JOIN THE JOURNEY TO NET ZERO

Power Generation Symposium | Europe

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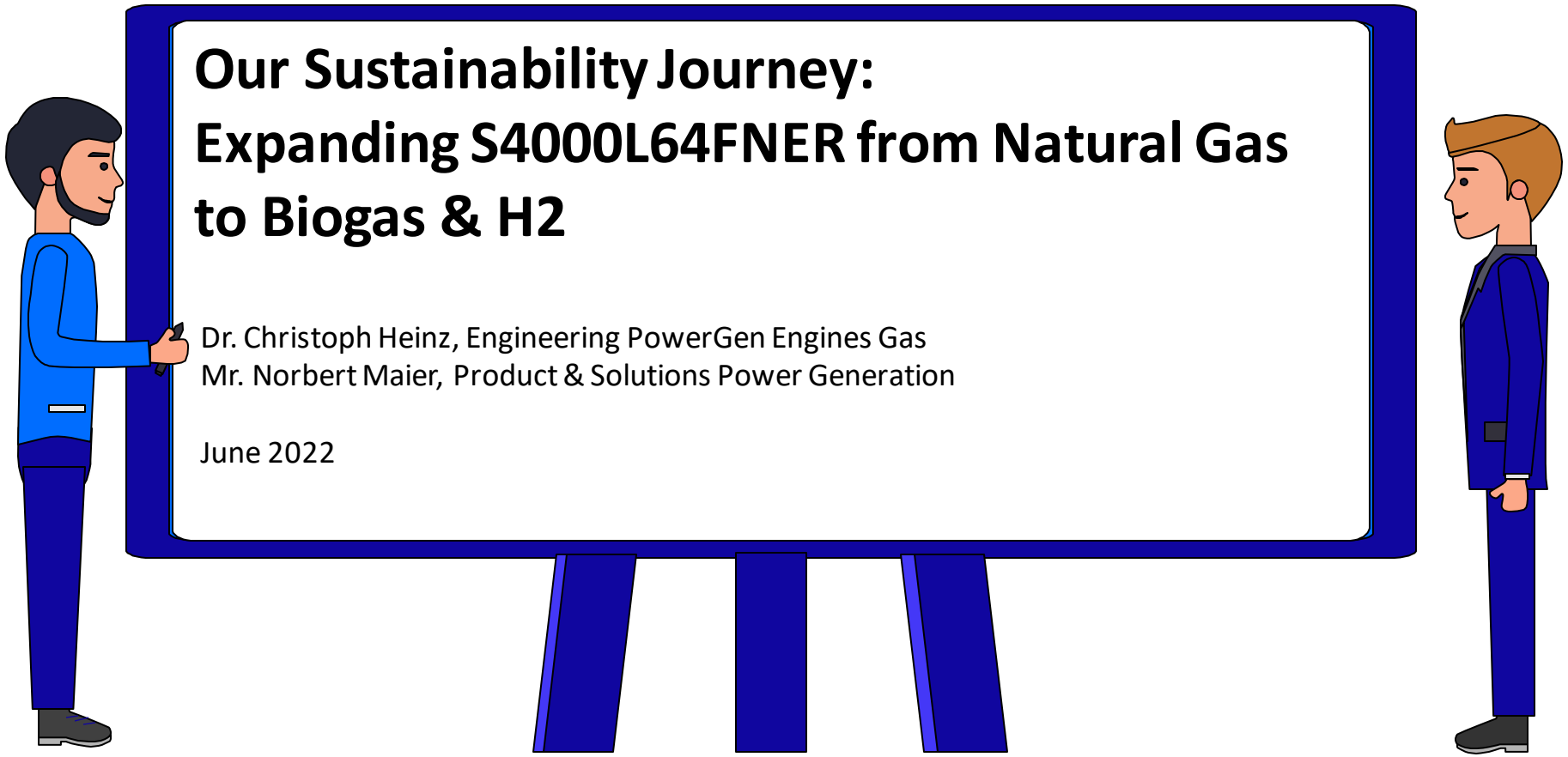
Session 4



Our Sustainability Journey: Expanding S4000L64FNER from Natural Gas to Biogas & H2

Dr. Christoph Heinz, Engineering PowerGen Engines Gas
Mr. Norbert Maier, Product & Solutions Power Generation

June 2022

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Agenda Session 4

S4000 100% Hydrogen (Session 1)

2024
2023

04 S4000L64FNER – H2 Blending

2023
2022

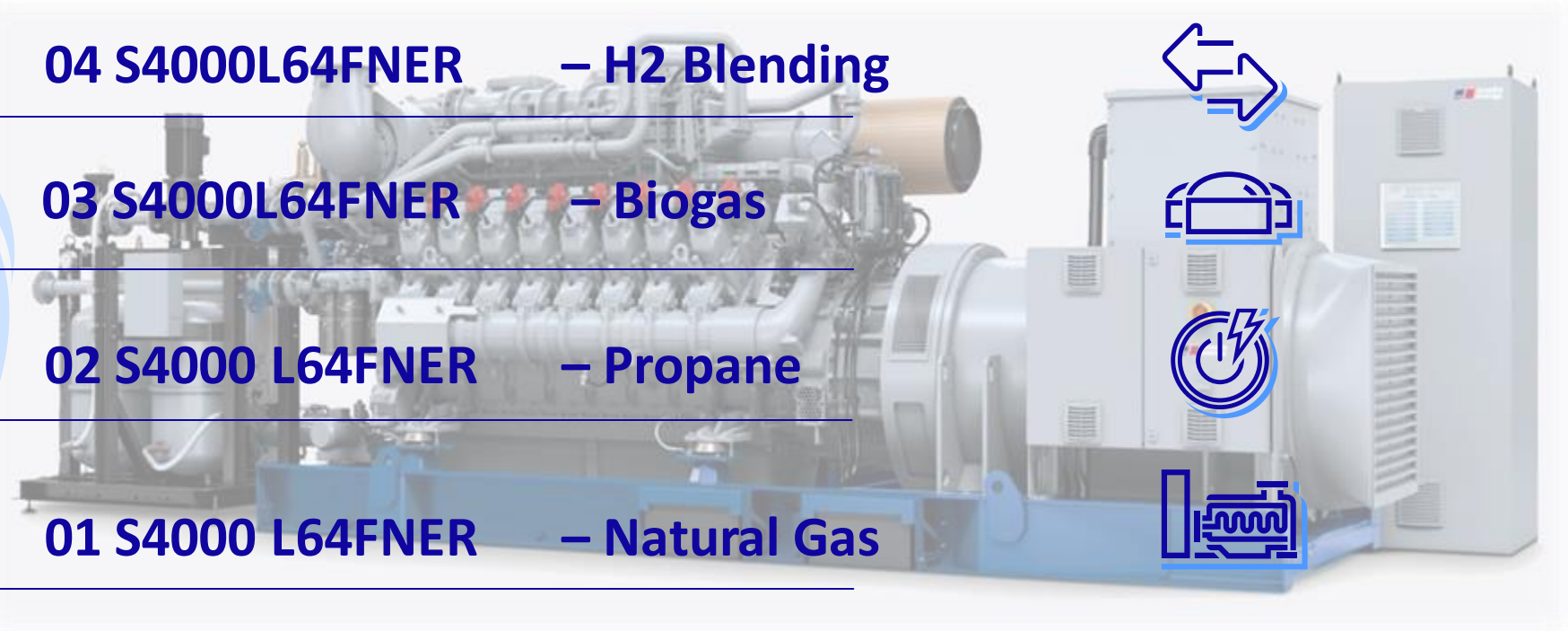
03 S4000L64FNER – Biogas

2022
today

02 S4000 L64FNER – Propane

2022
today

01 S4000 L64FNER – Natural Gas



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01

S4000 L64FNER – Natural Gas

…Economical, Sustainable, Reliable, Flexible

High Speed Gas Systems

Summary

S4000FNER is the best choice for many kind of applications,

L64 FN**ER:**

- **E**fficient
- **R**eliable
- **E**nvironmental friendly
- **R**obust
- **E**conomical
- **R**eady for the market!

