Usage of Biomethane on Combine Harvesting Applications

Fabian Wohlfahrt – CLAAS Selbstfahrende Erntemaschinen GmbH

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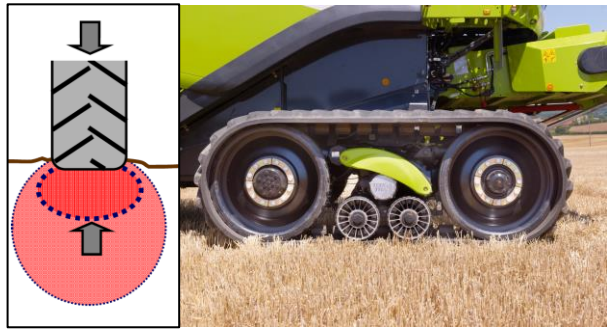
Motivation - Reducing CO2-Emissions on High Performance Harvesting Applications

- Decarbonizing high performance harvesting applications bears major challenges

High Power Demand

Long Operation Times

Soil pressure



Motivation - Reducing CO2-Emissions on High Performance Harvesting Applications

- Decarbonizing high performance harvesting applications bears major challenges

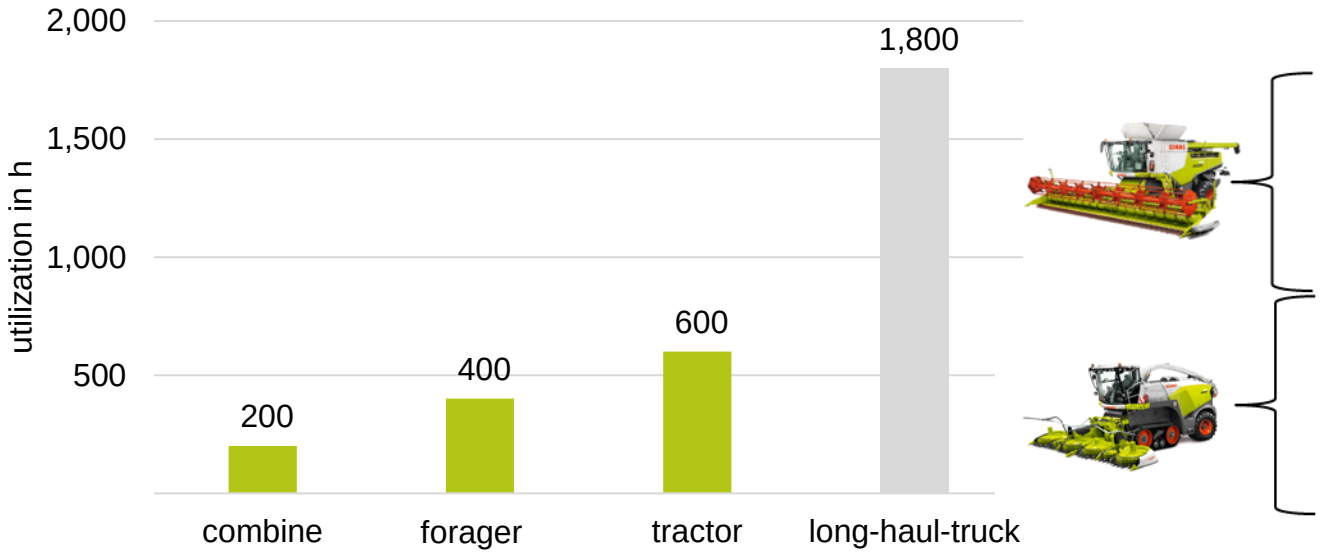
High Power Demand

Can methane-based powertrains cope these requirements?

Long

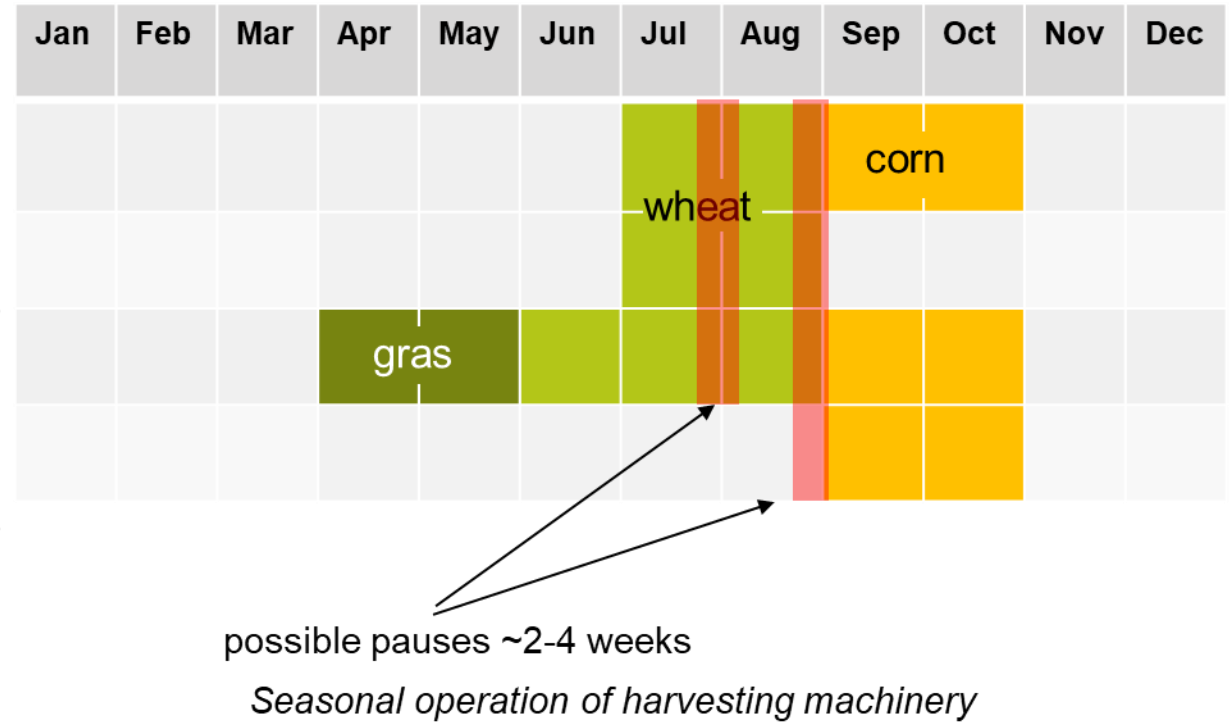
Requirements - Duty-Cycles of Heavy-Duty Agricultural Machinery

