Dekarbonisierung mit Gasmotoren–KWK

Erfahrungen und Ausblick mit Wasserstoff

www.innio.com

Dr. Klaus Payrhuber
INNIO Jenbacher

TSB KWK Impulstagung, Bingen
5. Dezember, 2019
INNIO is a leading technology provider of gas engines, power equipment, a digital platform and related services for power generation and gas compression at or near the point of use. With our renowned Jenbacher* and Waukesha* product brands.

INNIO pushes beyond the impossible and looks boldly toward tomorrow. Our diverse portfolio of reliable, economical and sustainable industrial gas engines generates 200 kW to 10 MW of power for numerous industries globally. We provide life-cycle support for more than 48,000 gas engines worldwide. And, backed by our service network in more than 100 countries, INNIO connects with you locally for rapid response to your service needs.

Headquartered in Jenbach, Austria, the business also has primary operations in Welland, Ontario, Canada, and Waukesha, Wisconsin, US.
### INNIO Products

The broadest gas-fired portfolio ... 220 kW to 10.38 MW

#### Jenbacher* gas engines

**Technology**
- Gas engines (0.3–10.38 MW)

**Target segments**
- Power generation

**Benefits**
- Electrical efficiency
- High total efficiency
- Application diversity
- Fuel flexibility
- Advanced monitoring and diagnostics

#### Waukesha* gas engines

**Technology**
- Gas engines (0.2–3.6 MW)

**Target segments**
- Oil & Gas
- Power generation

**Benefits**
- Hot/high BTU fuels capability
- High altitude and ambient capability
- Fast load acceptance
- Durability/reliability

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* Indicates a trademark
INNIO Jenbacher supporting the Energiewende

International Trends ... „3 D’s“

Decarbonization

- High electrical efficiency
- >90% fuel utilization with CHP
- Pioneer with renewable fuels (biogas, etc.)
- Hydrogen as future carbon free fuel
  up to 60%(v) today
  100% until 2021

Decentralization

- Power generation at the point of use
- Alternative to grid
- Balancing volatility of RES
- Flexible operation
- Hybrid with Solar PV
- Microgrids

Digitalization & Big Data

- myplant ... engine monitoring
- Data analytics
- Condition based maintenance
- Outage management
- Fleet management
- Reliability, availability, performance

Jenbacher Products as an integral asset and pioneer for the Energiewende
Installed base in Germany

Jenbacher installed base in Germany

~3,000 units ...  >2,500 MW

Natural gas (incl. biomethane)

Renewable gas

more or less 100% CHP applications

German fleet in 2017

NG (CHP)  -> 12,000 GWh
Biogas / LFG  -> 4,900 GWh

Avoided CO₂ by replacing a gas boiler

Source: Agora Energiewende, IB data Jenbacher
Assumptions: avg. NG efficiency 44% and 485 g/MWh CO₂, avg. NG-CHP total efficiency 88% and 244 g/MWh CO₂
From biogas to more renewable fuels
H₂ in process gases ... our experience

Important fuel properties to consider
✓ Heating Value
✓ Methane Number
✓ Laminar Flame Speed
Jenbacher* non natural gas utilization

- C_xH_y based gaseous fuels
- H_2, CO based gaseous fuels

- Coal mine gas
- Bio-, Landfill- & Sewage gas
- Associated petroleum gas (APG)
- Steel gases
- Syn.- & Woodgas

* Indicates a trademark
Jenbacher* gas engine experience with high $\text{H}_2$

More than 200MW installed with syngas / process gases

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>$\text{H}_2$: ~50-70Vol%</td>
<td>$\text{H}_2$: ~15-17 Vol%</td>
<td>$\text{H}_2$: ~30-40 Vol%</td>
<td>$\text{H}_2$: ... 100 Vol%</td>
</tr>
<tr>
<td>$\text{CH}_4$: ~20-25Vol%</td>
<td>$\text{CH}_4$: ~1.5 Vol%</td>
<td>$\text{CO}$: ~25-30 Vol%</td>
<td>Nat. Gas or Inerts</td>
</tr>
<tr>
<td>LHV: ~5 kWh/m$^3$</td>
<td>LHV: ~0.5 kWh/m$^3$</td>
<td>LHV: ~2.5 kWh/m$^3$</td>
<td>LHV: ~3 kWh/m$^3$</td>
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Commercial operation (challenges: gas quality variations)

