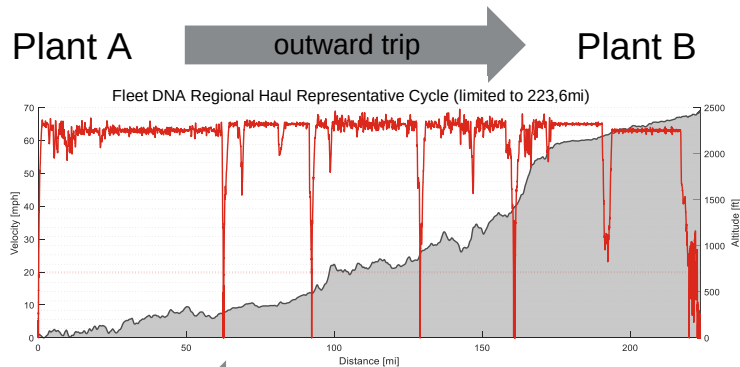
- Battery charging currents are limited at low cell temperatures
- This limits the electrical recuperation potentials of BEV trucks during cold ambiances
- Recuperation energy can be transformed into usable heat (e.g. by E-Drive)
- This increases battery heat up time and enables electrical recuperation

Approach:



Influence of driving cycle on heating strategy

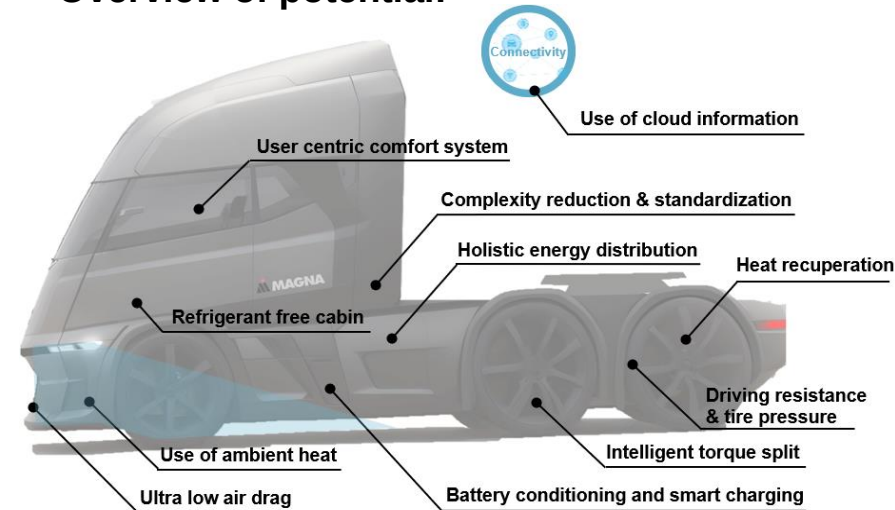
Comparison of recuperation potential



Summary

- The transition from ICE to electric trucks is on-going
- Second generation trucks with higher range and charging performance are entering the market
- Based on simulation results the investigated BEV truck is capable to drive 500 miles without charging
- If the driving cycle and environment conditions are not optimal, the range and efficiency can be significantly reduced (500→350 miles in this investigation)
- Intelligent energy management functions can reduce this limitations
- A holistic approach and innovations considering the complete truck specific eco system (vehicle, energy management, charging strategy, infrastructure, fleet operator, payload, rout planning and trustful SW functions) is required to enable high efficiencies

Overview of potential:





Forward.
For all.