mtu Series 4000 GS

8/12/16/20V Cylinders
776kWe – 2,530kWe
Natural & biological gases

Containerized solutions

CHP & Pure Power

Best in class power density

Efficient > 44.4% eff.el & max fuel utilization

Fast & flexible response +/-40% <30s

Low load operation down to 35%

Economic LCC w. cylinder heads up to TBO

TBO 84.000h

LOW EMISSIONS

HIGHLY EFFICIENT

gas powered cogeneration systems

3 FORMS OF ENERGY

Electrical, heat and cooling

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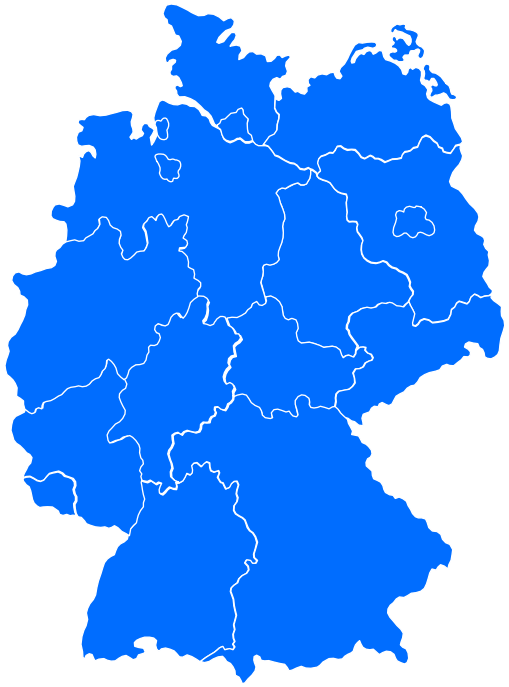
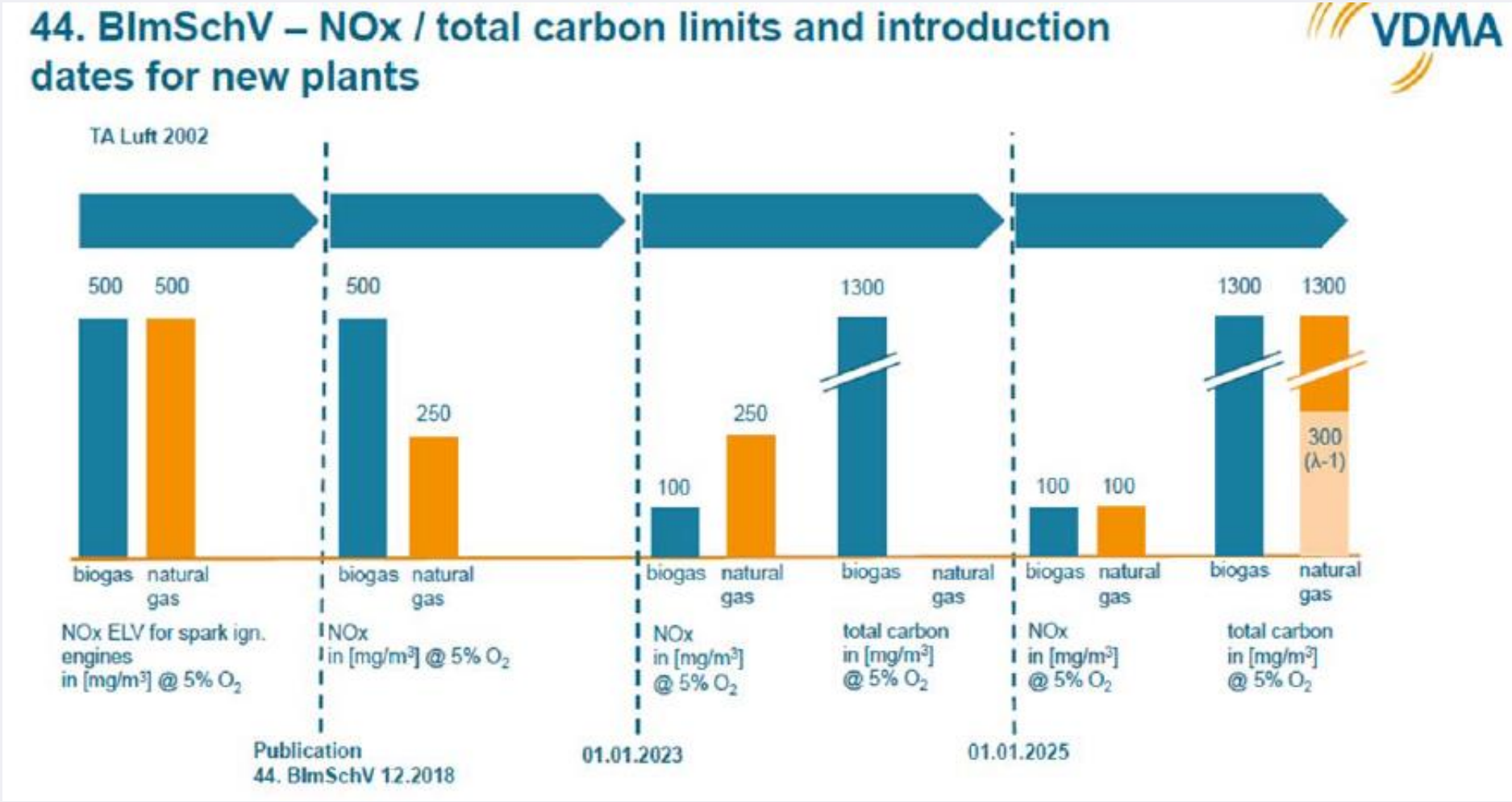
Emission reduction GAS operation

Legislation Germany





Source: VDMA, 44.BImSchV Fact Sheet

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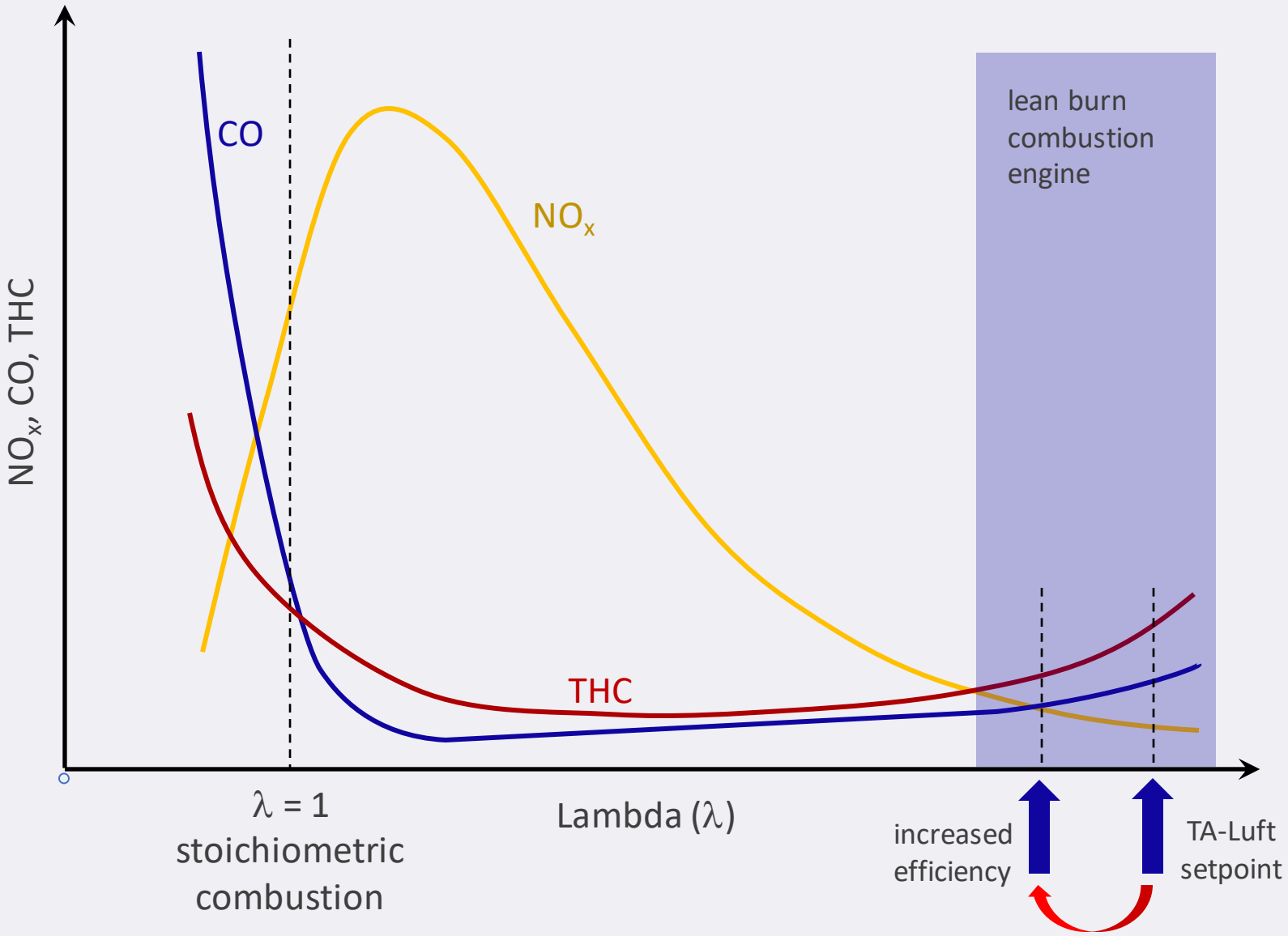
Emissions Overview

