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Electrified Drivetrains for Non-Road Mobile Machinery

ECO-MOBILITY 2019
A3PS, Vienna

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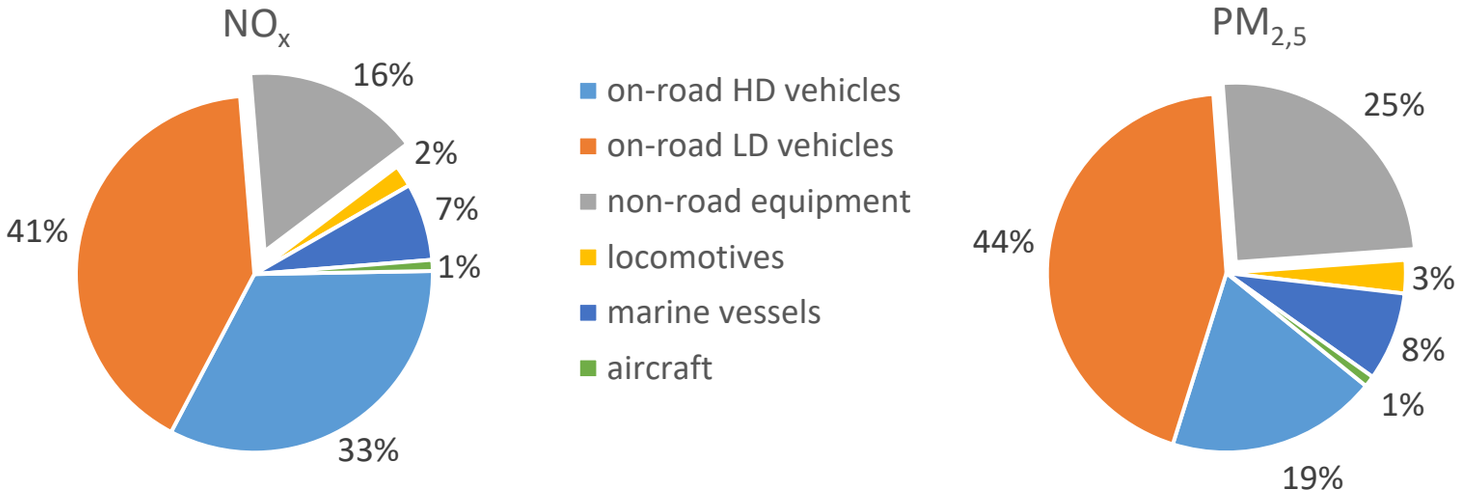
Motivation

- Non-road mobile machinery (NRMM) = 11% of the European diesel fuel consumption in road transport [1] [2]



- Expected CO_2-limiting legislation
  - Passenger cars 2030: -37.5 % CO_2 (2021)
  - Heavy-duty vehicles 2030: -30 % CO_2 (2019)

www.autoflotte.de

- Emission restrictions in and around urban areas

www.adac.de

[1] Vandenbroucke, D., Van Hyfte, A., Francx, L.: *„Study in View of the Revision of Directive 97/68/EC on Non-Road Mobile Machinery - Final Report Module1 - An Emissions Inventory",* Arcadis, Belgien, 2010

[2] Dallmann, T., Menon, A.: *„Technology Pathways for Diesel Engines used in Non-Road Vehicles and Equipment",* International Council on Clean Transportation (ICCT), Washington, 2016