Short annual utilization



Exemplary utilization of heavy-duty applications [1]

intensive seasonal utilization



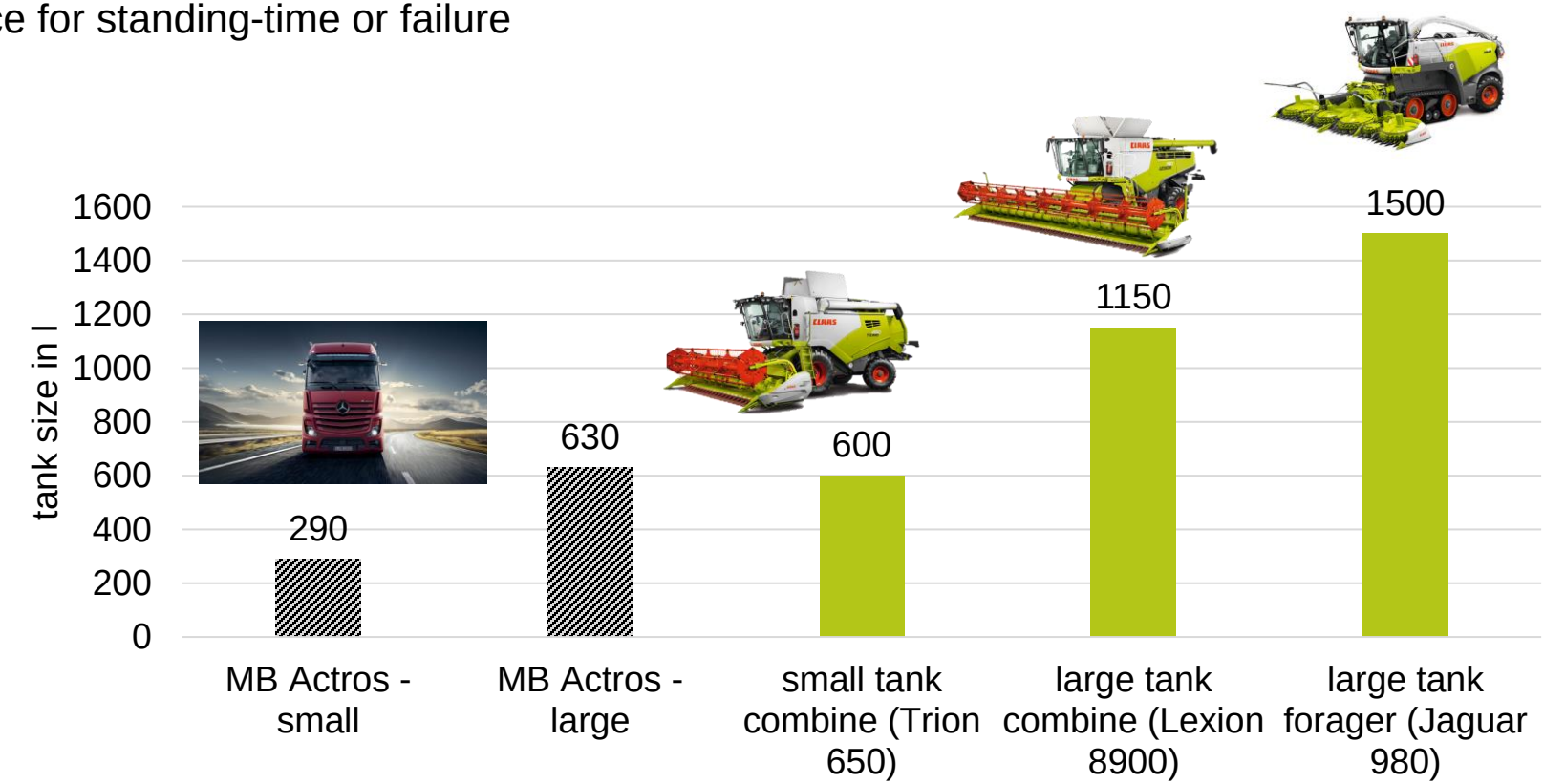
Seasonal operation of harvesting machinery

Requirements - Energetical Range for Heavy-Duty Agricultural Machinery

- Heavy harvesting machinery is used in extremely seasonal depended scenarios

  ⇒High utilization during harvest is demanded

  ⇒Low acceptance for standing-time or failure

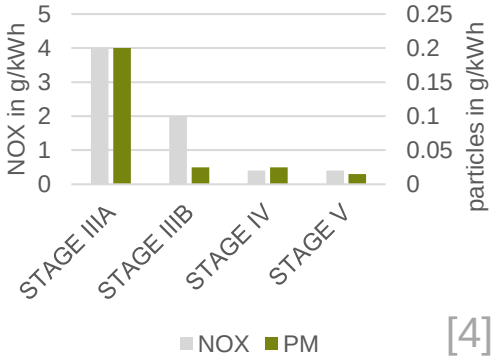


Comparison tank sizes - truck vs harvesters

[2]

Benefits of Methane Based Powertrains

- ✓ High Maturity
- ✓ Reduction of tailpipe emissions (up to 20 %)
- ✓ WtW-potentials (>50 %) (§6 Biokraft-NachV)
- ✓ Simpler exhaust-aftertreatment
- ✓ Cost-benefits (e.g. via quota-trade)



[4]

Emission restrictions for NRMM

Biomethane as a THG-potenial [3]

Key-Factors for a successful Machine Integration

- To evaluate the integrability on harvesting machinery 3 major aspects need to be analysed

1. Are suitable **engine systems** available?
2. Can a sufficient autonomy degree be reached with a suitable **storage technology?**
3. Can a viable **refuelling infrastructure** be integrated?