- L64FNER → lean burn engine
- optimized for NO_x-levels 500 and 250 mg / m_n^3 (TA-Luft and ½ TA-Luft)
- NO_x reduction to 100 mg / m_n^3 requires SCR-catalyst
- optimized engine calibration at lower λ-values possible:
  - improved engine efficiency
  - reduced THC
  - SCR for further NO_x reduction



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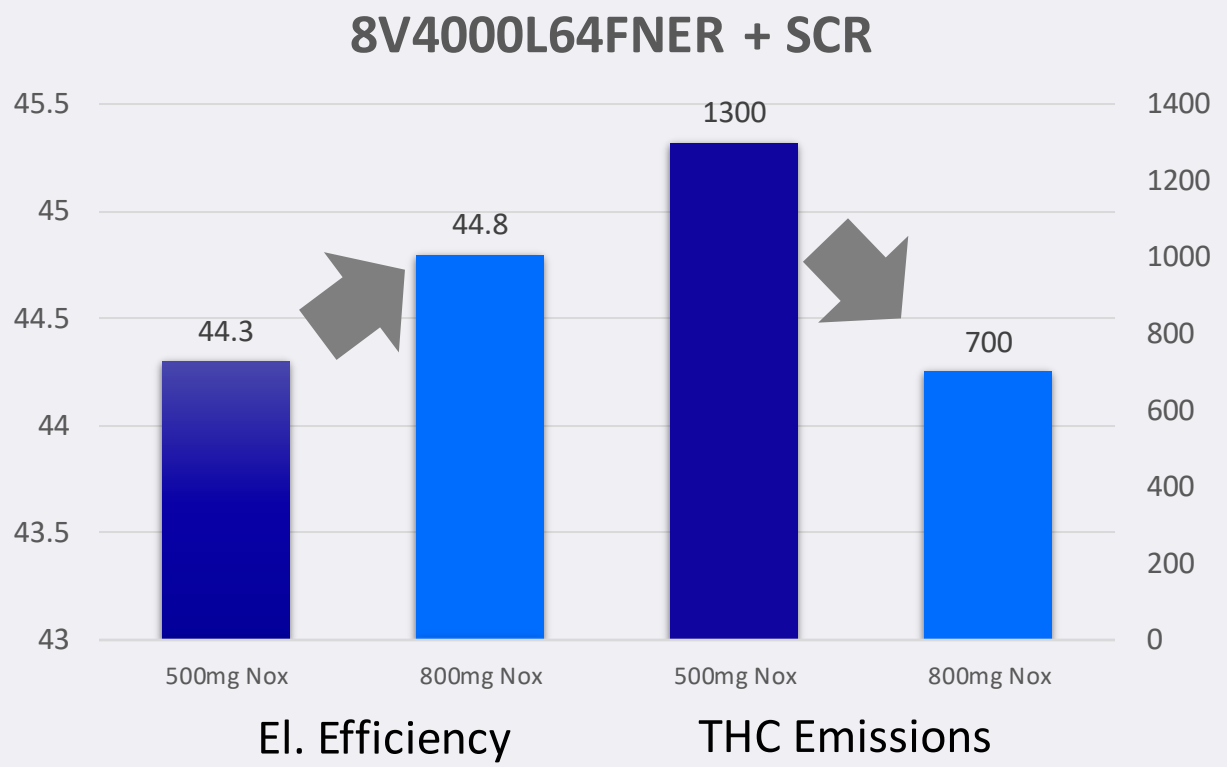
Genset Performance

- Enriching of the the engine results in higher El. Efficiencies -> fuel savings
- Better load step performance
- Lower THC emissions
- Reduced lifecycle costs (spark plug)



Profitability and Ecology isn´t a Contradiction

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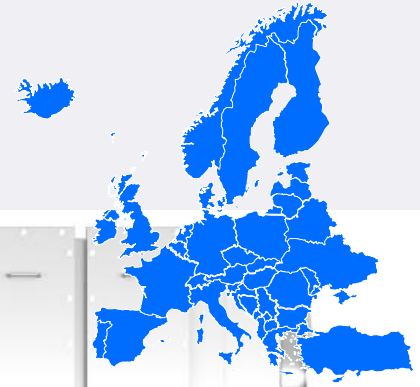
System Performance

*estimations



EGAT	250NOx	800NOx
Invest SCR	-	75.000 €*
Adblue + Maintenance /y	-	28.000 €

CASE NEW PLANT

Target Emissions: 250mg NOx

Ad blue costs: 0,25€/l

8000oh/year

Gas price: 0,35€/m³

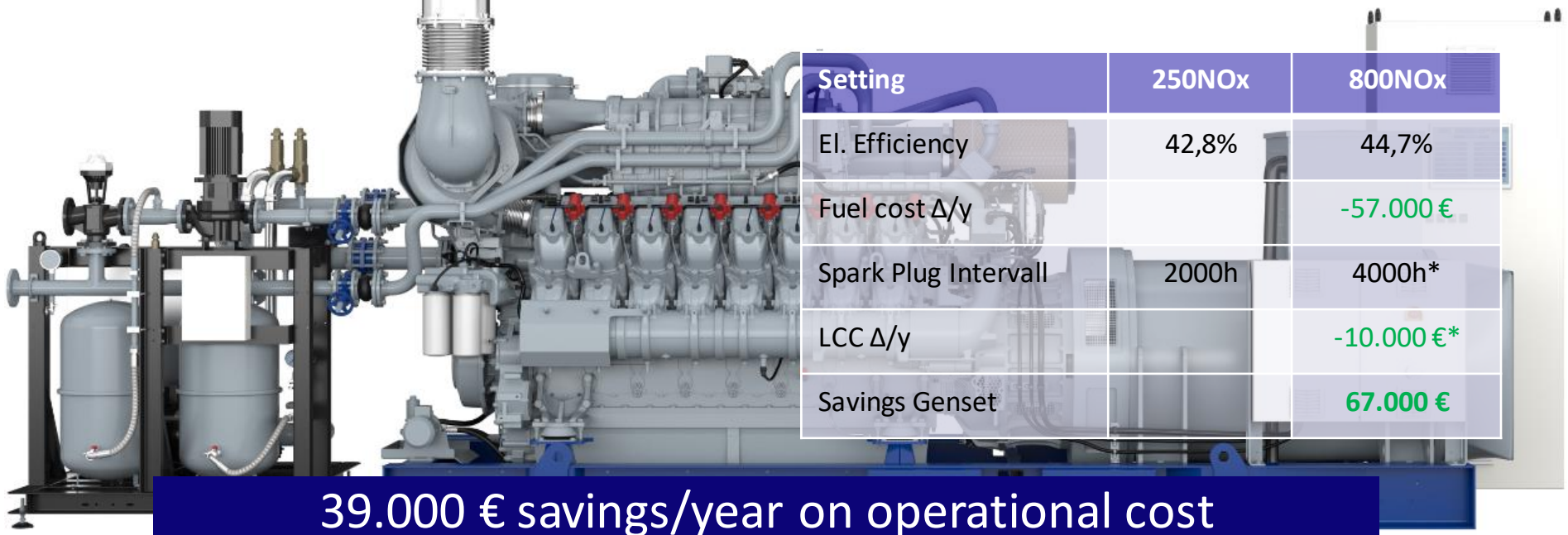
Comparison 16V4000L64FNER based on operation costs

