# Alternative Module Drives for Mobile Working Machines

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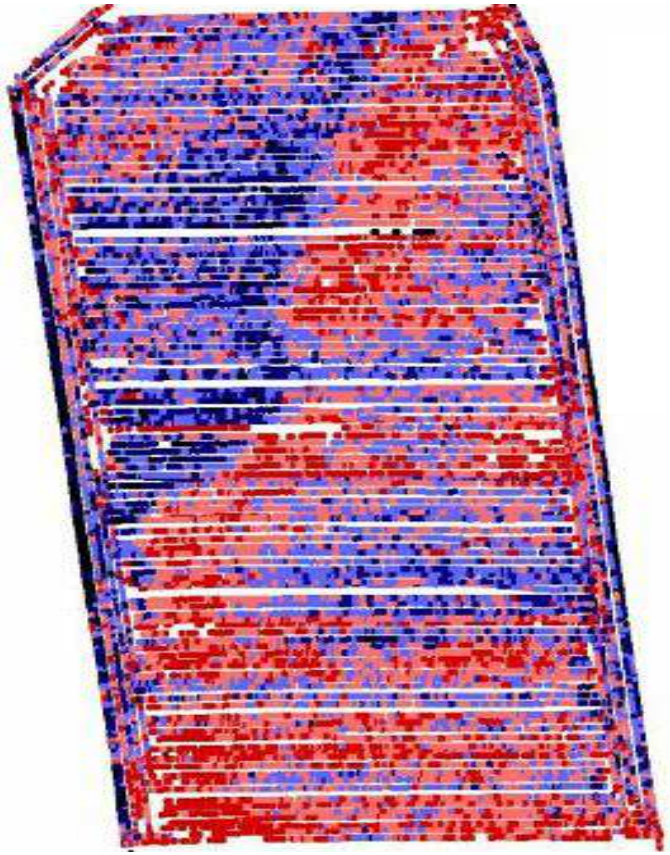
# Requirements resulting from material processing

Yield map of sugar beets,
field Hergern (Germany)
October 2001



| | Relative flow variability [%] | Standard deviation of yield [kg/ha] |
|---|---|---|
| Combine `02 | 78 | 96,2 |
| Combine `03 | 120 | 181,1 |
| Mower `01 | 29 | 15,8 |
| Mower `02 | 78 | 32,8 |
| Beet harvester `02 | 71 | 260,7 |
| Maize Chopper `02 | 134 | 235,0 |
| Maize Chopper `03 | 41 | 108,9 |

**Increased machine efficiency by:**

- Dynamic machine adaptation (KUTZBACH) → closed-loop module speed control
- Closed loop module control systems (BÖTTINGER)
- Increased driveline efficiency

# Objectives

## Problem:

Which technology fits future demands?

→ Assessment of alternative drive line concepts for usability in mobile working machines

**Criteria:**

- satisfying future requirements
- overall efficiency
- power to weight ratio
- overall size of the module drive and the peripheral equipment
- design aspects
- costs

# Methode

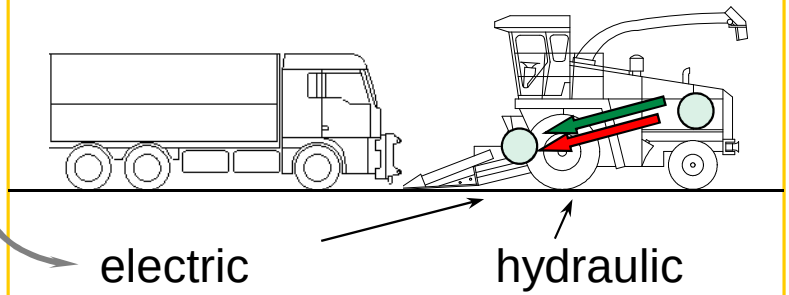
**Field Tests**

Hydraulic driveline
(Series production)

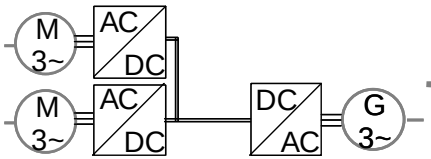
Monte-Carlo Analysis

**Typical Loadcycle**

**Test Stand**




**Electric driveline (Prototype)**




**Field Tests**

Electric driveline
(Prototype)

Hydraulic driveline:

Operational behaviour

Power-to-weight ratio $m_P$

Hydraulic driveline:

$\eta_{t\ driveline}$

$\eta_{t\ module}$

$\eta_{t\ transmission}$

Electric driveline:

$\eta_{t\ driveline}$

$\eta_{t\ module}$

$\eta_{t\ transmission}$

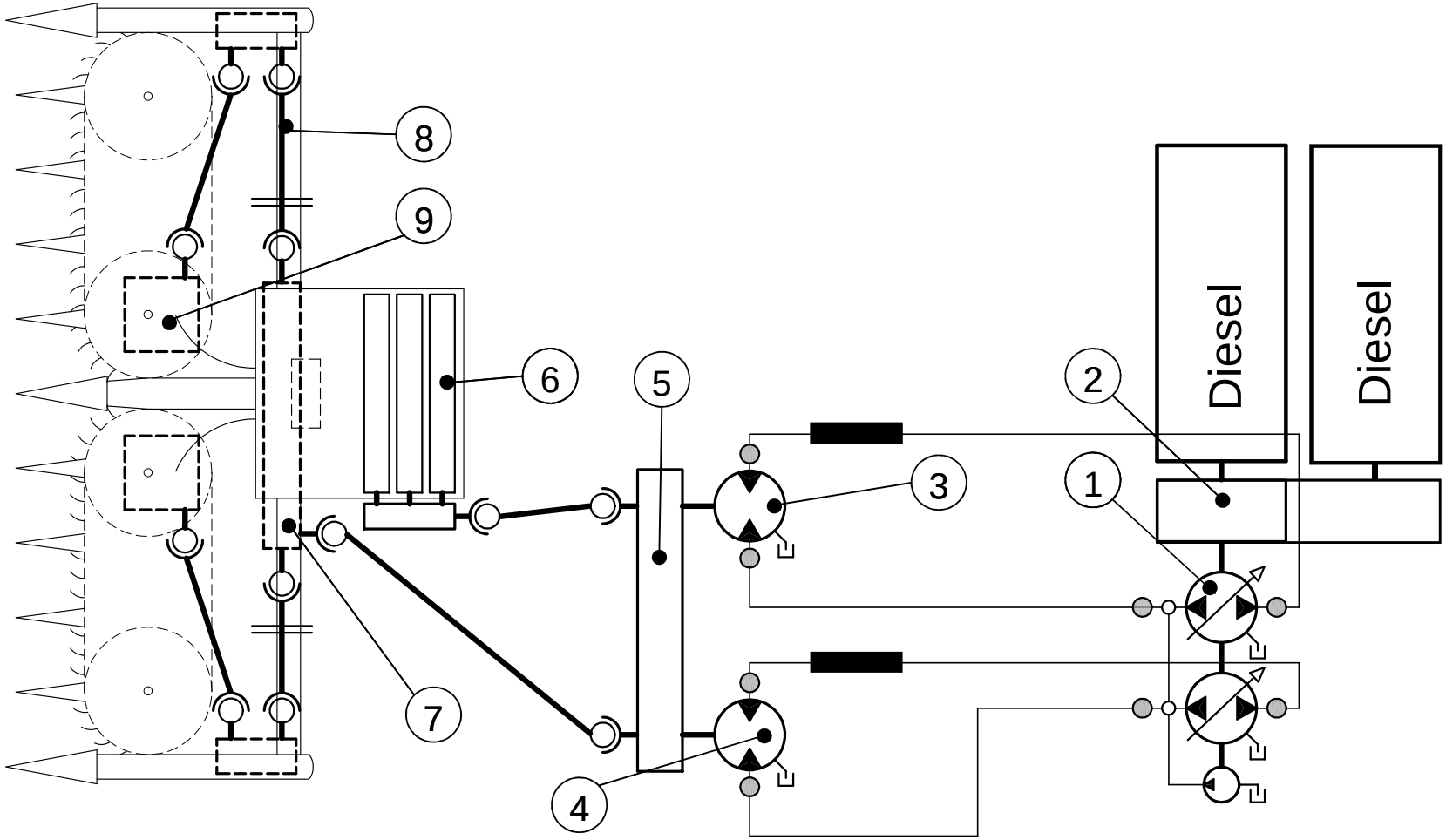
Electric driveline:

Operational behaviour

Power-to-weight ratio $m_P$

# Carrier Big-X with easyCollect

# Hydraulic Header and Intake Drive

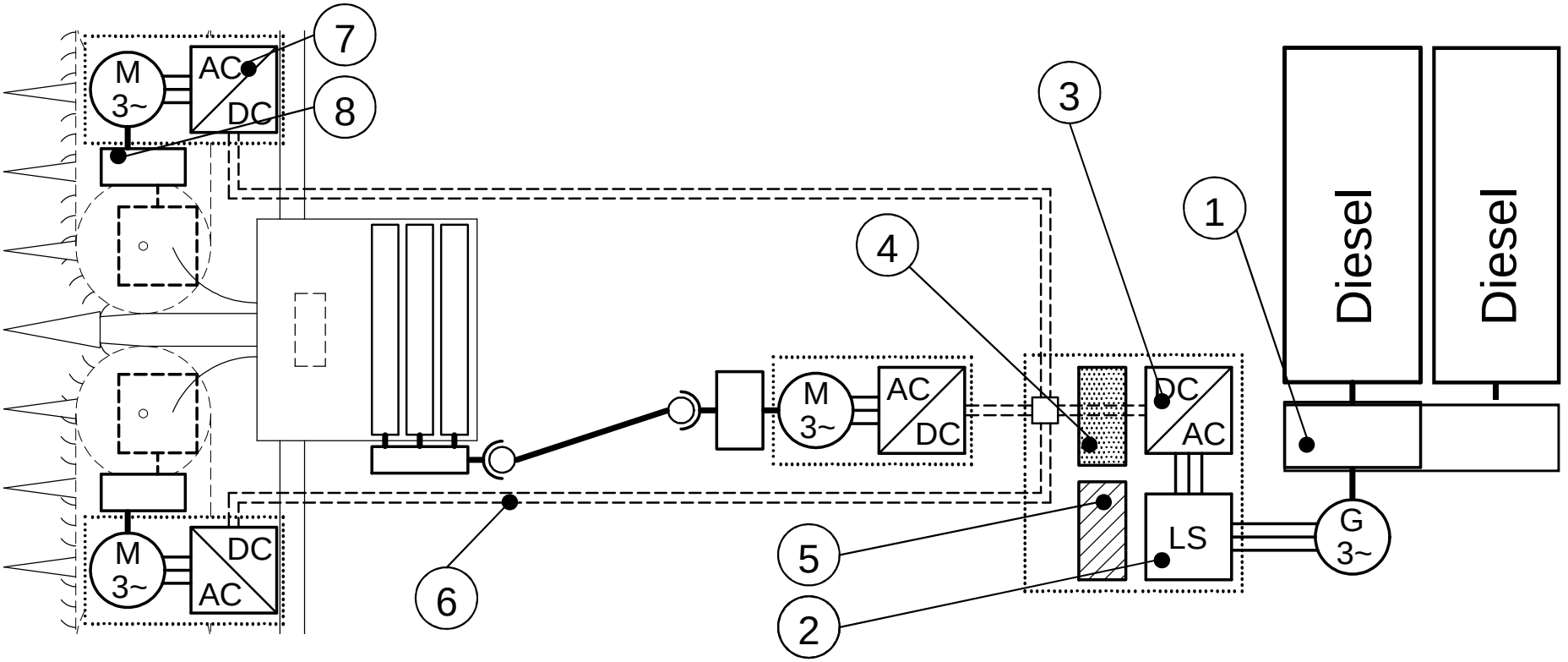



1. Pumps
2. Motorvgearing
3. Hydr. Intake Drive
4. Hydr. Header Drive
5. Gearing
6. Intake Module
7. Split Gearing Header
8. Mech. Driveline Header
9. Chaindrive Gearing