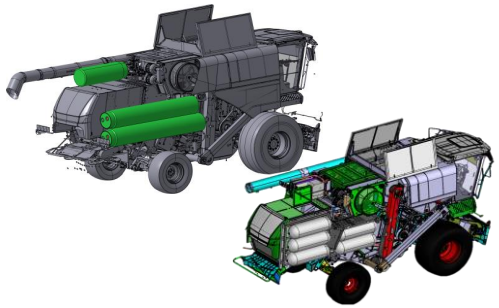
engine systems

[5]

refuelling infrastructure

[6,7,8]

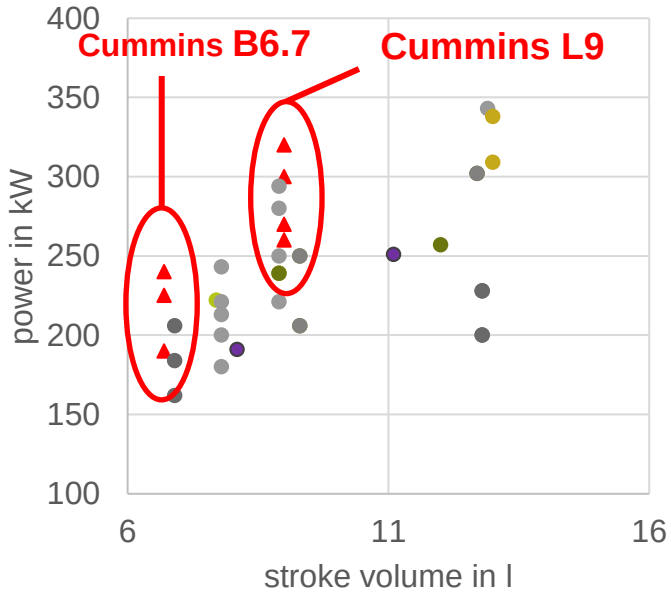
storage technology



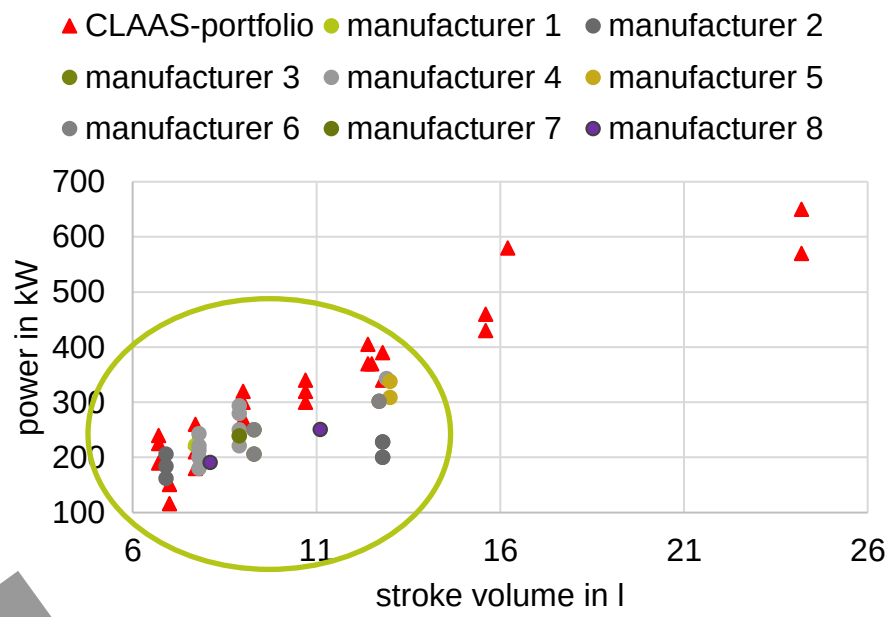
Engine-Availability - A Midrange Solution

- For medium-range combine solution a reasonable engine portfolio exists
- Mainly spark-ignited stochiometric solutions

CLAAS Trion 660



Engine portfolio for CLAAS Trion vs available gas-engines

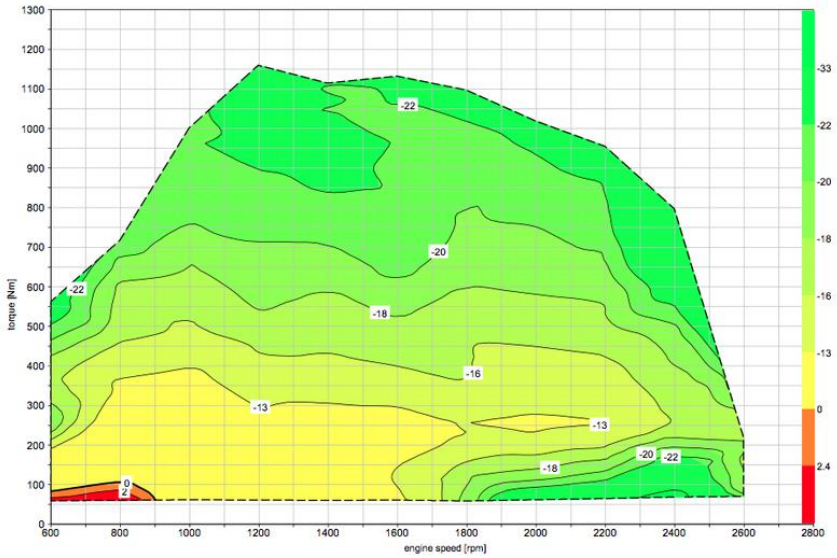


CLAAS engine-portfolio vs mobile gas-engines on the market

[9]

