DECENTRALIZED H_2-BASED ELECTRICITY STORAGE

H_2 applications for power generation

Mag.(FH) Markus Strömich-Jenewein

20th June 2024

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INTRODUCTION

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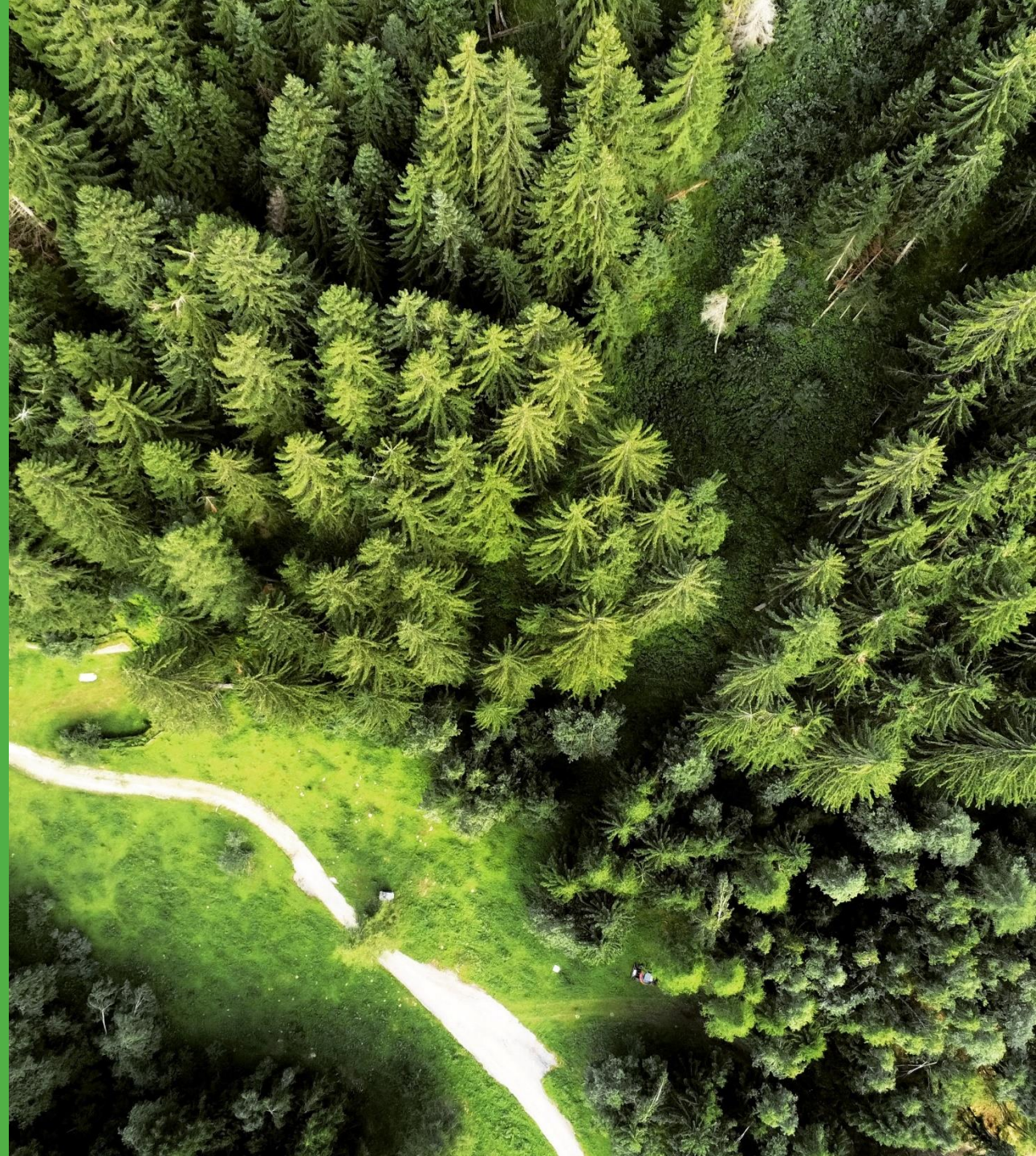


ENERGY TRANSITION CHALLENGES & SOLUTIONS

Energy transition is a marathon, not a sprint!