Pressure Sensor

Flow rate Sensor

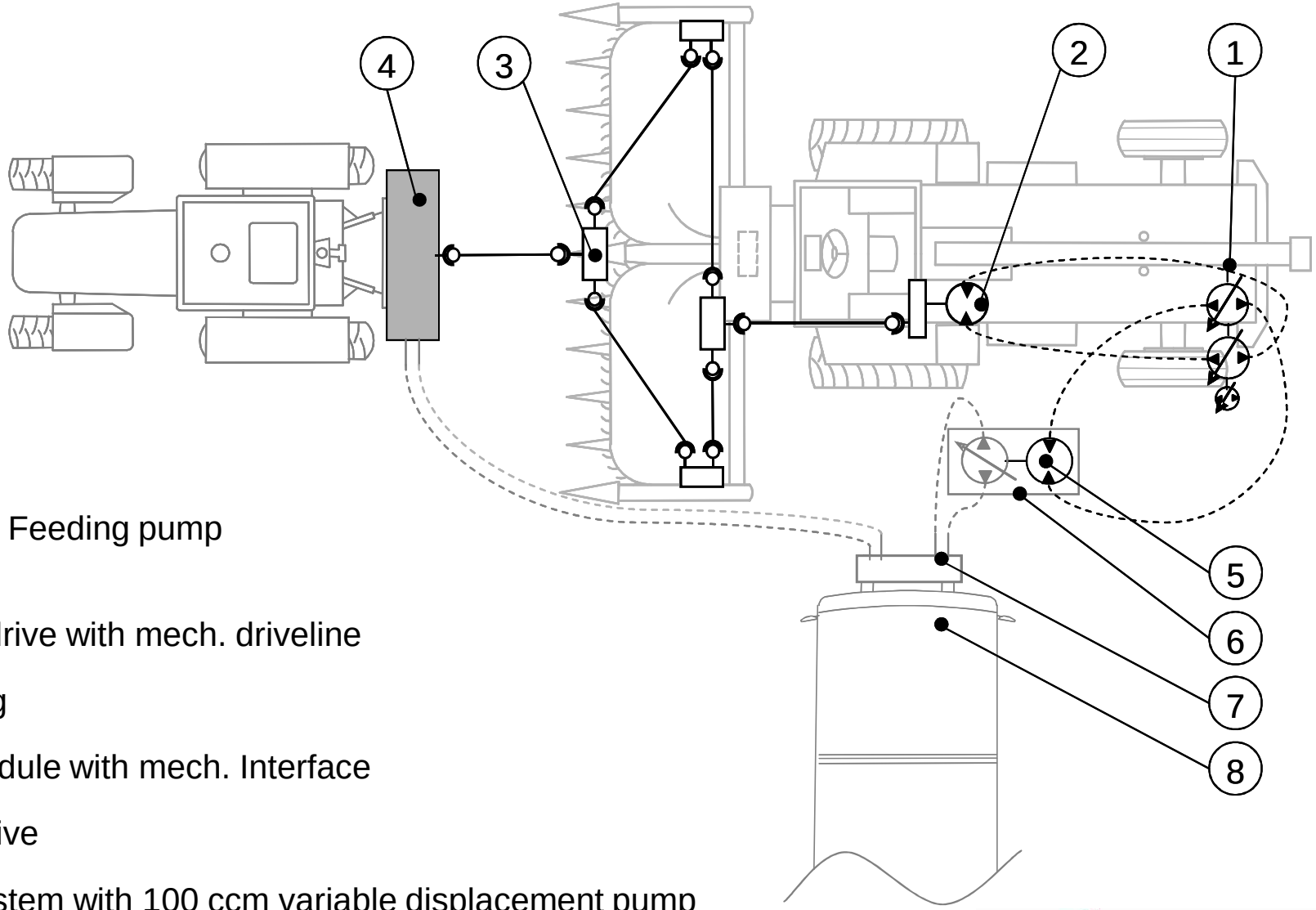
# Diesel-electric Header and Intake drive (without Cooling System)




1. Synchronous Generator
2. Power switch
3. Rectifier
4. Capacitors DC-Link & Braking resistors
5. Control and Safety
6. DC-Link (400-750 V)
7. Motor with Converter
8. Planetary Gearing