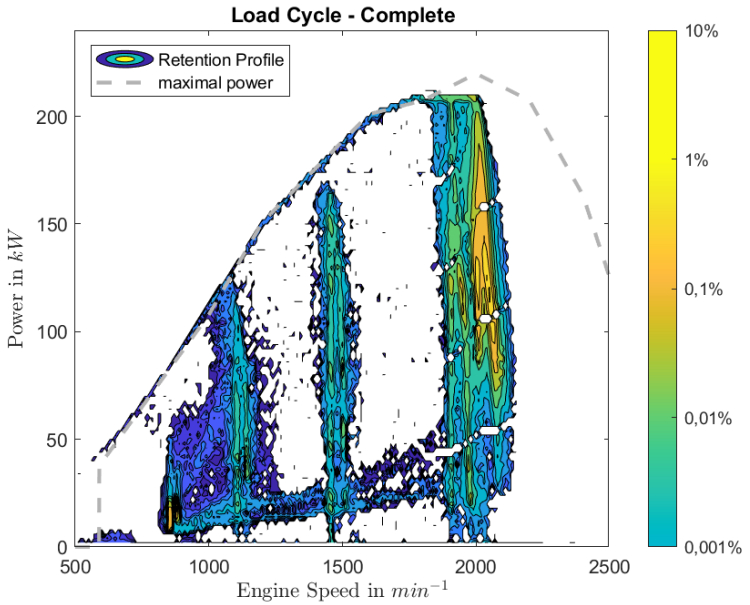
Evaluation of GHG-Influences

- **Simulative evaluation of tailpipe-emissions on a midrange combine (<250 kW):**
  - CO2-reduction potentials of **~10 %** for a typical combine-duty-cycle
  - Further potentials can be gained with bio-methane, if WTT-potentials are accounted
  - ! Methane slip to be monitored regarding **RDE behaviour** (especially in idle-operation)

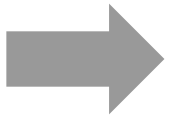


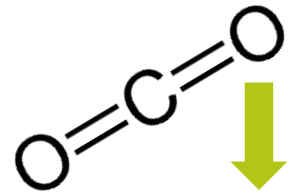
CO2-reduction-potentials of an exmemplary methane-based 8l-engine [11]

+



Load-cycle of a medium-range combine (<250 kW)





~10% CO2-reduction,

still ~12% efficiency-loss

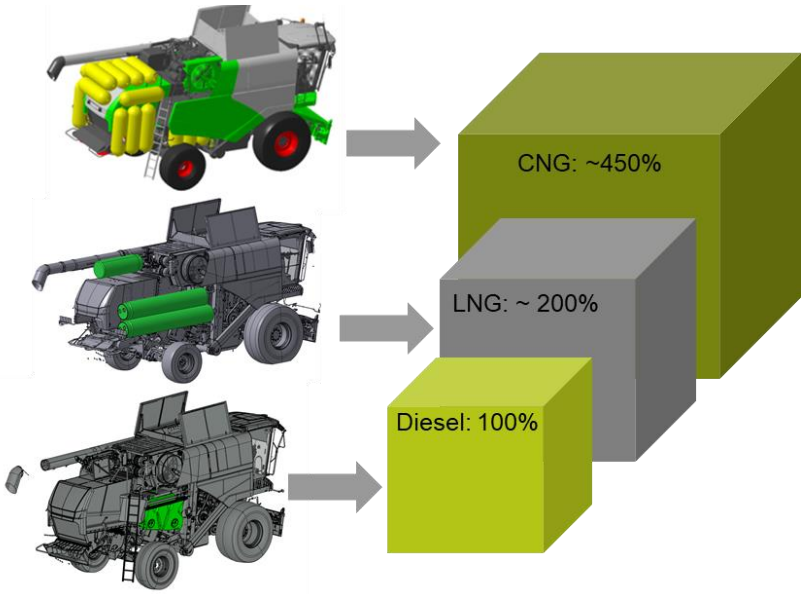
Storage Technology - A Packaging Challenge

- Storage weight, costs & volumetric demands rise significantly

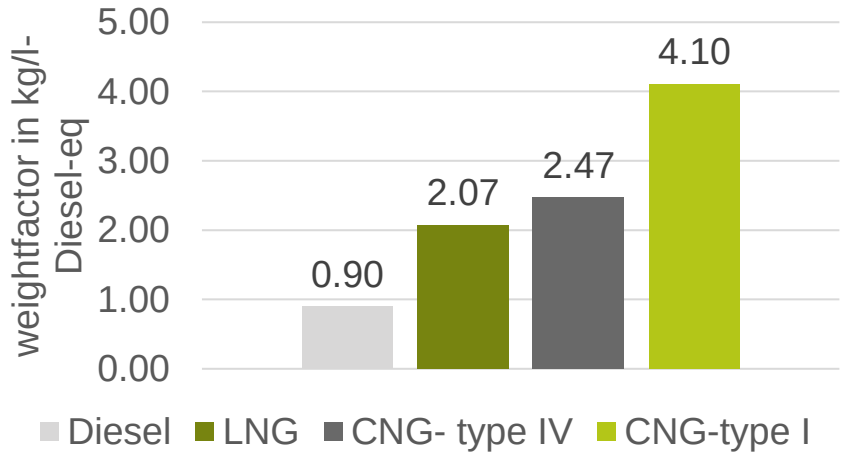
  ⇒New integration spaces for storages to be defined

  ⇒Weight-limitations (axle-load) vs energetic-range

- Efforts for the secure & reliable integration (e.g. ECE-R110-compliance)



Volumetric storage requirements for energetic equivalents



Weight-factors of storage technology (kg-full storage/l-Diesel-eq.)