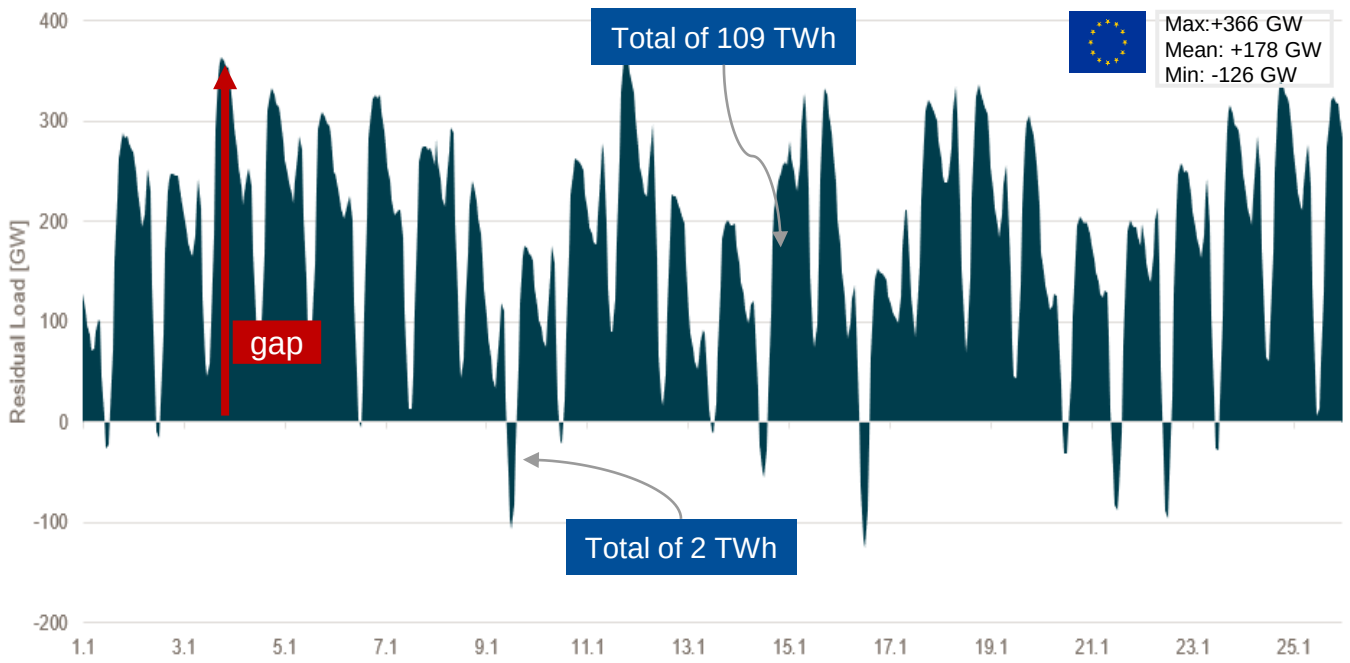
	1 Coal phase-out & increasing demand	2 Volatility vs. grid stability	3 Infrastructure change
CHALLENGES			
SOLUTIONS	Expand renewables Increase energy efficiency	Flexible, dispatchable gas power plants (ideally CHP) Large & seasonal energy storage	Flexibility at point of use (demand side response) Enable smooth transition

RESIDUAL LOAD REQUIREMENTS IN EU 2050

The winter gap

Distributed Energy and 2050 – EU-27

Residual loads in the EU-27 in 2050 during a 3-week-period in January



Source: Frontier Economics based on TYNDP data and weather year 2010

Typical 3 weeks in January 2050:

- 109 TWh is required as residual load
- 2 TWh are available only as surplus energy to re-load batteries