# Diesel-electric Solution

# Test Stand Set up

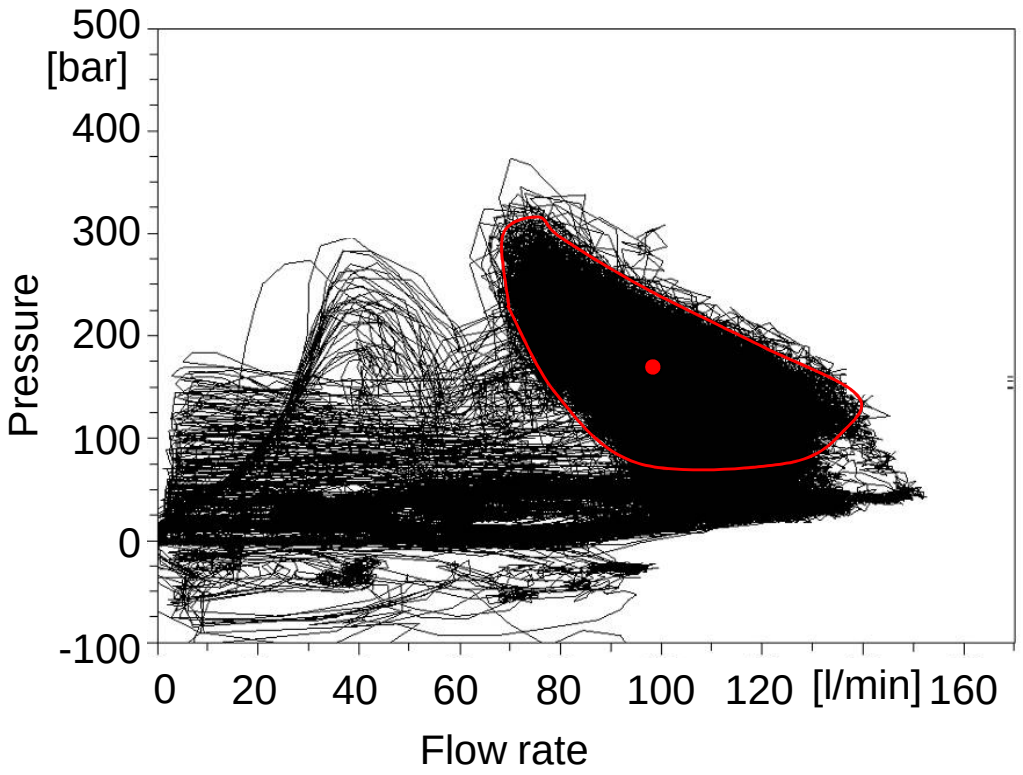


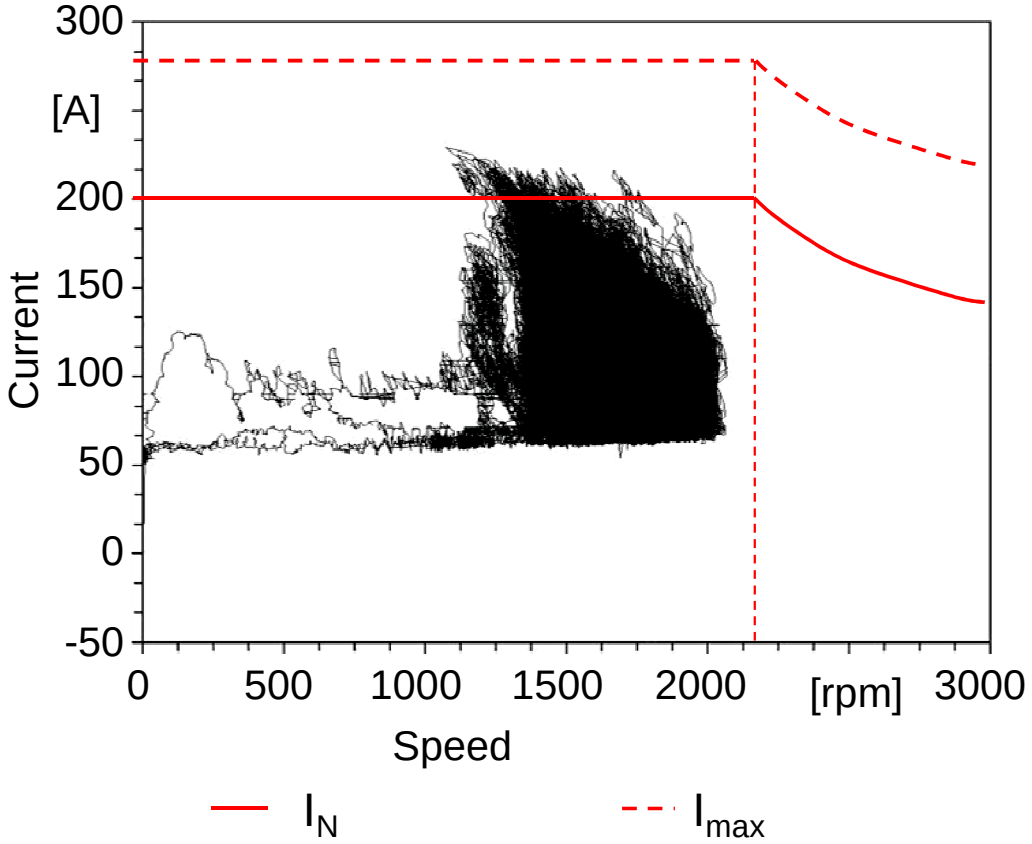

1. Header, Intake und Feeding pump at Engine Gearing
2. Hydraulic Header drive with mech. driveline
3. Summation gearing
4. DLG PowerMix Module with mech. Interface
5. Hydraulic Intake drive
6. Hydraulic pump system with 100 ccm variable displacement pump
7. Hydraulic Interface DLG PowerMix ($DLG_{hydr}$)
8. DLG PowerMix Drawbar Test Vehicle

# Results

- Operational behavior during field tests
- Efficiency during stationary operation
- Efficiency during dynamic operation
- Power-to-weight ratio
- Power density
- Costs

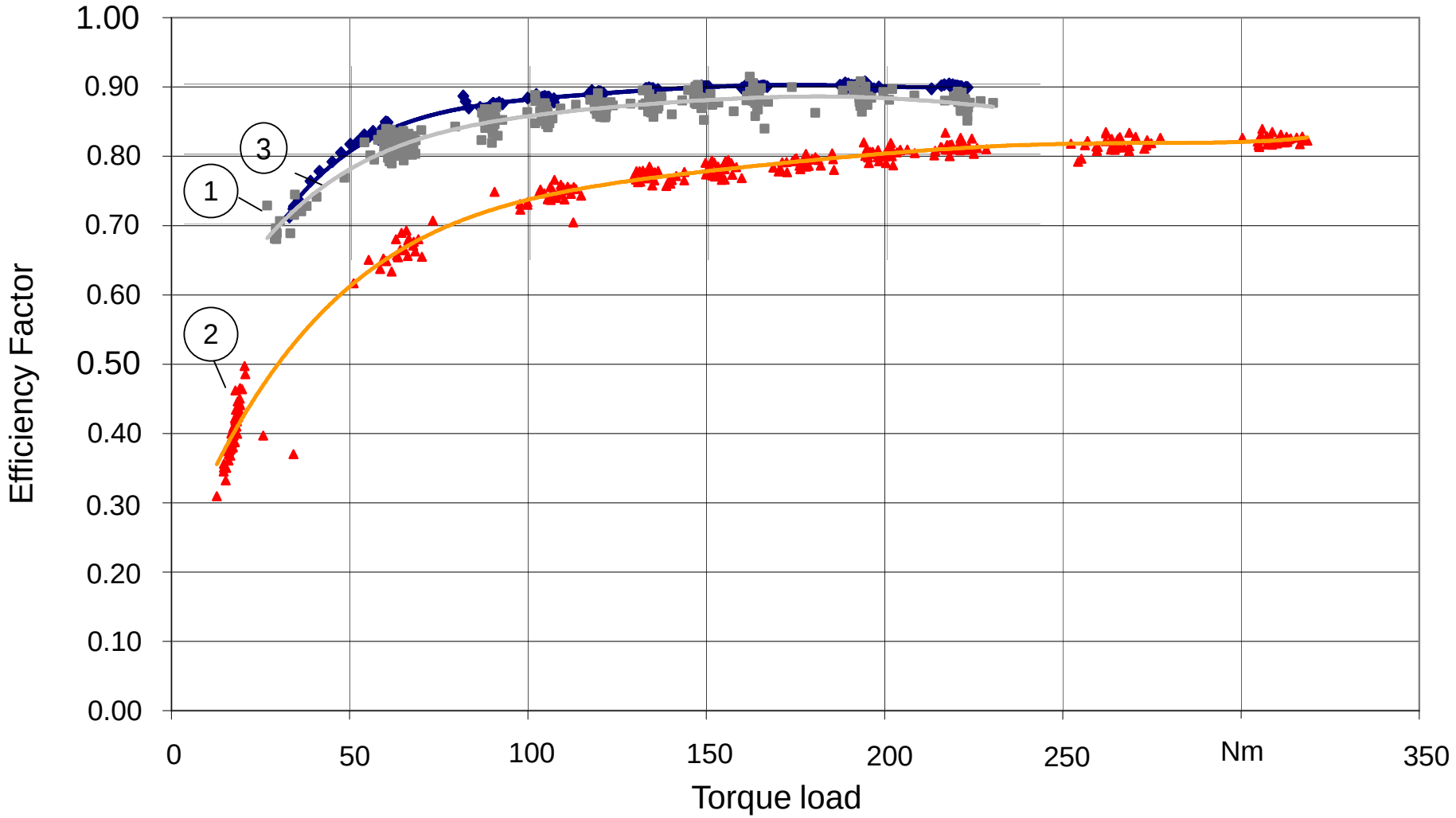
# Operational Behavior
## - Hydraulic and Electric Intake Drive during Field Tests -