source: own estimations from market study

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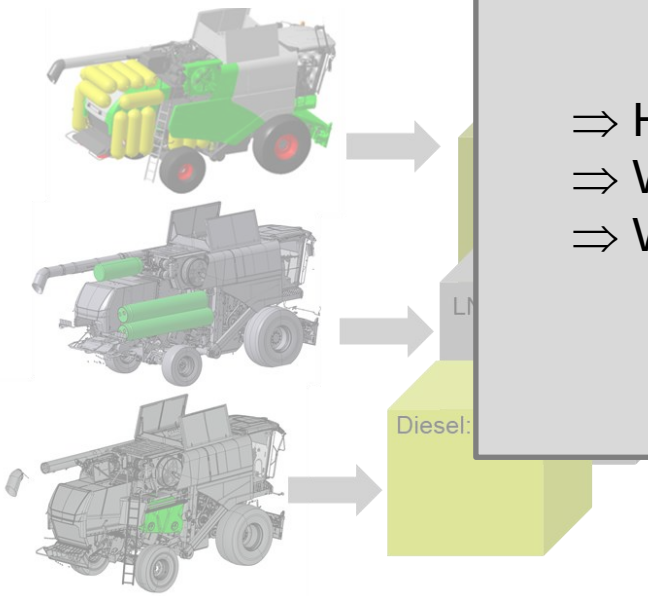
- Efforts for the secure

Key questions

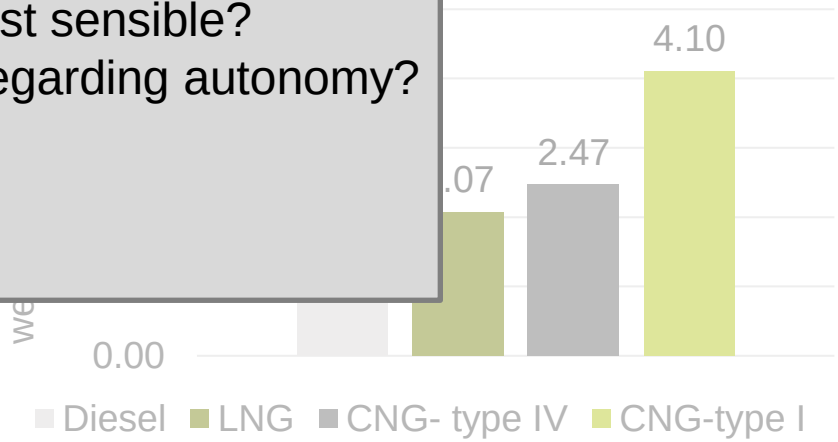
⇒ How much autonomy is really needed?

⇒ Which storage technology is most sensible?

⇒ Which impacts does this have regarding autonomy?



Volumetric storage requirements for energetic equivalents

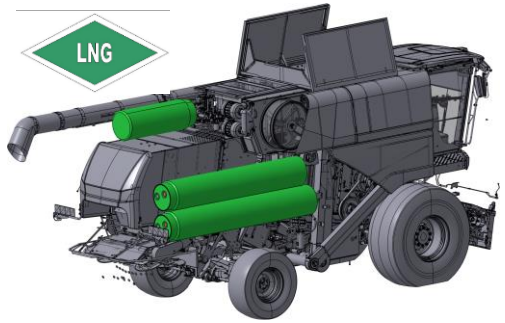


Weight-factors of storage technology (kg-full storage/l-Diesel-eq.)

Storage Technology - LNG - Thermal Handling & Refuelling-technology

- ✓ LNG-technology eases the weight- and storage-problematics
- ! **Thermal management still as a major challenge**
- ! Evaporation of gas during standing times ("boil-off")

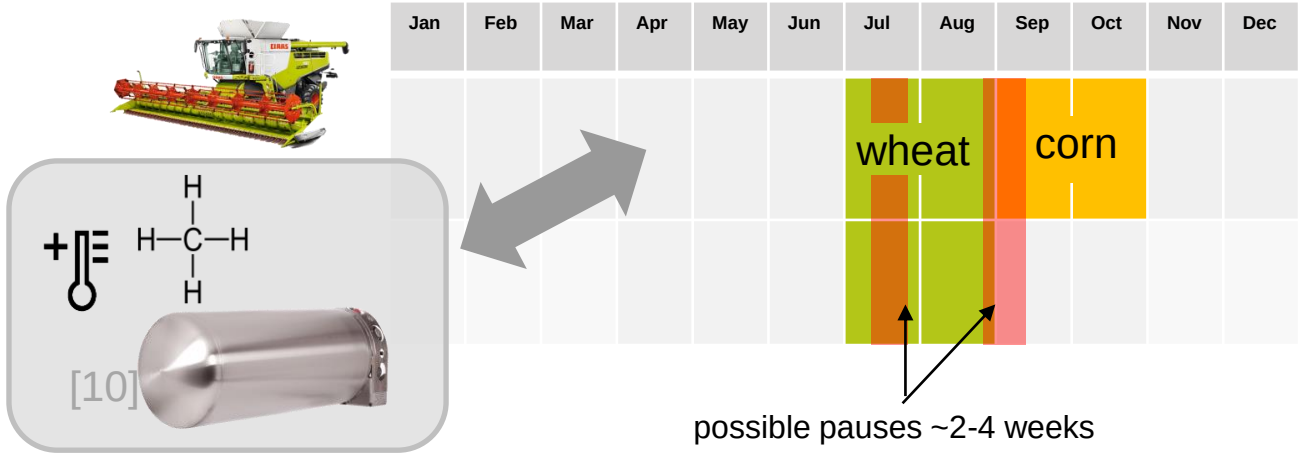
  ⇒Seasonal usage and low utilization enforce boil-off-problematics
- ! Higher storage costs
- ! Refuelling infrastructure more complex