Content

- Methodology
- Results
- Conclusion

Methodology

www.wackerneuson.at

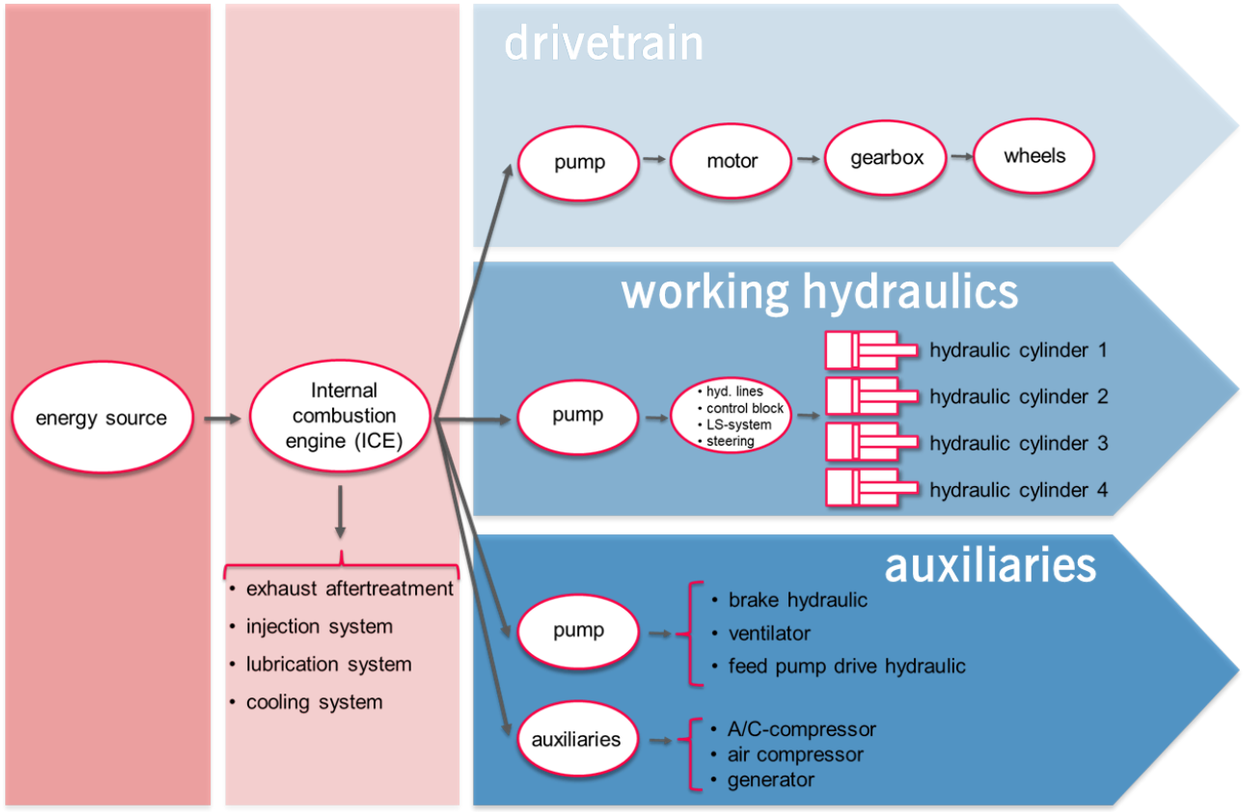
www.liebherr.com

www.liebherr.com

www.wackerneuson.at

Methodology

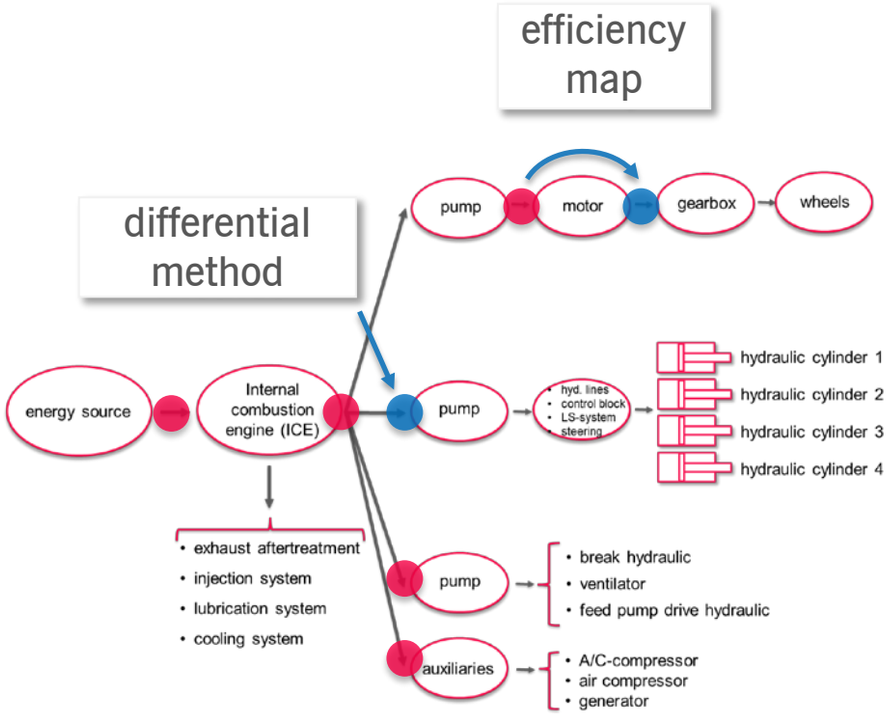
Structure of drivetrain



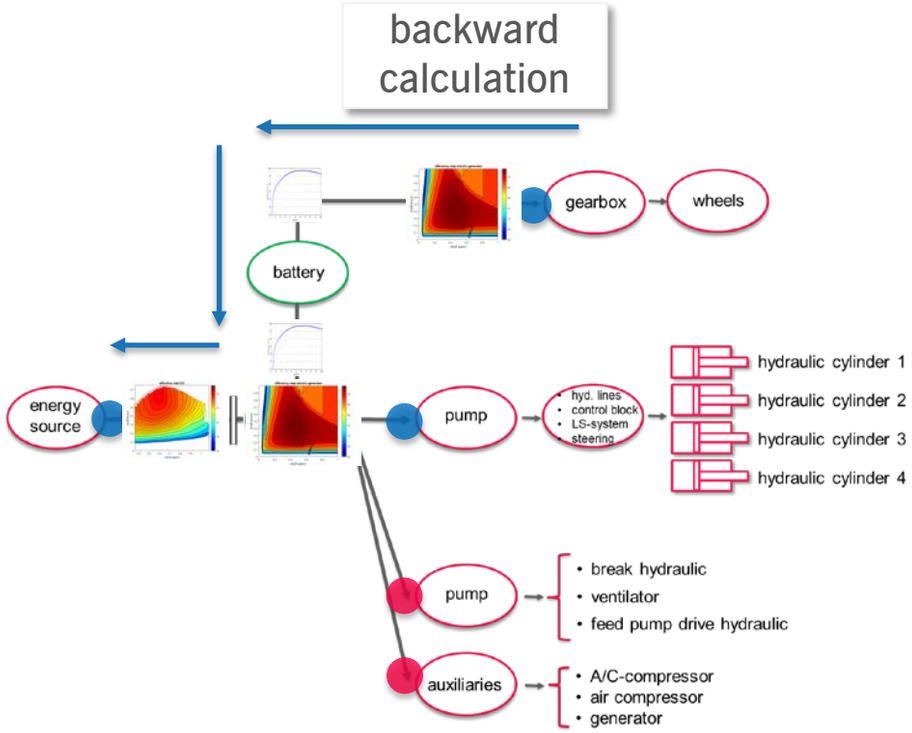