# Efficiency of module Drives depending on load

($n_{Diesel}$=1750 1/min; $x_{th}$ = 8 mm)

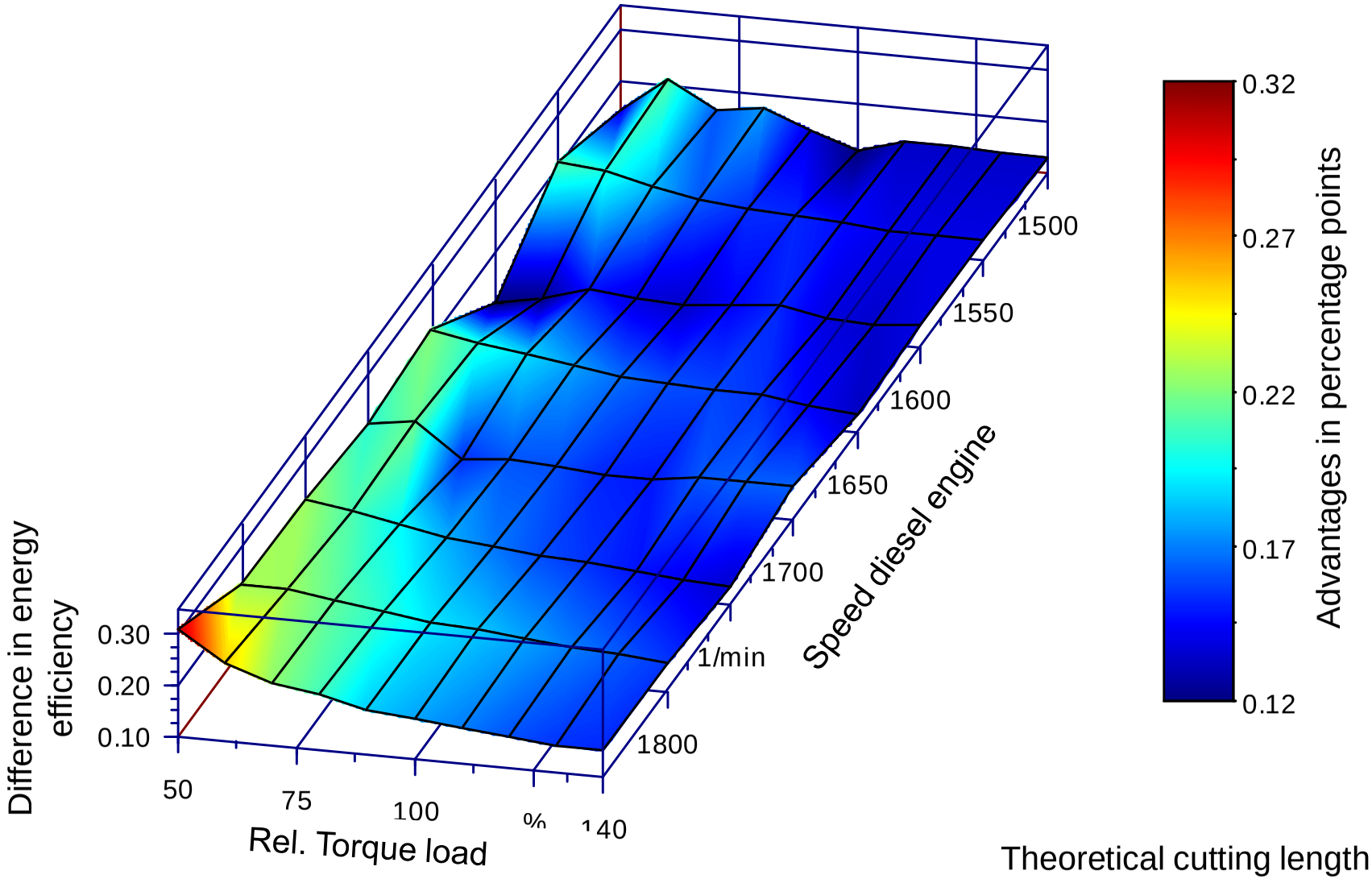



1 Hydraulic intake drive

2 Hydraulic header drive with mechanic transmission

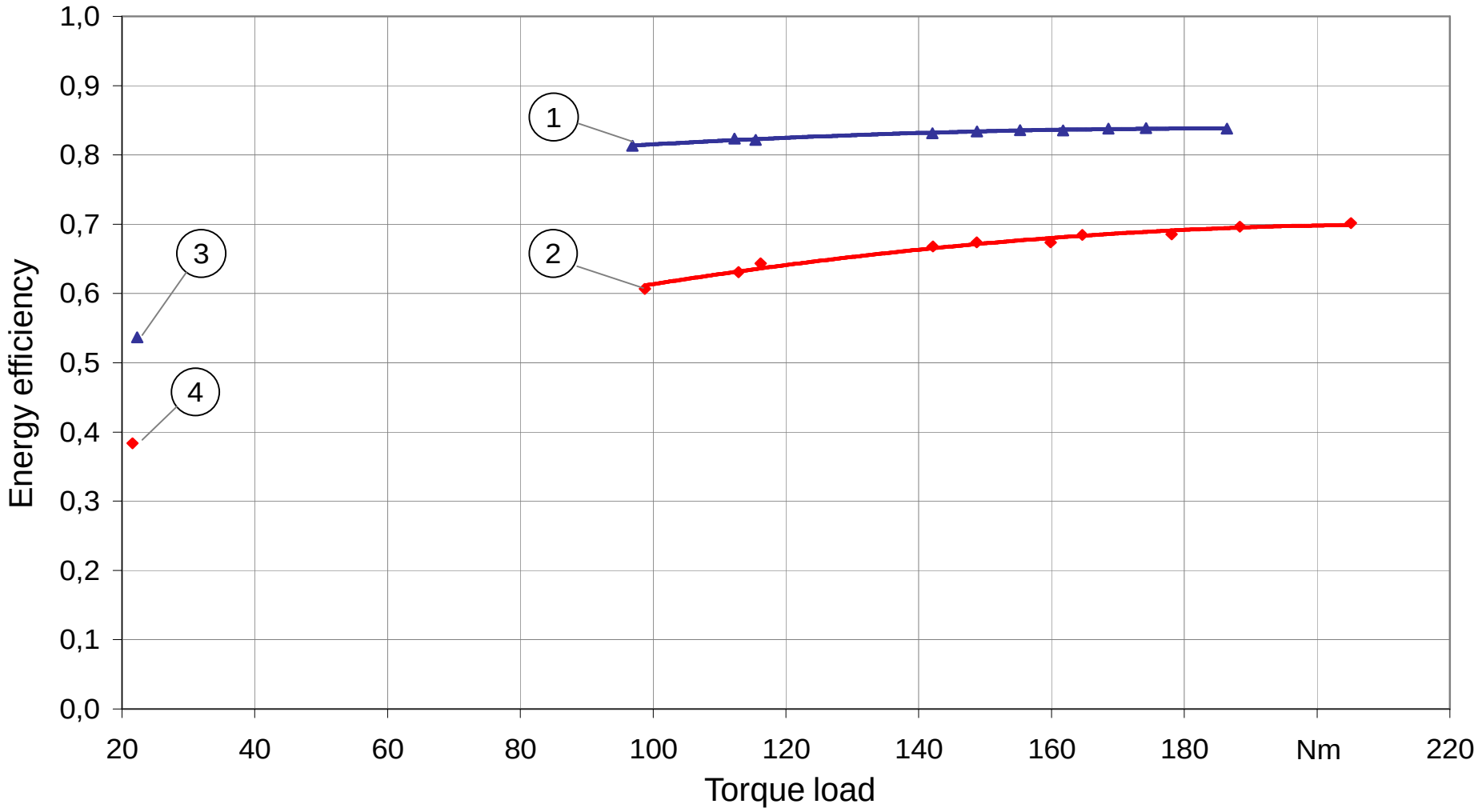
3 Electric header drive

# Efficiency Benefits of the electric driveline




Theoretical cutting length: 8 mm

# Energy efficiency during typical load cycles




1 Electric driveline

2 Hydraulic driveline

3 Non-load operation electric driveline

4 Non-load operation hydraulic driveline