Reduced volumetric & weight demands

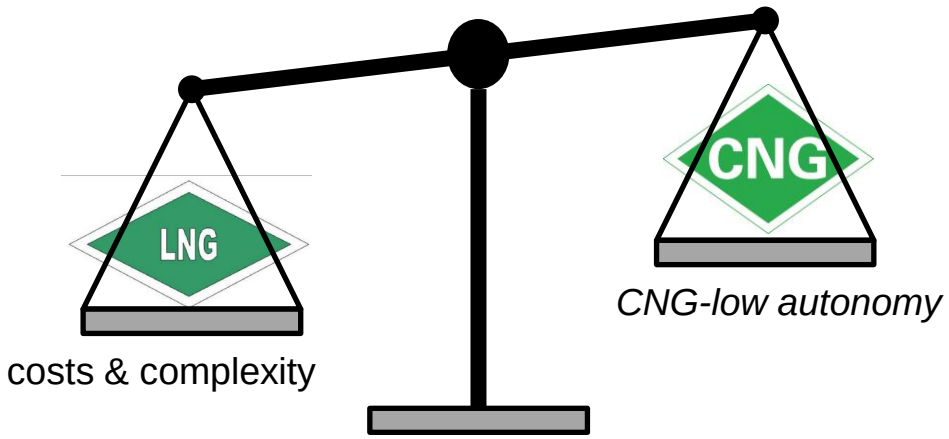
Technological complexity of refuelling-technology

[6]



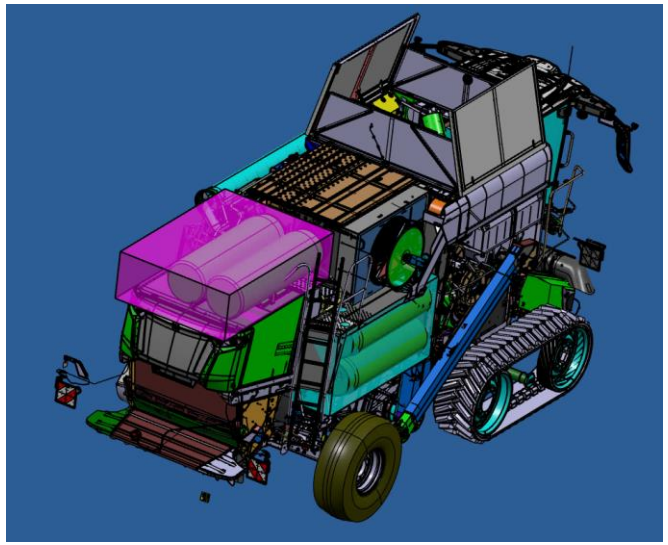
Boil-off-effects in the context of seasonal usage