LT Temp. 43°C

MN=80

SCR **as option**

Setting	250NOx	800NOx
El. Efficiency	42,8%	44,7%
Fuel cost Δ/y		-57.000 €
Spark Plug Intervall	2000h	4000h*
LCC Δ/y		-10.000 €*
Savings Genset		**67.000 €**



39.000 € savings/year on operational cost
2-3 years SCR amortisation time in this case

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*estimations

System Performance

CASE NEW PLANT

Target Emissions: 250mg NOx

Ad blue costs: **0,80€/l**

8000oh/year

Gas price: 0,**0,70€/m³**

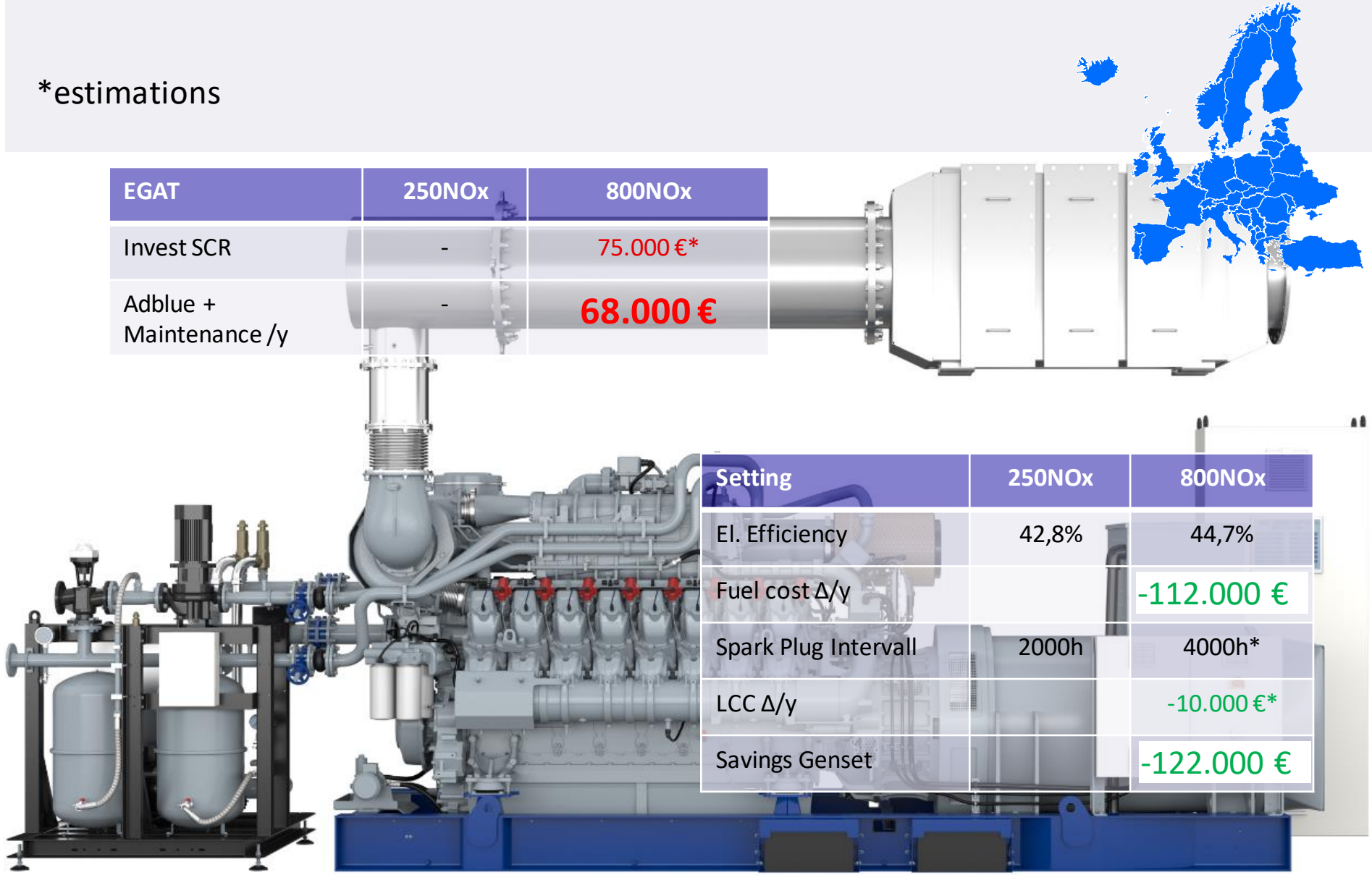
Comparison 16V4000L64FNER based on operation costs

LT Temp. 43°C

MN=80

SCR **as option**

EGAT	250NOx	800NOx
Invest SCR	-	75.000 €*
Adblue + Maintenance /y	-	**68.000 €**



Setting	250NOx	800NOx
El. Efficiency	42,8%	44,7%
Fuel cost Δ/y		-112.000 €
Spark Plug Intervall	2000h	4000h*
LCC Δ/y		-10.000 €*
Savings Genset		-122.000 €

Scenario strongly depends on Gas price + Urea costs

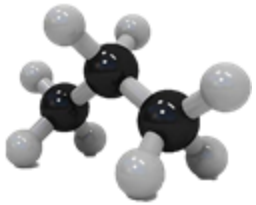
02

S4000 L64FNER – Propane

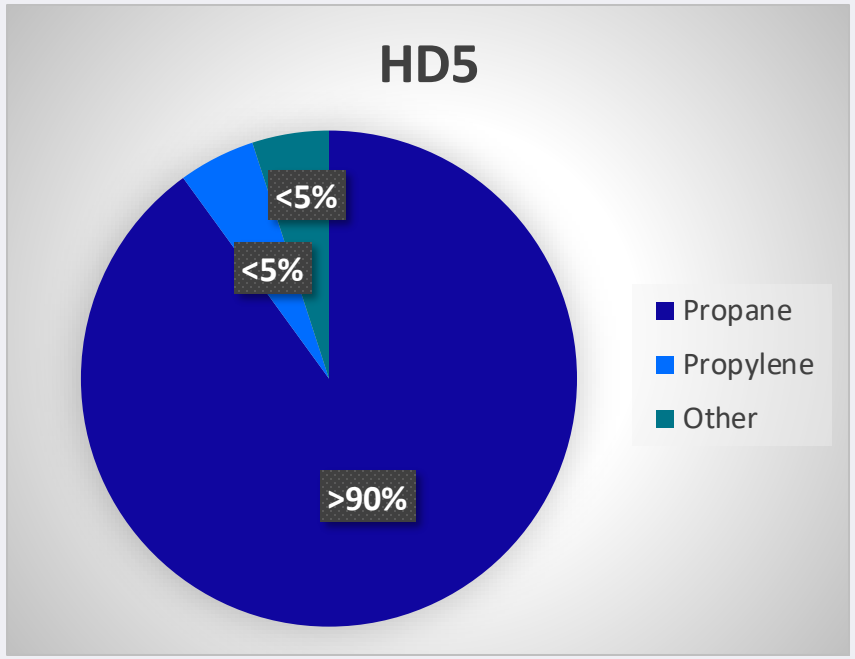
…an reliable and flexible option for your power plant!

What is Propane?

Propane



- Typically seen as **HD-5 Type**
- Methane number: **~32-35**
- LHV: **~28 kWh/m³**
- Ignition Limits: **2,1 - 9,5 Vol.-%**
- Boiling Temperature: **-42,1°C** (@1013mbar)
- Often stored liquid **@8bar** -> Volume reduced by **1/260**



- Minimum of 90% propane
- Maximum of 5% propylene - propylene is used in the manufacture of plastics
- Other gases constitute the remainder (iso-butane, butane, methane, etc.)