# Power-to-weight ratio of modules and drivelines

- Obvious disadvantages at the electric module drives:

  ⟹ Averaged electric drives 3 times heavier than hydraulic ones

- New approches enable advantages for the driveline at a glance :

  ⟹ elelctric header drive: 11.3 kg/kW

  ⟹ hydraulic-mechanic header drive: 15.9 kg/kW

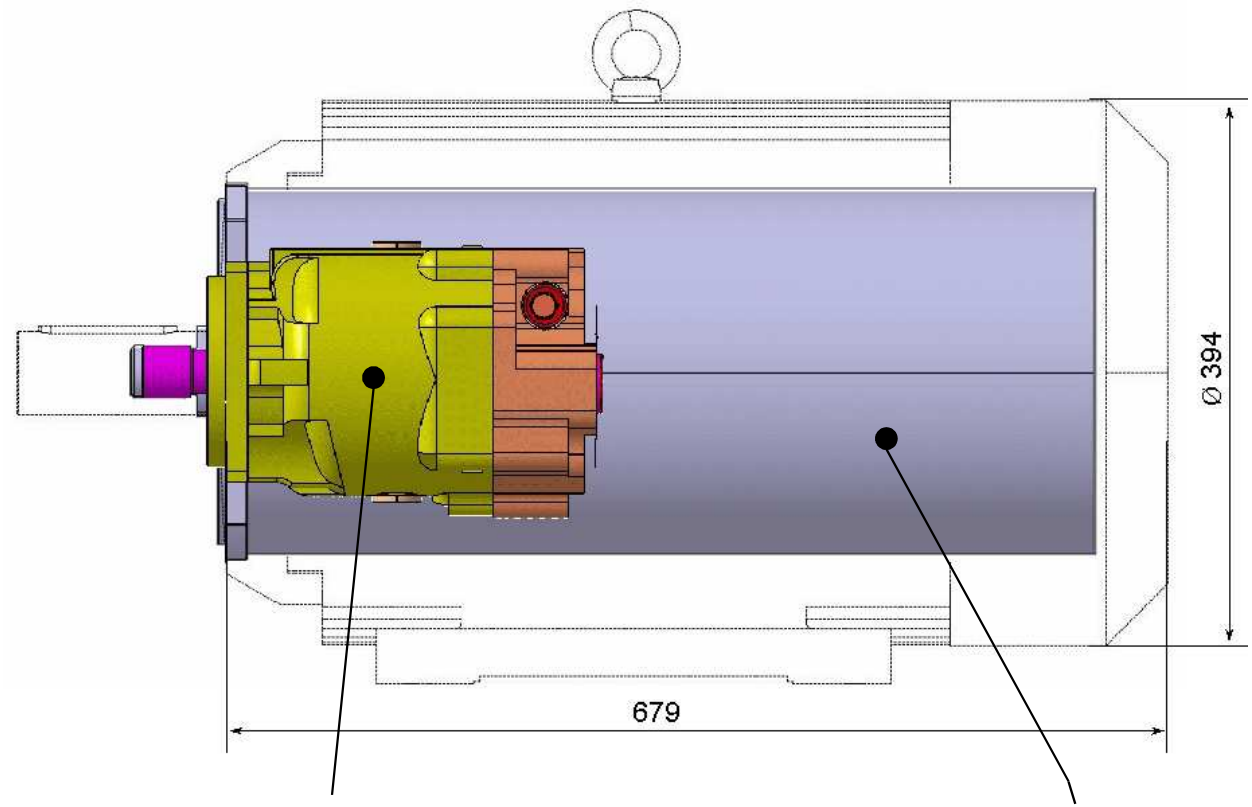
- the powertrain for header and intake at a glance:

| | | |
|---|---|---|
| ⟹ diesel-electric approach: | 689.6 kg | 17.2 kg/kW |
| ⟹ hydraulic approach: | 565.6 kg | 14.1 kg/kW |