Storage Technology - Integration Concepts



costs & complexity

CNG-low autonomy



Exemplary LNG-concept

Storage-volume: 1.900 l

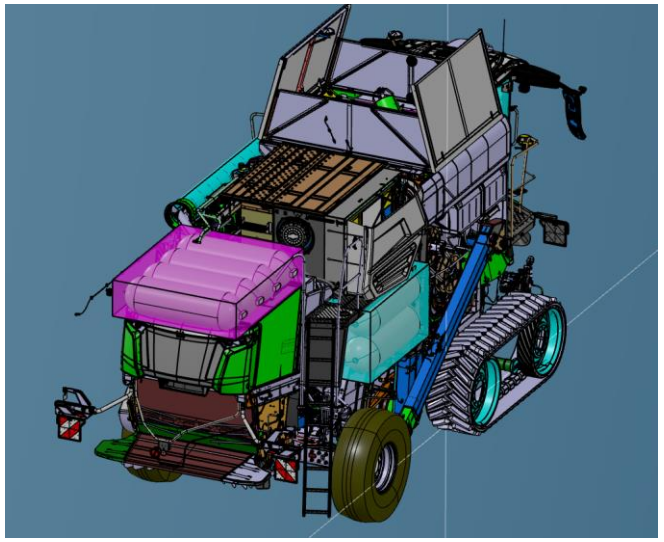
Storage cylinders: 4

Diesel-equivalent: 655 l

Storage-volume: 1.410 l

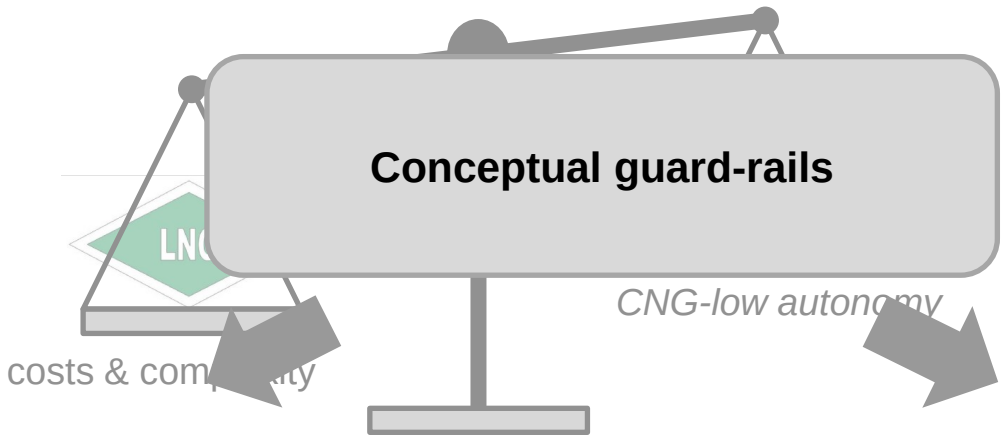
Storage cylinders: 6

Diesel-equivalent: 250 l



Exemplary CNG-concept

Storage Technology - Integration Concepts



LNG: "*Make it worth the fuss"*

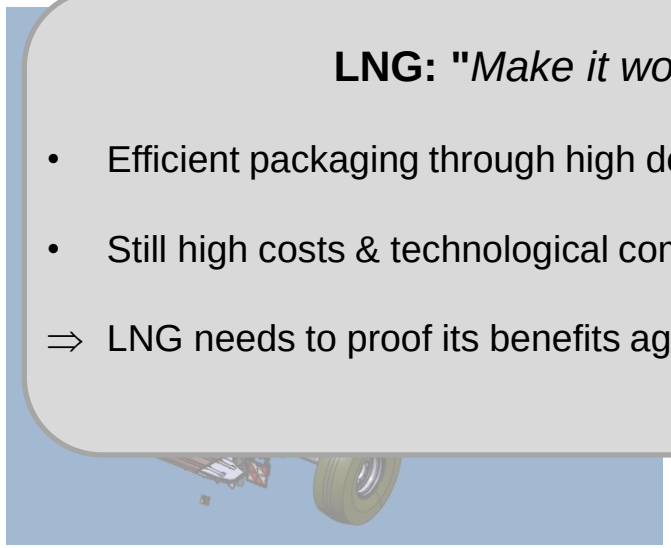
- Efficient packaging through high density
- Still high costs & technological complexity

⇒ LNG needs to proof its benefits against simpler CNG

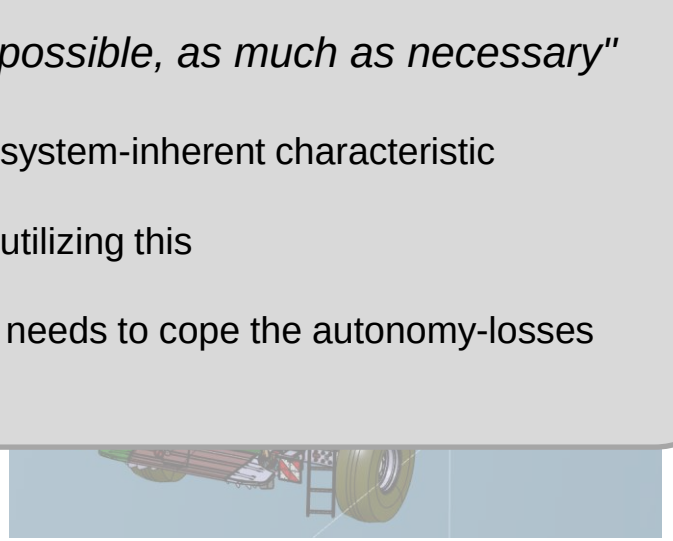
CNG: "*As few as possible, as much as necessary"*

- Limited autonomy is a system-inherent characteristic
- Costs can be reduced utilizing this

⇒ The refuelling-concept needs to cope the autonomy-losses



Exemplary LNG-concept



Exemplary CNG-concept

Refuelling infrastructure - Refuelling in the Off-Grid

- Additionally the factor refuelling comes into play

Today's court filling stations

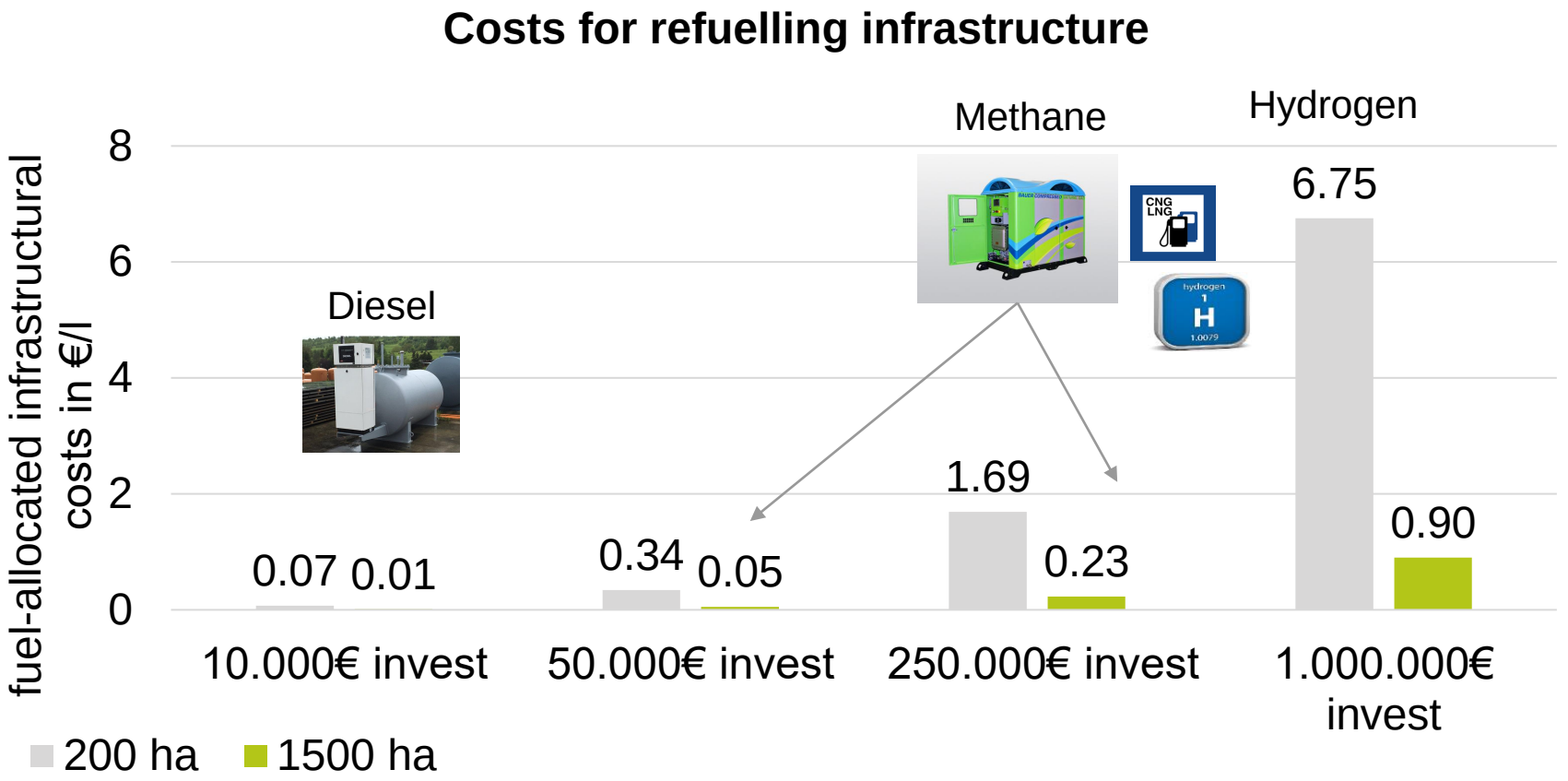
Refuelling for LNG

CNG/H2 compressor station

Mobile CNG/H2-station [6,7,8]