Methodology | Example Series Hybrid

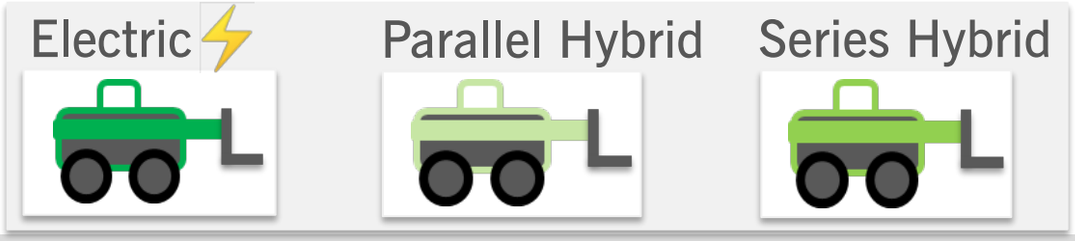
measured
calculated

Existing system



New system





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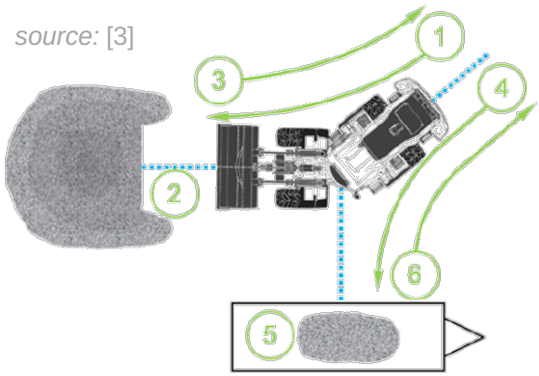
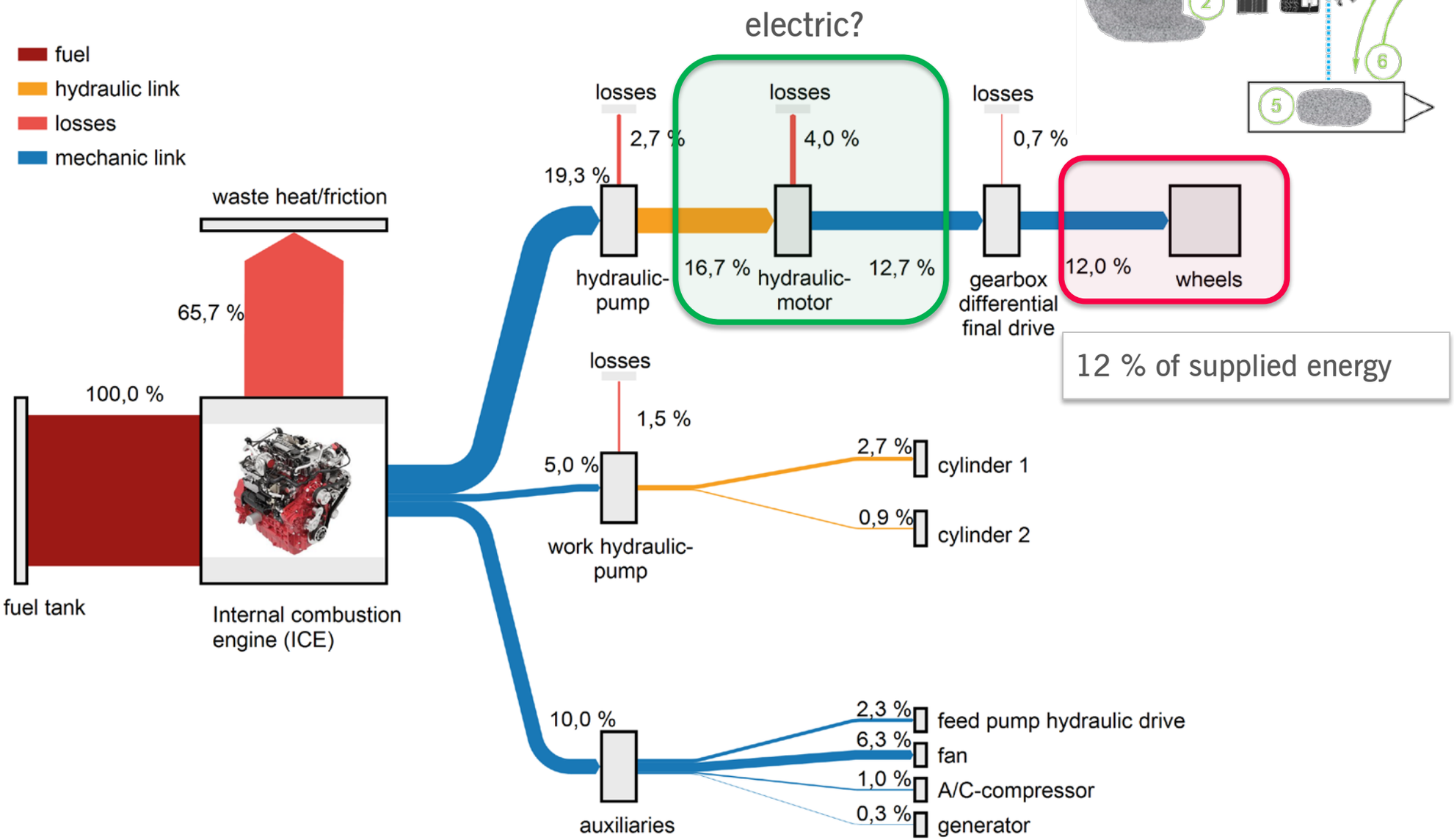
Results | Existing System