But: comparability of the used systems is limited

=> Series Production vs. Prototype

# Size and Power Density of electric motors




(by HARMS)

Hydraulic Motor (Series production)

→ 7.6 dm³

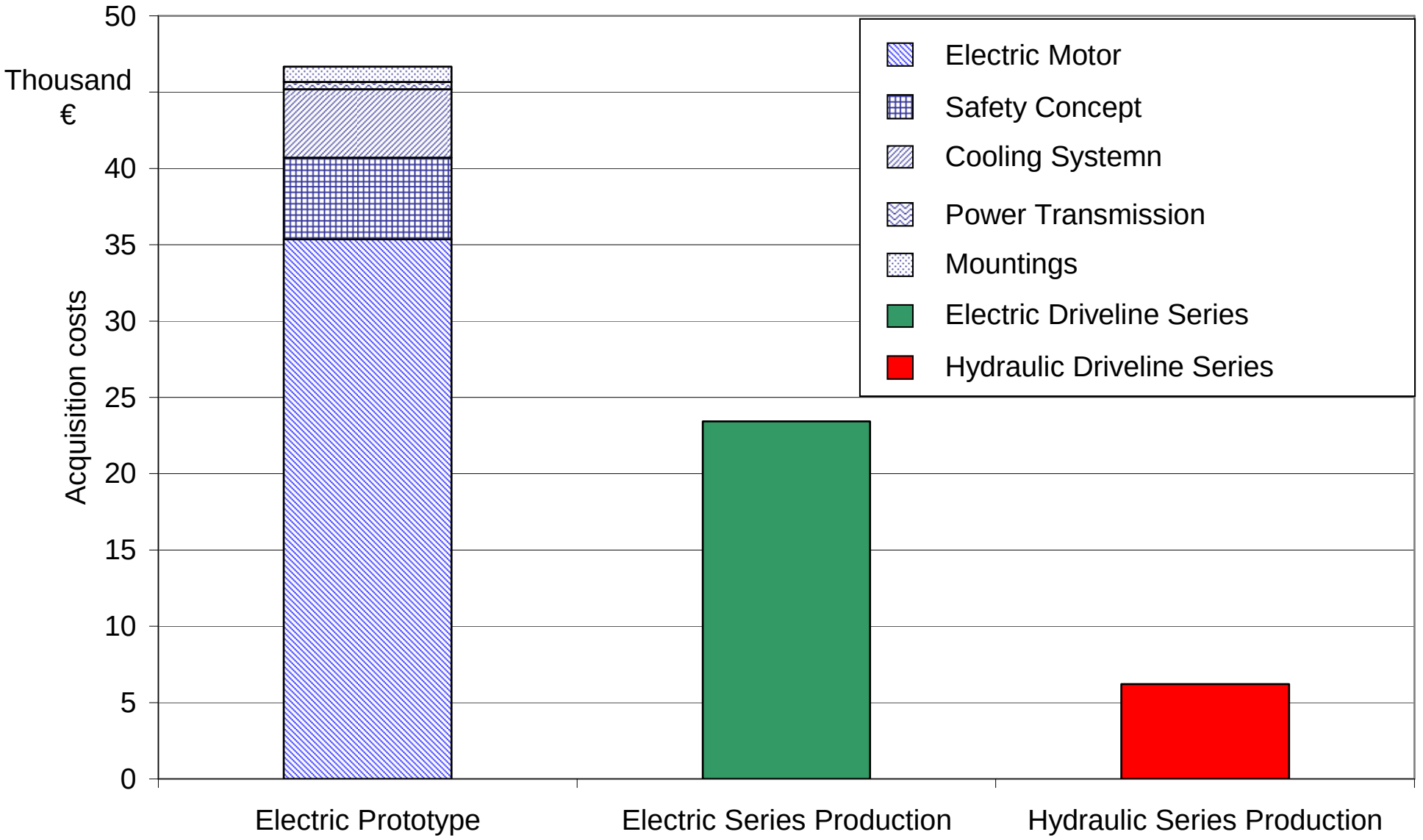
→ 3.566 kW/dm³

Electric Motor (Prototype)