Future

* Indicates a trademark
H₂ admixing to natural gas

Important fuel properties to consider
✓ Heating Value
✓ Methane Number
✓ Laminar Flame Speed

Controlled admixing

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<tr>
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<tr>
<td>CH₄ Vol-%</td>
<td>0</td>
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<td>93.2</td>
</tr>
<tr>
<td>C₂H₆ Vol-%</td>
<td>0</td>
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<td>4.8</td>
</tr>
<tr>
<td>C₃H₈ Vol-%</td>
<td>0</td>
<td>C₃H₈ Vol-%</td>
<td>2</td>
</tr>
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</tr>
<tr>
<td>LHV kJ/Nm³</td>
<td>10 800</td>
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<td>38 443</td>
</tr>
<tr>
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<td>41 000</td>
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</tr>
<tr>
<td>MN -</td>
<td>0</td>
<td>MN -</td>
<td>82</td>
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H₂ admixing demo projects

30% H₂
Bozen – Italy
Horizon 2020 Demo

42% H₂
Hychico – Argentina
Operating since 2008

60% H₂
H2ORIZON – Stuttgart
Commissioning 2020

60% H₂
Ando Hasama – Japan
Commissioning 2019
Hychico, Argentina

Hychico, Diadema Wind Park and Hydrogen Plant, Chubut Province, Argentina

About the region:
Currently large oil & gas fields
2,000 GW wind power potential, compared to 600 GW global installations today
Ideal place for exporting green H₂ and e-fuels in the future

Green H₂ demo:
6.3 MW wind park with 54.9% CF (2017), avg. >50%
0.8 MW of electrolyser (2 units), 120 Nm³/hr H₂
H₂ with high purity (99.998%), O₂ for local market
Underground H₂ storage research

J420 converts H₂ back to power
Output 1,415 kWₑ
Main Fuel: NG MN >90
Operation with controlled H₂ blending
0–27 v% H₂  1,415 kW
28–42 v% H₂ 1,415 to 1,180 kW

www.hychico.com
100% H₂

Important fuel properties to consider
✓ Heating Value
✓ Methane Number
✓ Laminar Flame Speed

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R&D example for 100% H₂

HyMethShip

GREEN REVOLUTION
ON THE HIGH SEA

Source: Dr. Igor Sauperl, project coordinator, LEC Graz
https://www.hymethship.com/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 768945
“Emission-free” Ship Propulsion (concept with Methanol CH$_3$OH)

- 97% reduction in GHG emissions
- Elimination of SO$_x$ and PM emissions
- Minimization of NO$_x$ emissions
- ~45% increase in system efficiency compared to the technology with conventional CO$_2$ capture / separation
- Full-size (1 MW) system demonstrator (land based)
H₂ mixed in pipeline natural gas

Important fuel properties to consider

✓ Heating Value
✓ Methane Number
✓ Laminar Flame Speed
✓ H₂ content
✓ Rate of Change
✓ Plug flow

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About decarbonizing natural gas with hydrogen

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<td>CH4 Vol-%</td>
<td>97.6</td>
<td>0</td>
</tr>
<tr>
<td>C2H6 Vol-%</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>C3H8 Vol-%</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>H2 Vol-%</td>
<td>0</td>
<td>100</td>
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<td>-</td>
<td>92</td>
</tr>
<tr>
<td>Stoichiom. air requ. Nm³/Nm³</td>
<td>9.7</td>
<td>2.4</td>
</tr>
<tr>
<td>Laminar flame speed cm/s</td>
<td>30</td>
<td>&gt;100</td>
</tr>
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Hydrogen added to pipeline Natural Gas

![Graph showing CO₂ reduction with H₂ in natural gas](image-url)

- 7% decarbonization with 20% H₂ blending
- Nat. Gas produces 202g CO₂ /kWh
Hydrogen added to pipeline Natural Gas

5% $H_2$
Ref. gas 1: MN is going from 92 to 88 a delta of 4
Ref. gas 2: MN is going from 82 to 79, a delta of 3
Ref. gas 3: MN is going from 72 to 71, a delta of 1