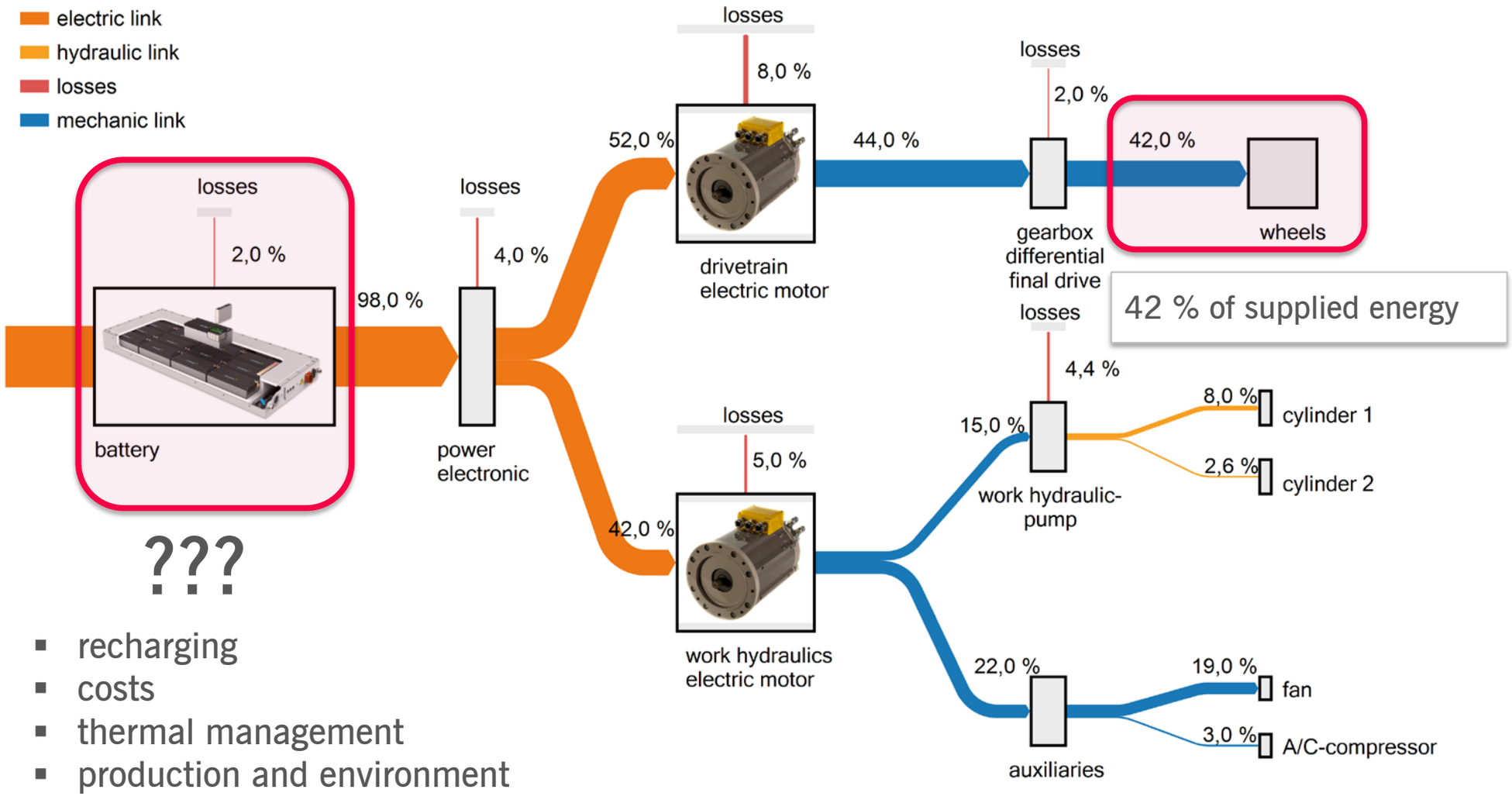




12 % of supplied energy

[3] Schneider, M.: *„Erstellung und Optimierung einer Hybrid-Betriebsstrategie von Non-Road-Arbeitsmaschinen mittels Simulation und Prüfstandsmessung“,* Technische Universität Graz, Masterarbeit, Graz, 2014

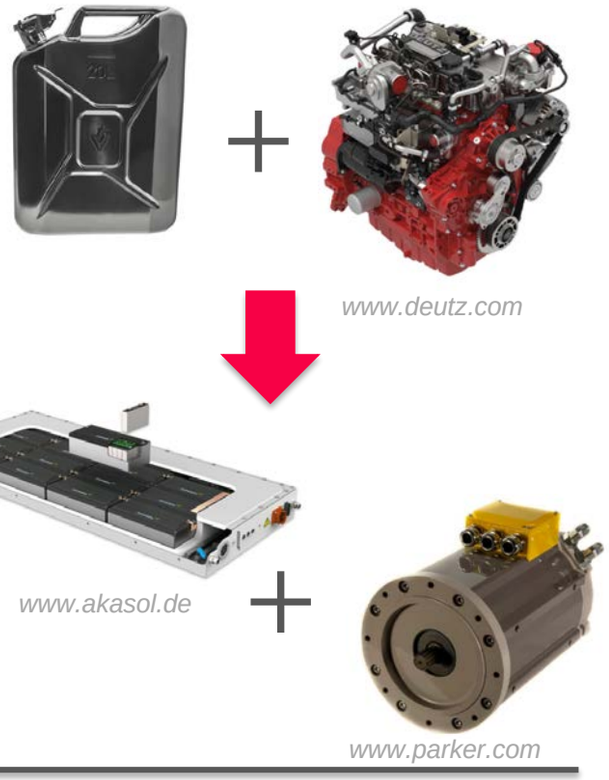
Results | Electric Drivetrain



???