→ 29.6 dm³

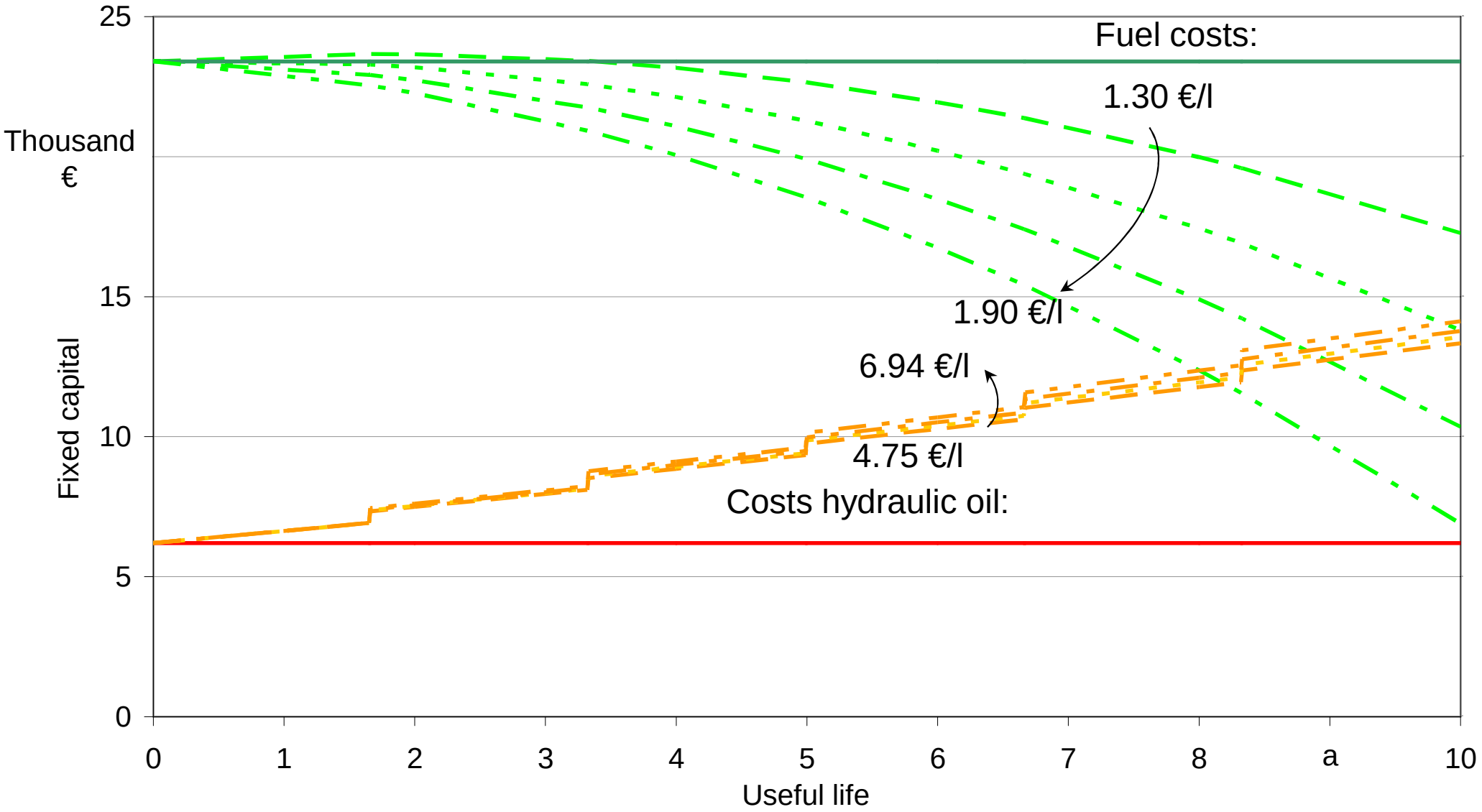
→ 0.916 kW/dm³

# Costs of acquisition




*) estimated

# (Careful) Costs of Operation



# Summary

## Advantages of the diesel-electric driveline:

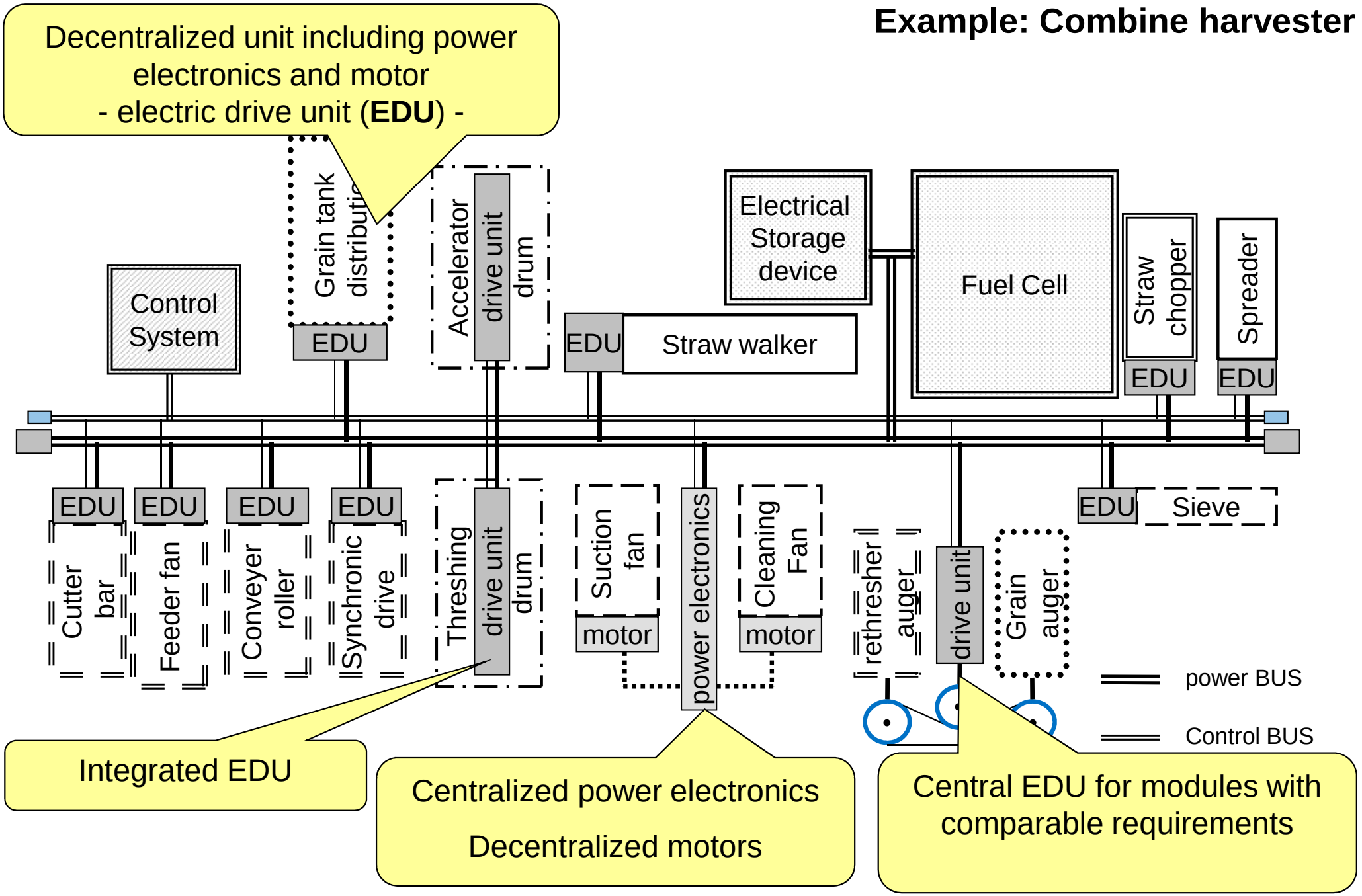
- Closed loop control of the drives and feedback of the process parameters enables easy integration into driveline managements system
- Efficiency benefits at a wide range of the operation map of about 16 percentage points (between 13.5 to 30 percentage points)
- Efficiency benefits during typical load cycles between 14 to 20 percentage points

## Disadvantages of the diesel-electric driveline

- Power-to-weight ratio of the total driveline is about 22 % higher
- Power Density is about 3.9 times inferior
- Amortization or increased  acquisition costs after the total useful life

# The future power train design in mobile working machines?

**Example: Combine harvester**



# Conclusions

## Diesel-electric drivelines

- are an additional alternative in mobile working machines
- show high efficiency even under low work load
- improve control and adjustment
- have highest benefit in systems with very large variable requirements
- allow direct use of electricity from solar and fuel cells

**Thank you for your attention !**

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