Propane Properties and LPG Quality Control (missiongas.com)

- Propane does not occur naturally though. Raw crude oil or raw natural gas is refined to make different types of petroleum products, one of which is propane.
- Propane is not considered a greenhouse gas

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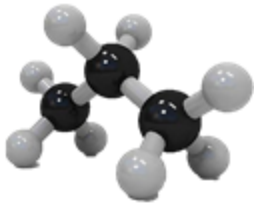
Fully tested L64FNER with HD5 Propane

Available
NOW
SOS in Q3/22 8V to 16V
20V in Q4/22

Propane



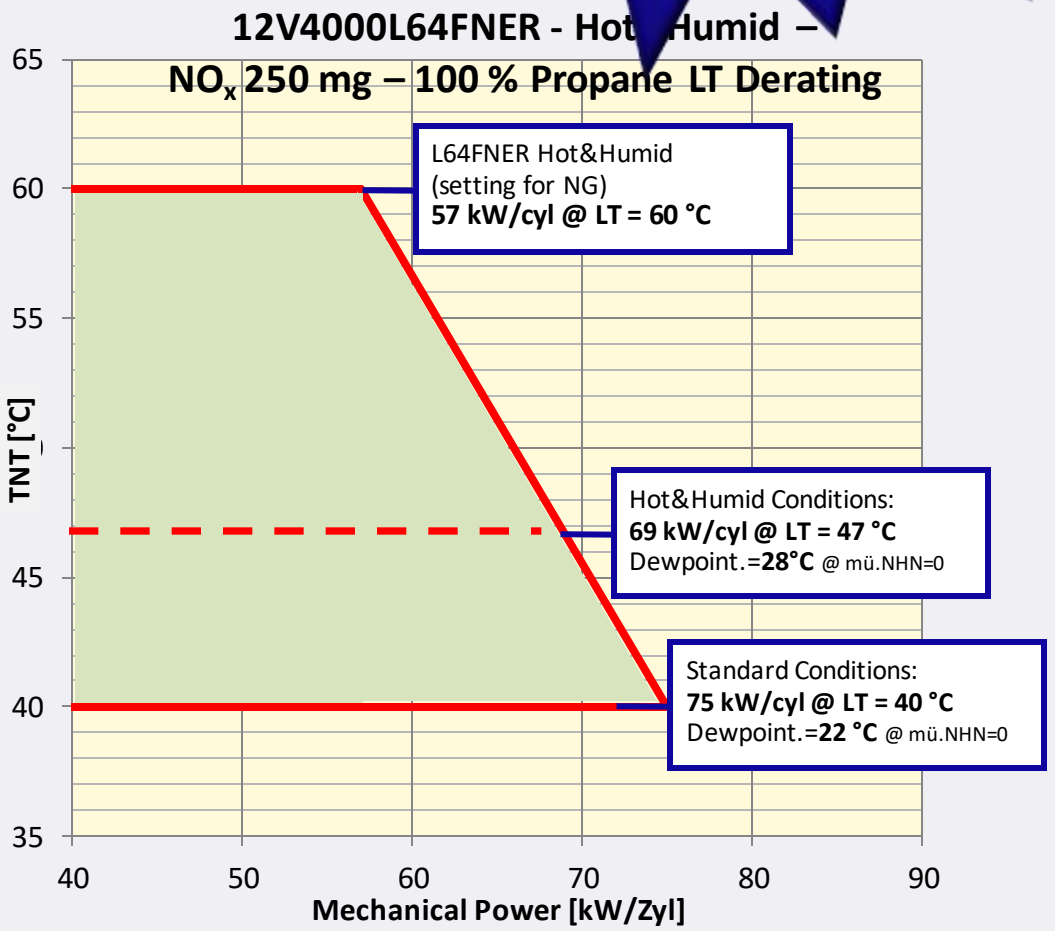
- Typically seen as HD-5 Type
- Engine Development maintaining (Trade-Off):
  - ✓ Combustion Stability
  - ✓ Low BMEP
  - ✓ Power Output
    - ❖ compared very low MN
    - ❖ Mixture Cooler Temp.
  - ✓ High Efficiencies (> ~40%)
    - ❖ Comparable to APG

Engine:
- Only hardware change compared to L64FNER is the spark plug
- Specific data setting for propane

Genset:
- Smaller alternator – lower price level
- Gas train

75 kW_m/cyl @ MN = 32
NOx = 250 mg @ 5% O_2

More power output possible depending on MN and turbocharger variation



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03

S4000 L64 - Biogas

…an economical and 100% sustainable solution!

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Let´s talk about the role of biogas!

Biogas
From base load to flexible storage…

German Government plans to shut down nuclear and coal power plants

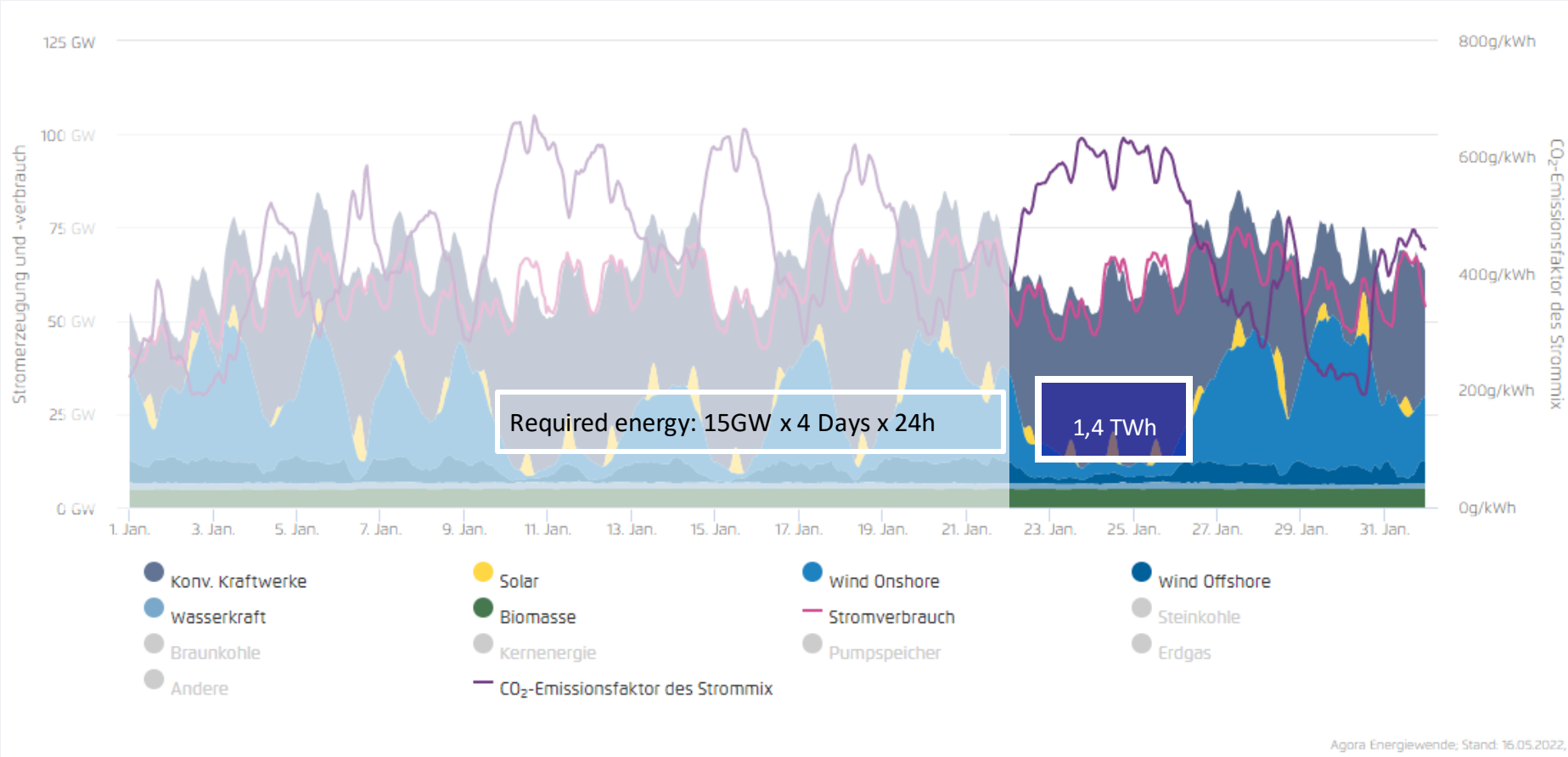
-> Grid stability is mandatory

Wind & Sun are not constant, reliable

Biogas is 100% renewable & reliable and predictable

Local Biogas production

Biogas not only for base load but also as storage option



Biogas can contribute to cover fluctuations in the grid!