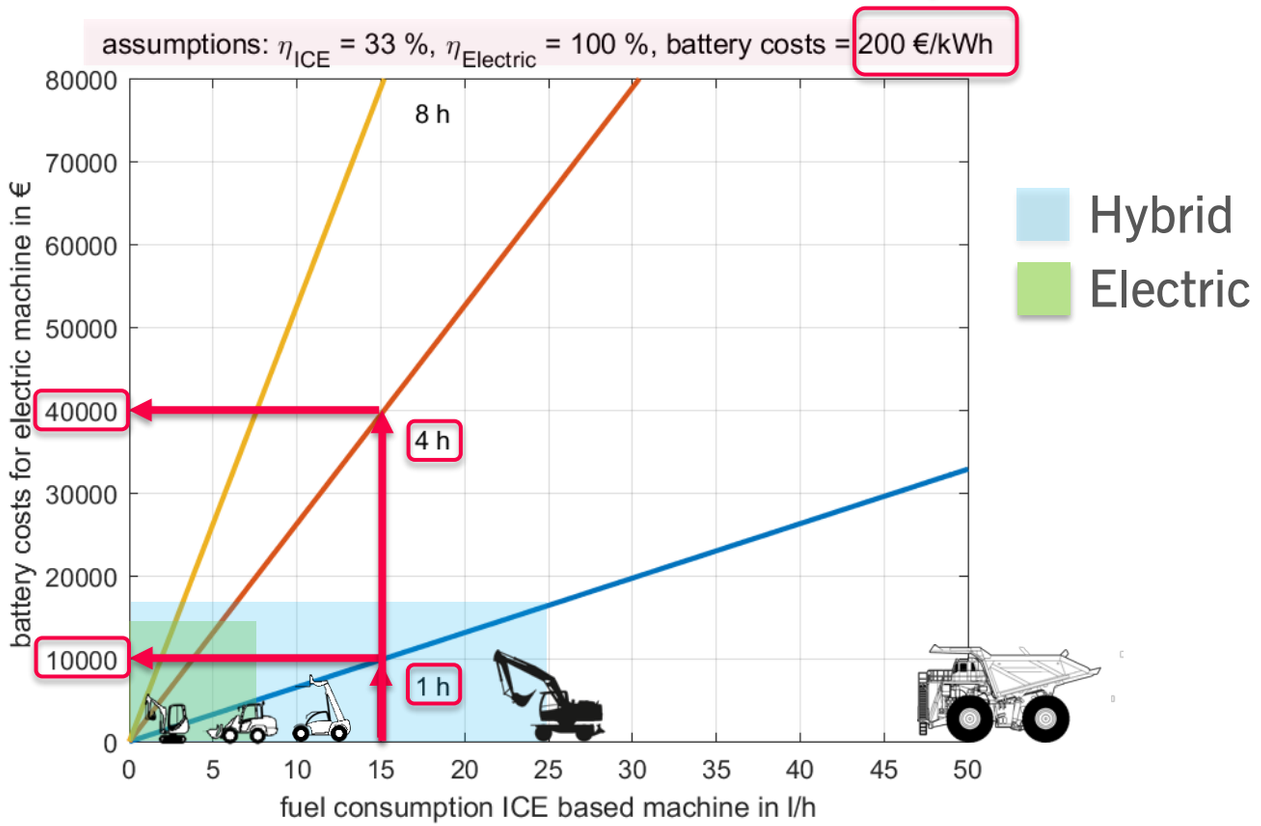
- recharging
- costs
- thermal management
- production and environment

Results | Assumptions of Costs & Drivetrain Technology



rest = same

most important factor



costs = killer (above a certain machine size)

not considering space requirements, safety, …

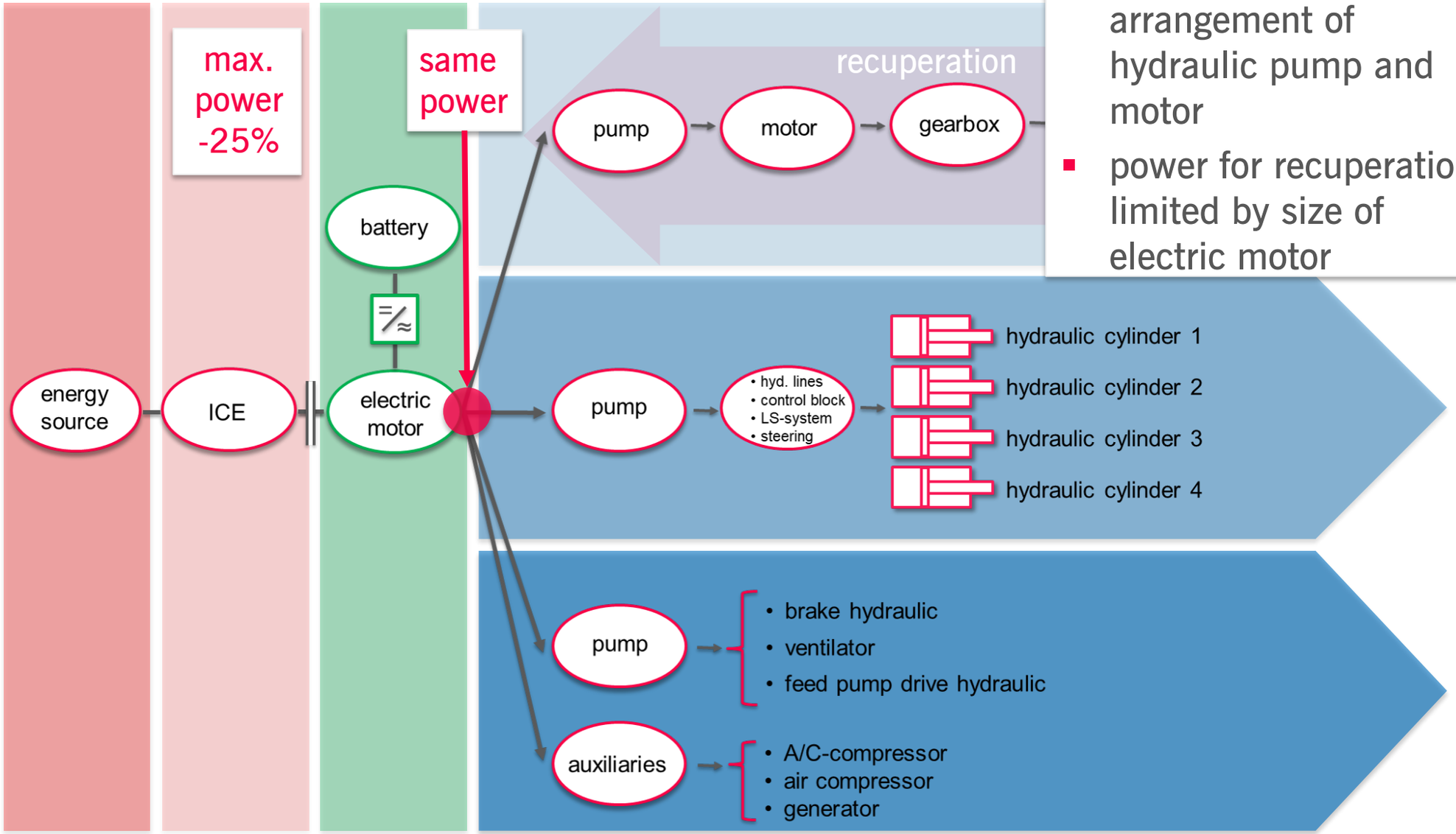
Results | Electric Drivetrain | Refuelling

diesel drivetrain	electric drivetrain	electric drivetrain
fuel pump: 30,000 kW (50l/min)	**domestic power: 22 kW**	**fast charger: 300 kW**
 www.elaflex.de	 www.mennekes.de	 www.phoenixcontact.com
→ 1 min refuelling = 3.3 h operation	→ 1 min refuelling = 27 sec operation	→ 1 min refuelling = 6 min operation