Refuelling infrastructure - Refuelling in the Off-Grid

⇒ Significant logistical & economical efforts for the end-user



fuel-consumption	100 l/(ha*a)
amortization period	10 a
operating costs	2% of invest
calc. interest	5%

Simulation of Autonomy Concepts - Lean solutions with mobile infrastructure

- The combination of tank-sizes and refuelling infrastructure is decisive

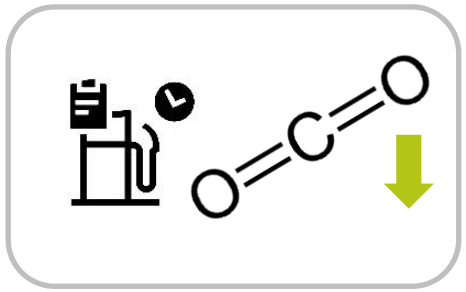
Number of refuellings for a 200 kW-combine - comparison to diesel-baseline

no of "pit stops" (time loss in min)	10 ha /~5 h	20 ha/~10 h	40 ha/~20 h
10% of diesel-range	**1** (17 min)	**3** (49 min)	**6** (109 min)
30% of diesel-range	**0** (0 min)	**1** (28 min)	**2** (57 min)
60% of diesel-range	**0** (0 min)	**0** (0 min)	**1** (45 min)
100% of diesel-range	**0** (0 min)	**0** (0 min)	**0** (0 min)

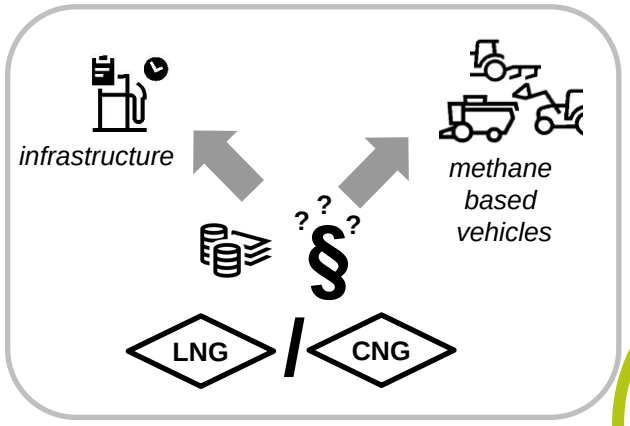
source: own simulations

Conclusions
Gas based Powertrains for Agricultural Applications a Chance - a Challenge - a Risk

Chance



Reducing GHG-emissions & operation-costs



High invests in infrastructure & vehicles at unclear political future

Risk

Challenge

Providing viable concepts with sufficient autonomy

Refuelling infrastructure

Machine concepts

Contact

Fabian Wohlfahrt

Development Engineer

Advanced Development - Functional Technology

CLAAS Selbstfahrende Erntemaschinen GmbH

33428 Harsewinkel

mail: fabian.Wohlfahrt@claas.com

Thank you for your attention!

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Ressources

[1] **estimation for annual machine utilizations-** *CLAAS & estimation from kba-kilometer data* *https://www.kba.de/DE/Statistik/Kraftverkehr/VerkehrKilometer/vk_revisionsbericht_2019_pdf.pdf;jsessionid=83CC772553A0595044FB19D66E95FA5D.live21303?__blob=publicationFile&v=6*

[2] **source for MB-data & photo**: *https://www.mercedes-benz-trucks.com/de_DE/models/new-actros/technical-data/type-overview.html*

[3] **Depiction of a biogas plant:***: https://de.wikipedia.org/wiki/Biogasanlage#/media/Datei:2012-05-13_Nordsee-Luftbilder_DSCF8567.jpg*

[4] **EU STAGE IIIA-V, emission limits for NOx and particle emissions** *https://dieselnet.com/standards/eu/nonroad.php#s5*

[5] **Depiction of Daimler M936G:** *K. Hoffmann, M. Benz. et. al.: Der neue Erdgasmotor für mitelschwere NFZ von Mercedes-Benz, MTZ 11/2014*

[6] **Refuelling process for LNG-trucks:** *https://www.weser-kurier.de/bremen/bremen-wirtschaft_artikel,-erste-lngtankstelle-im-norden-eroeffnet-_arid,1769291.html*

Ressources

[7] **compressor station for natural gas -** *https://www.bauer-kompressoren.de/*

[8] **mobile transport solutions for gaseous fuels-** *Wystrach GmbH https://www.wystrach.gmbh/*

[9] **market study for CNG-engines** - *CLAAS Selbstfahrende Erntemaschinen GmbH*

[10] **depiction of a LNG-storage unit** *Salzburger Aluminium Group* - *www.sag.at/produkte/lng-tanksysteme/#gallery-3*

[11] **CO2-reduction map for Daimler M936G** - *M. Benz, K. Hoffmann, M. Weirich, H. Herrmann (2014) "The New Euro VI Natural Gas Engine for Mercedes-Benz Medium Duty Commercial Vehicles," 35th International Vienna Motor Symposium*

[12] **picture of a court filling station** *https://www.tankhandel.at/3000-Liter-Betriebstankstelle-Dieseltankstelle-doppelwandig-DIN-6616-2*