Biogas is an economical storage solution!

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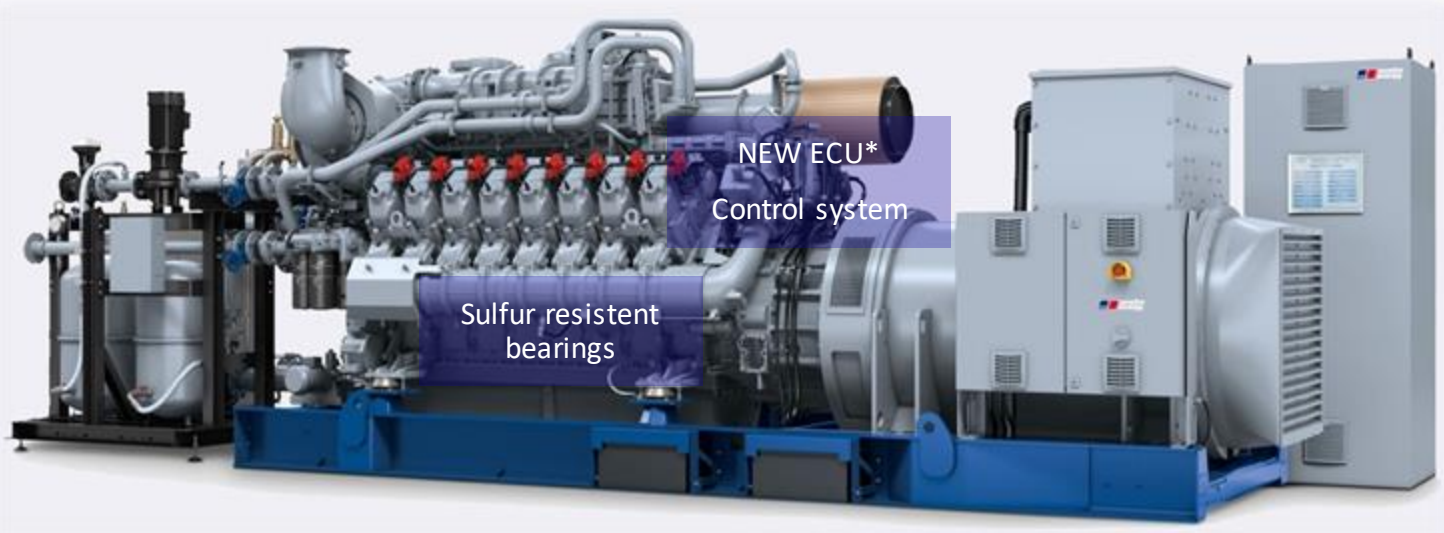
L64FNER & L64 Biogas with almost identical Genset hardware…



2 Parameter Settings:

- High LT temperature for low auxiliary cooling power and worldwide use
- Raw emisson optimized version for Germany (44. BImschV) (in development)

*Blending Option:

Full Power Output (130kWm/cyl) in Natural Gas and Biogas operation (with new ECU)

- L64 Biogas Version with same Power output as L64FNER; +30% vs. L32FB
- L64 Biogas Efficiency > L32FB (hot ambient)
- Low L64 Biogas LCC -> TBO & Cylinder head =84.000 h
- L64 Biogas Price = ~ L64FNER + 3% (Gas train, TecJet, …)

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Fuel Flexibility: Technical Highlights – Blending

Blending of

2 Gases on the Engine

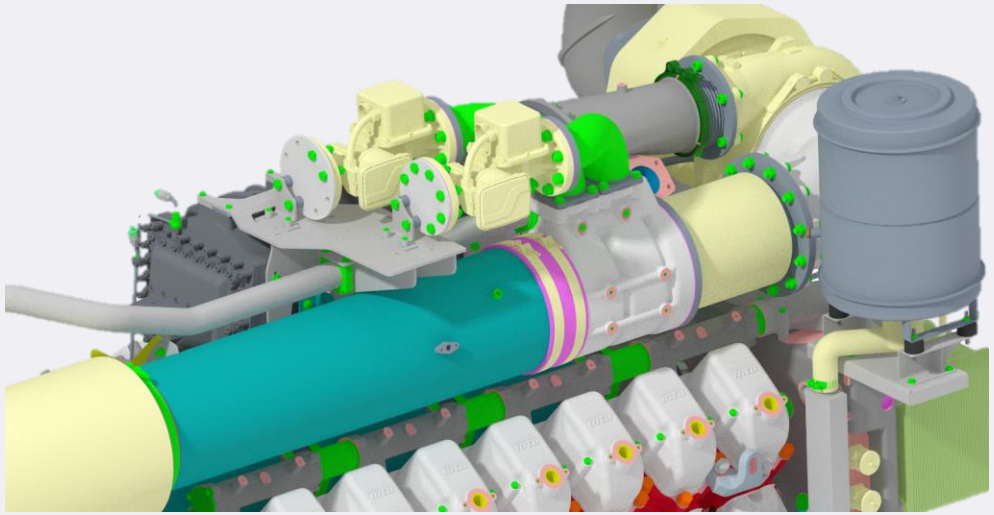
Application examples:

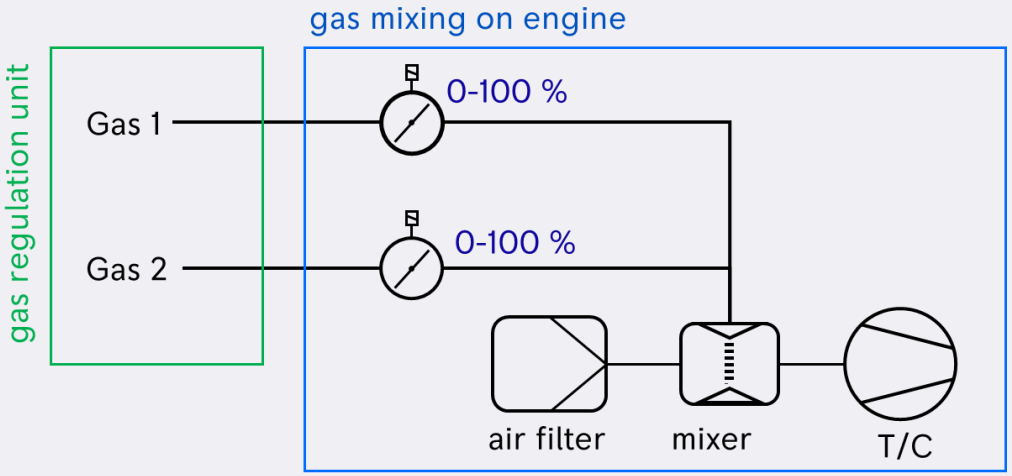
- **BioGas** with fluctuating quantity blended with NatGas
- **Weak Gas** (low LHV) upgraded by NatGas
- **Hydrogen** mixed to NatGas to reduce Emissions
- In case of emergency the NatGas engine can be switched to **Propane**

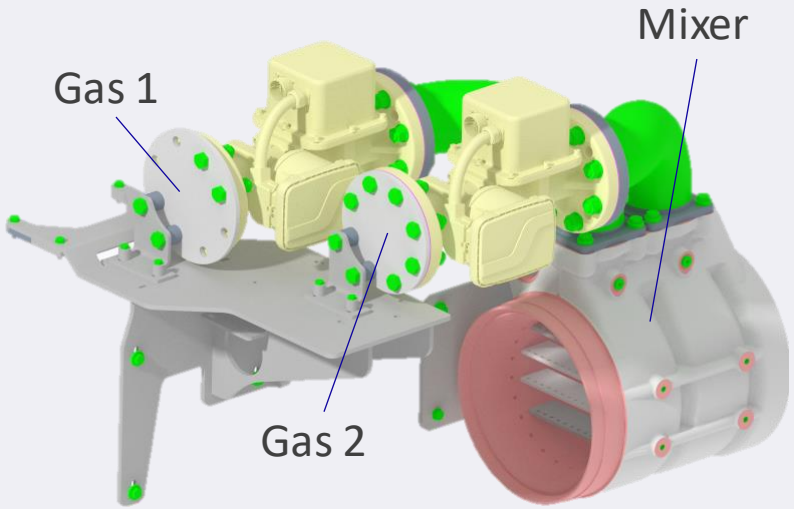
Mixing of 2 gases via metering valves on the engine