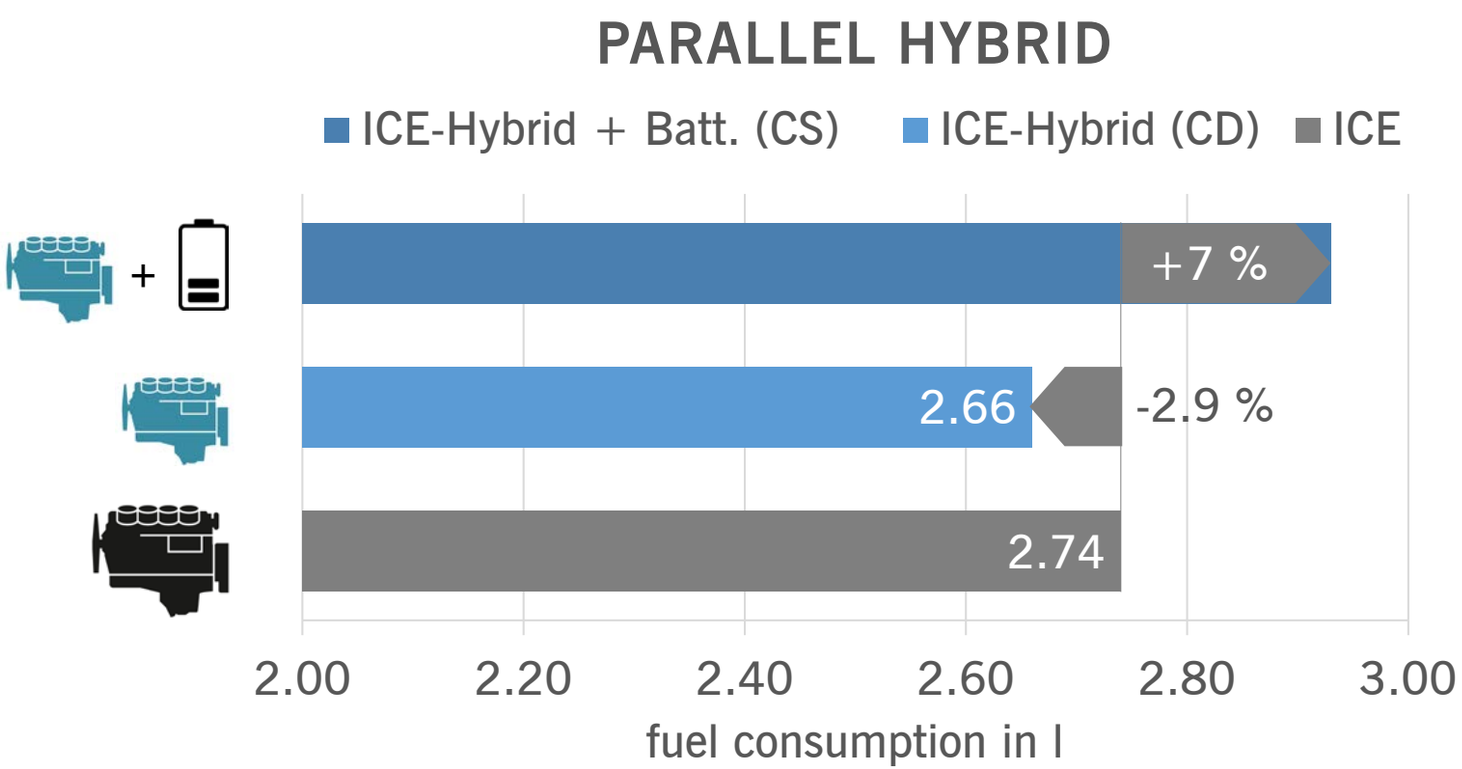
*calculation based on 42 kW effective power