10% $H_2$
Ref. gas 1: MN is going from 92 to 84 a delta of 8
Ref. gas 2: MN is going from 82 to 76, a delta of 6
Ref. gas 3: MN is going from 72 to 69, a delta of 3

20% $H_2$
Ref. gas 1: MN is going from 92 to 75 a delta of 17
Ref. gas 2: MN is going from 82 to 69, a delta of 13
Ref. gas 3: MN is going from 72 to 64, a delta of 8

>5% $H_2$ in pipeline gas ... we recommend a signal to gas engines about $H_2$ content
Decarbonization with gas engine CHP

-225 g/kWh achievable with 90% fuel utilization 
(45% el. and 45% th. efficiency) 
heat bonus method

with fuel decarbonization 
(H₂ and other carbon free/neutral fuels)

193 g/kWh achievable with 90% fuel utilization 
(45% el. and 45% th. efficiency) 
and 20%(v) H₂ in gas engine fuel

209 g/kWh achievable with 90% fuel utilization 
(45% el. and 45% th. efficiency) 
and 20%(v) H₂ in gas engine & boiler fuel

Notes: CHP is calculated with the heat bonus method. GT ... Gas Turbines, GE ... Gas Engines (small – s, middle – m, large – l size)
Kiel ... Coal to Gas switch (COD end of Nov, 2019)

Municipality Kiel CHP plant, GER

20 x J920 FleXtra gas engines

190.4 MW  plant net electric output
45  %  plant net electric efficiency
191.8 MW  thermal output
91  %  total efficiency

4 x 5 unit blocks
One of the largest gas engine based CHP plant worldwide

Coal replacement
Benefits from new CHP incentives to replace coal and reduce CO₂ by approx. 70%
Case study Lemene microgrid

Core asset is the 4,000 kW solar PV (RES)

Jenbacher Gas Engines:
3 x J416 CHP, 250 mg NOx
3 x J420 CHP, 250 mg NOx
Total: 8,112 kWel
Total: 8,373 kWth for DH

By using INNIO’s Jenbacher gas engine CHP system, the LEMENE project will avoid 235 g/kWh of CO₂ compared to electricity-only operation and heat provided by a natural gas boiler. This results in 7,629 tons of CO₂ reduction if all six engines run a total of 4,000 oh per season.

Biomethane replacing natural gas results in 15,725 tons CO₂ reduction
CHP ... dispatchable renewable energy
The role of hydrogen

**Horizon 1: Medium term**
Fossil H₂ with CCUS to be the initiator and accelerator of the hydrogen society

Near and Mid term applications for distributed power:
- pilot projects to demonstrate P2G and re-conversion
- microgrids with P2G, local gas storage and balance RES
- demonstration of a 100% H₂ infrastructure

**Horizon 2: Long term**
Renewable H₂ to become dominant through high share of RES and economy of scale with significant cost reduction

Long term applications for distributed power:
- microgrids
- islands
- seasonal storage of RES
- ...
Towards dispatchable RES until 2050

**Decentralized power generation and cogeneration**

- Reliable energy supply for remote areas
- Supporting local power needs
- Avoiding transport and distribution losses
- Enhanced total efficiency
- Jenbacher Types 2, 3, 4, 6, 9

**Oilfield power (associated petroleum gas)**

- Reliability for rugged, remote applications
- Reducing global warming effects from CH4 emissions and flaring
- Emission regulations driving increased use of natural gas versus diesel-powered generator
- Jenbacher Types 2, 3, 4, 6
- Waukesha* Types VGF*, VHP*, 275GL**

**Renewables and waste-to-energy utilization**

- Waste usage
- Alternatives to fossil fuels
- Biogas, landfill gas, coal mine gas, special gases (steel gas, wood gas, process gases)
- Jenbacher* Types 2, 3, 4, 6

**Carbon free power and cogeneration**

- Carbon free power generation
- Dispatchable renewable energy source (dRES)
- Using renewable fuels such as hydrogen, methanol, synthetic nat. gas, ammonia, etc.
- Using conventional proven and affordable gas engine technology
- Any conventional application
- Jenbacher Types 2, 3, 4, 6, 9

**Natural Gas, CNG/LNG**

- Natural Gas

**Renewable Gas**

- H₂ / SNG / Methanol ...
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