Control of the admixture by the engine controller - high integration into the engine

Highest possible flexibility for individual customer projects







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04

S4000 L64FNER – Hydrogen

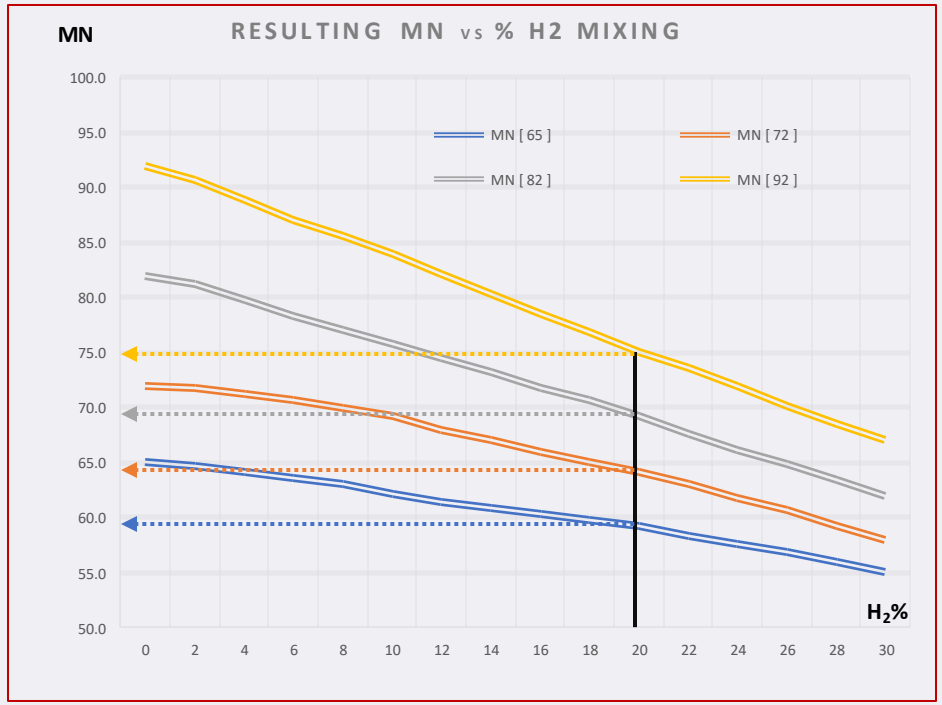
…Sustainability at its best!

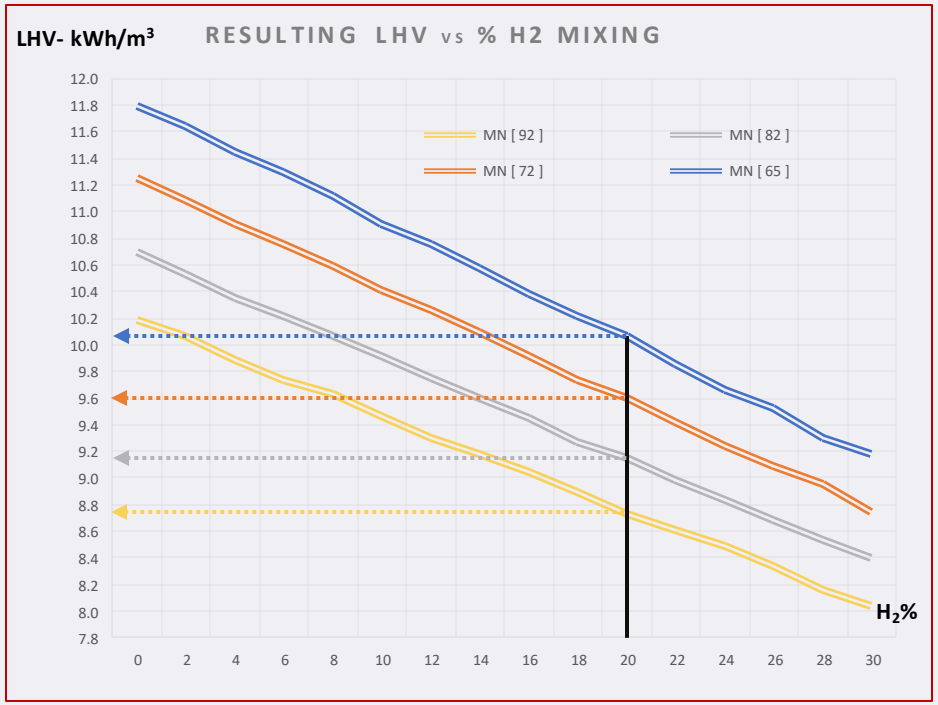
Fuel Flexibility: Technical Highlights – H_2 Addition / Blending

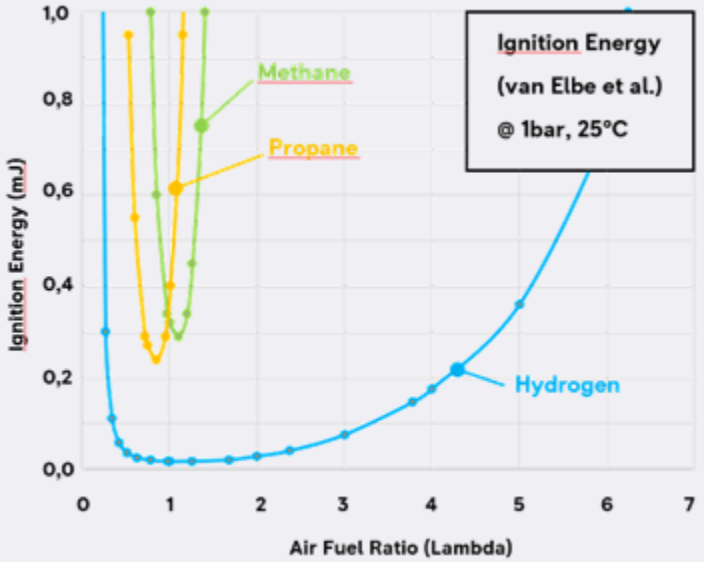
Hydrogen

addition to NatGas
(mixing on Gas Grid)
(blending on Engine)

- New requirements due to sector coupling with Power-2-Gas
- Local H_2 generation and blending into the NatGas Grid
- Contribution to climate protection
- H_2 changes the ignition and combustion properties of the mixture
- Influence on the Safety Concept
- Full power output with lambda adjustment







Parameter		NatGas	H_2
LHV	kWh/m³	10.2	3.0
MN	-	90	0
Laminar Flame-Speed	cm/s	~ 40	» 300

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Fuel Flexibility: Technical Highlights – H_2 Addition

Hydrogen addition to NatGas (mixing on Gas Grid)