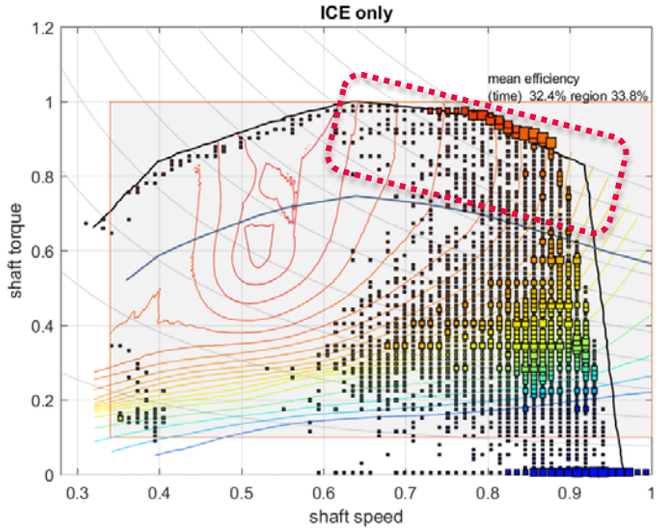
Parallel Hybrid

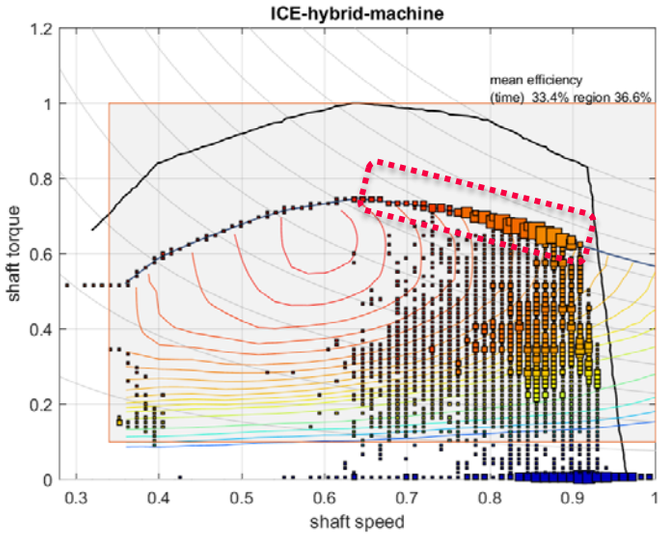
- recuperation efficiency limited by serial arrangement of hydraulic pump and motor
- power for recuperation limited by size of electric motor