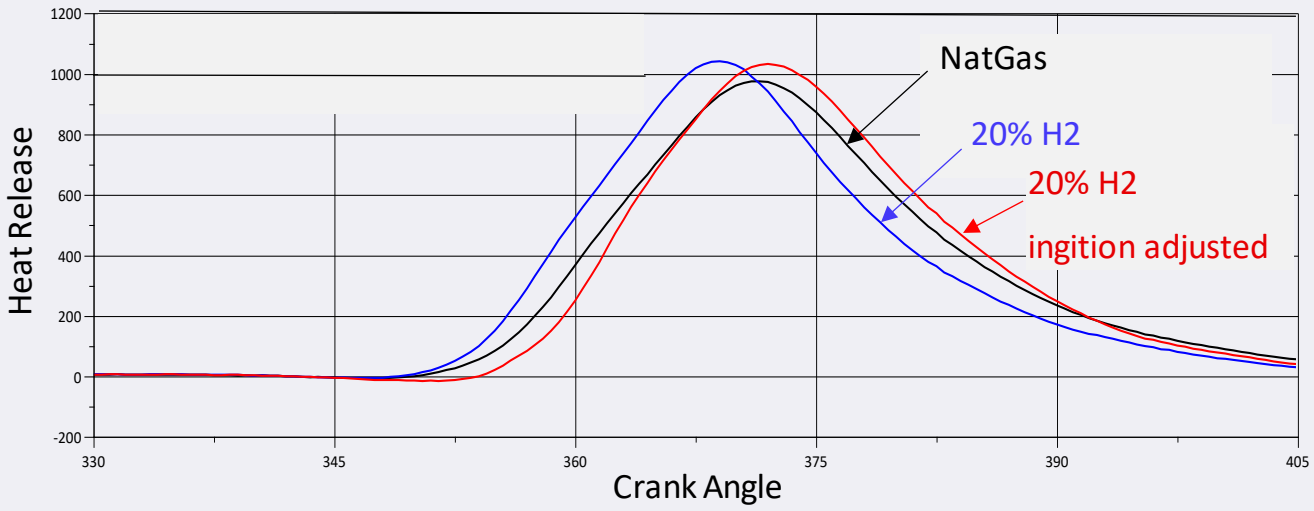
- New requirements due to sector coupling with Power-2-Gas
- Local H_2 generation and blending into the NatGas Grid
- Contribution to climate protection
- H_2 changes the ignition properties of the mixture
- Influence on the Safety Concept
- New flame arresters and experimental verification of the safety concept necessary

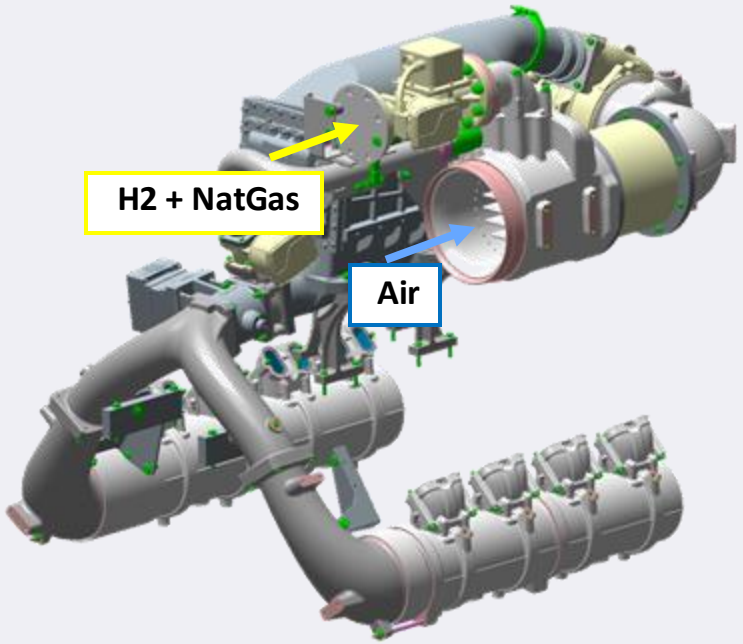
Influence on combustion

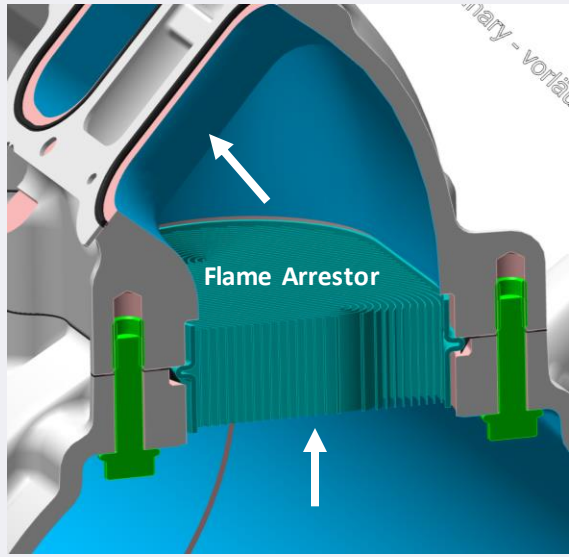
Combustion speed increases with H2 content

Adjustment of ignition timing necessary

Required: Detection of the H2 content through a new detection concept







Objective:

H2-Readiness up to 20 - 25 vol.-% into NatGas

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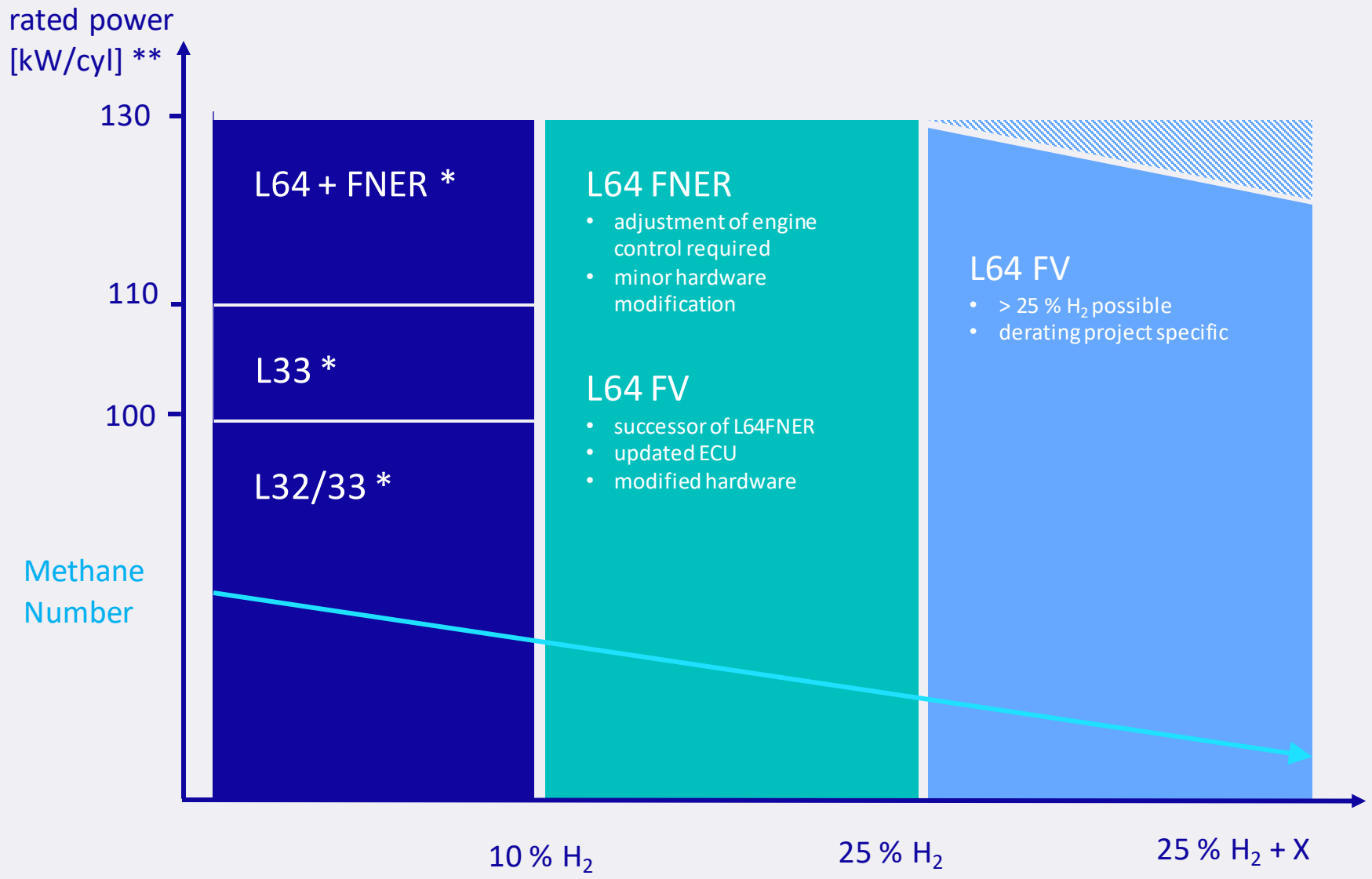
S4000
Mixed H2/NG
Performance



* constant H_2-concentration in fuel gas required with existing engine control

** achievable rated power depending on H_2-content in gas mixture and Methane Number of base fuel (natural gas).

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Thank you for your attention!

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Q&A

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