Parallel Hybrid | y-Cycle | Energy Consumption



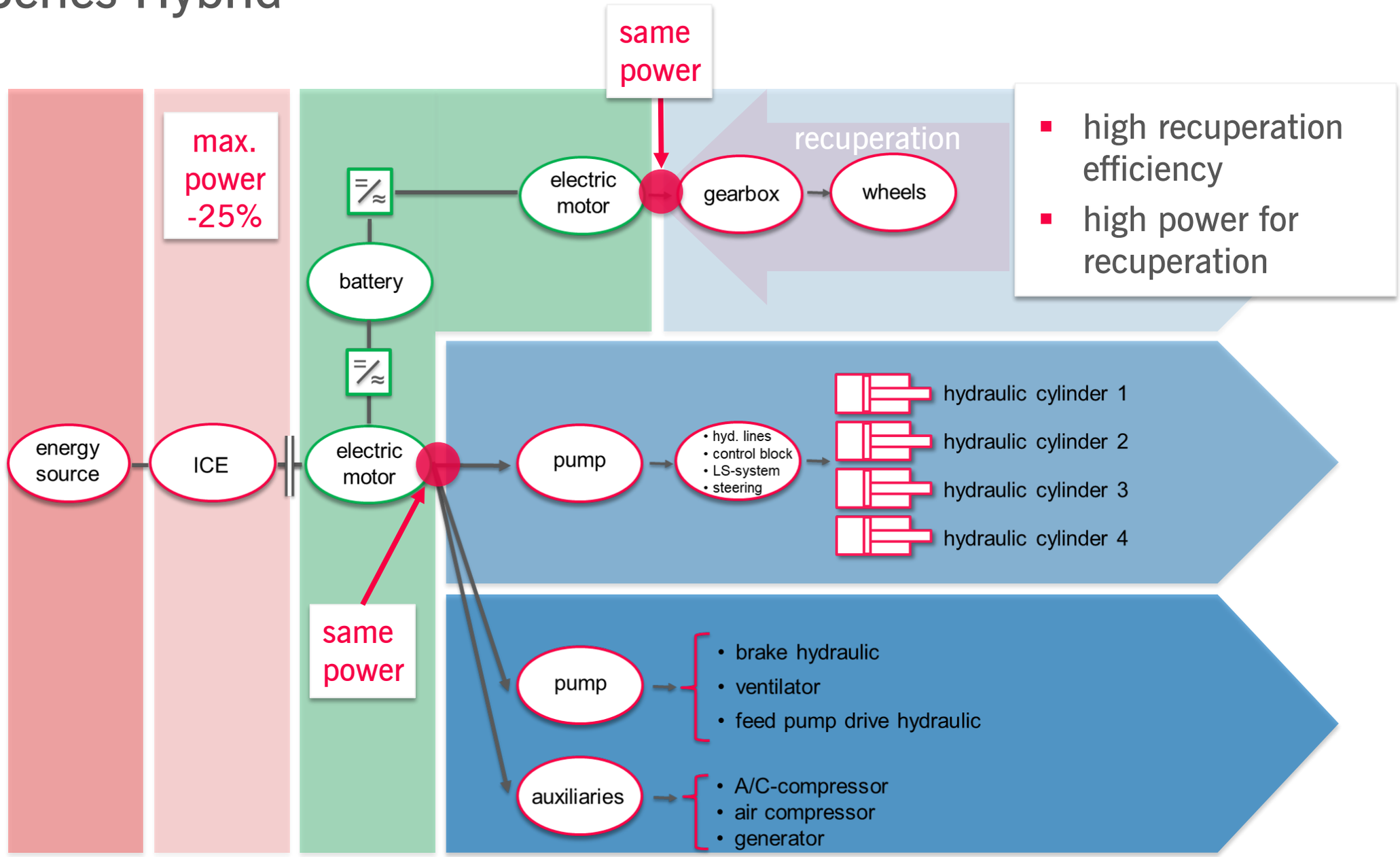




CD = charge depleting mode

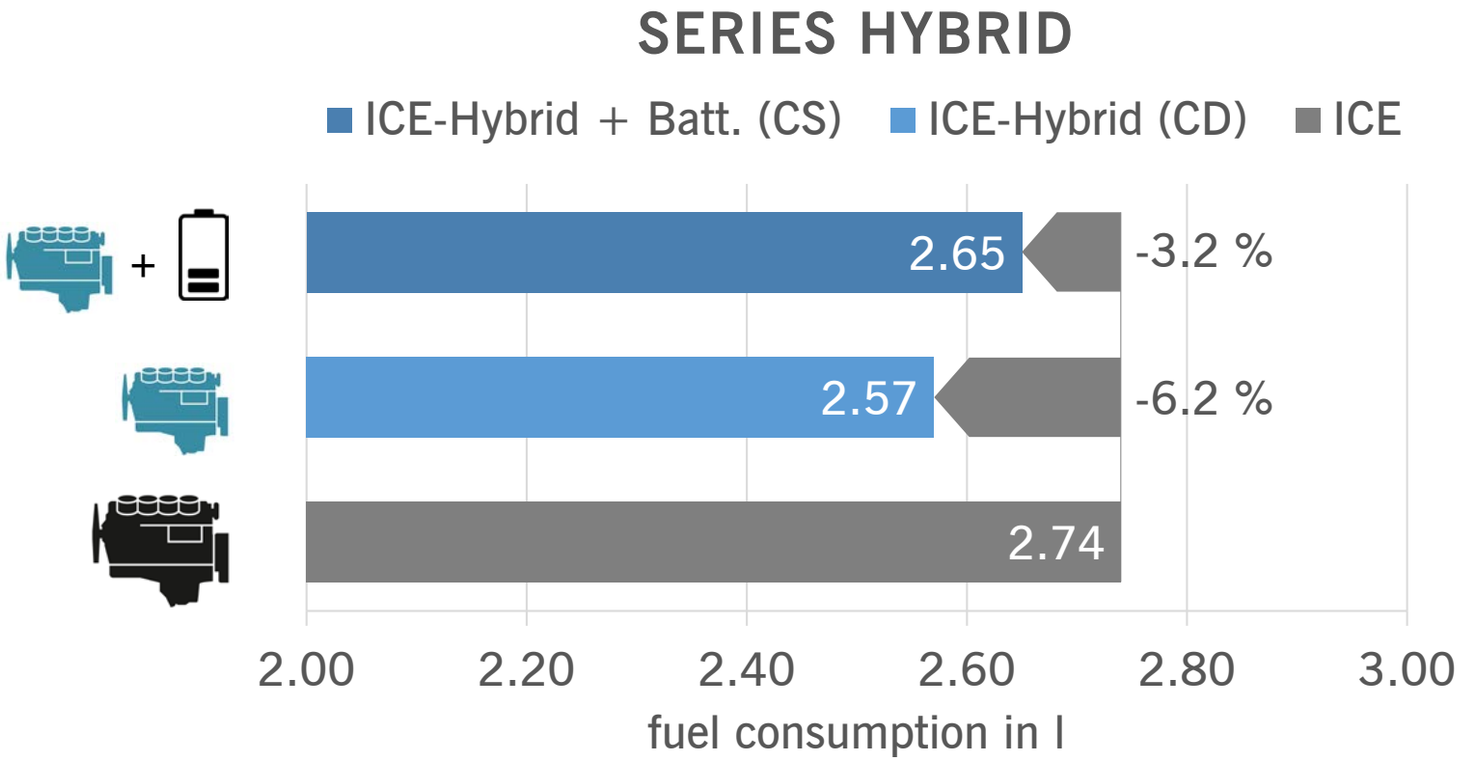
CS = charge sustaining mode

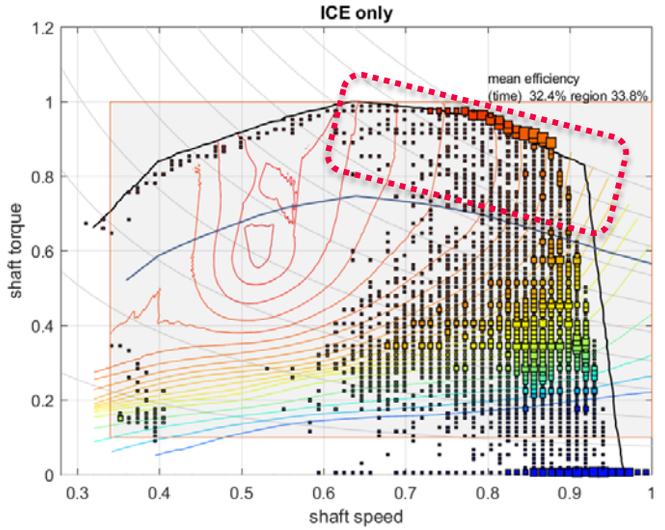
Series Hybrid

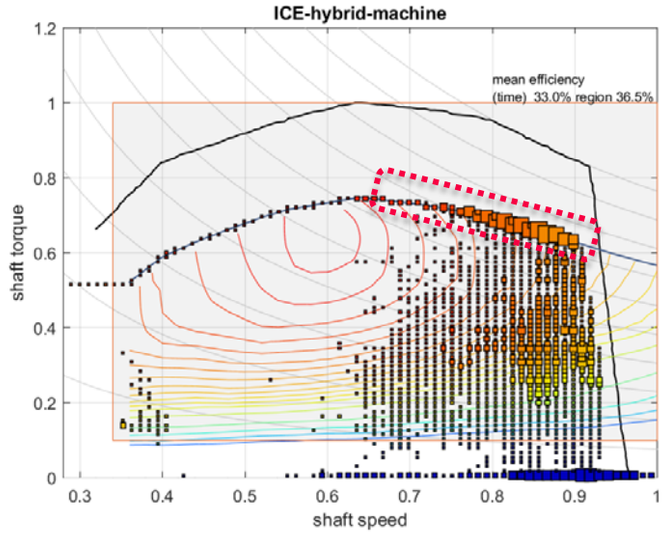


- high recuperation efficiency
- high power for recuperation

Series Hybrid | y-Cycle | Energy Consumption







CD = charge depleting mode

CS = charge sustaining mode

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Conclusion

- Electric Drivetrain
  - Highest efficiency in drivetrain
  - Challenges concerning the battery
    - Profitability = f(battery price)
    - Recharging time on construction site
    - Space, production and environment
  - Realistic for small construction machines
- Parallel Hybrid Drivetrain
  - Recuperation possible (limited power, limited efficiency)
  - Less fuel consumption than “ICE only machine” in charge depleting mode
  - Due to charge/discharge losses in charge sustaining mode, more fuel consumption (low efficiency improvement of ICE)
- Series Hybrid Drivetrain
  - High recuperation potential (power, efficiency)
  - Higher efficiency in charge depleting and sustaining mode
  - Best solution for hybrid drivetrain

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Thank you for your kind attention!

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