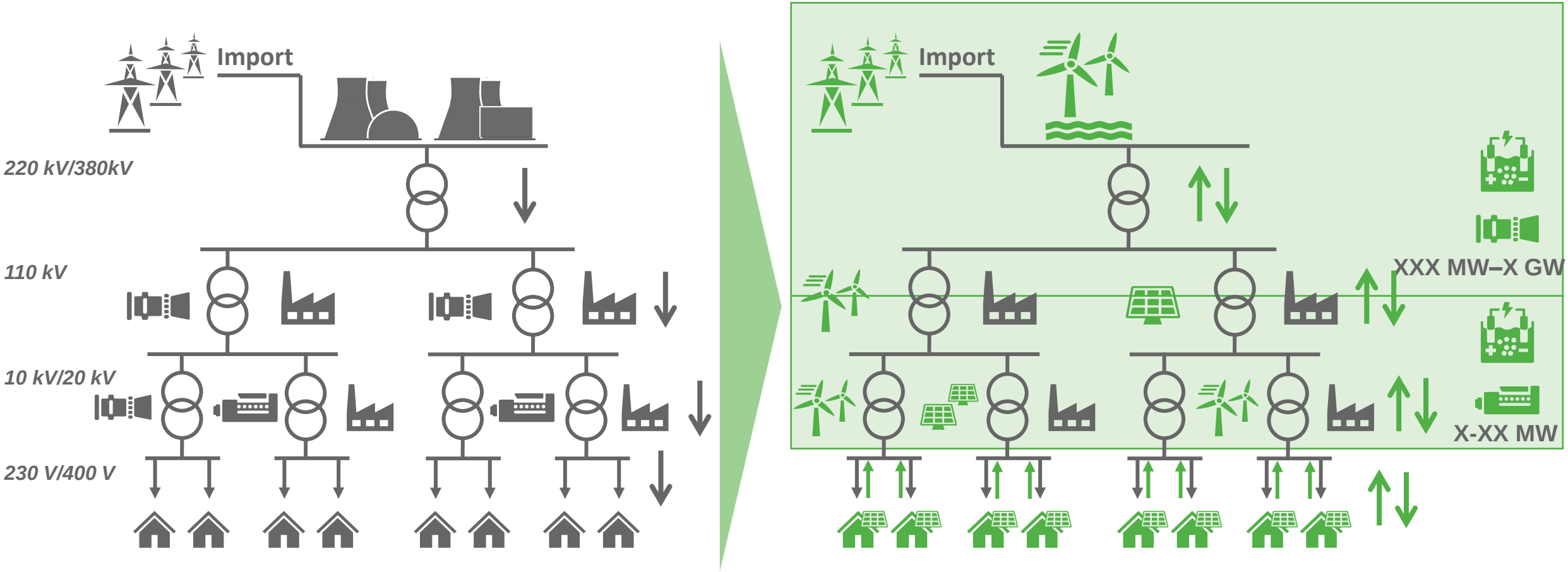
- **366 GW** is the maximum residual load needed to fill a gap.
- 35 GW can be provided from demand side management
- 59 GW from pumped hydro

Even with a perfect grid (Europe as one big “copper-plate”) there will be
longer periods with not enough renewable electricity generated to meet demand

Source: „The need for clean flexibility in Europe‘s electricity system“, Eugine, 2023

THE NEW ROLE OF THE POWER GRID AT DISTRIBUTION GRID LEVEL - TRANSITION FROM SUPPLY GRID TO FEED-IN GRID

Need for decentralized storage/balancing capacity



TRANSITIONING TO 100% RENEWABLE GASES

Jenbacher engines already work with a variety of energy sources

Today

45% ⬅ EU ➡ 55%

Pipeline Gas

Climate-neutral gases

Today's mix
of energy sources

Tomorrow

Biomethane or synthetic methane CHP

Biomethane & CO_2 usage

Hydrogen CHP/CCHP

Biogas (Flex-Biogas) CHP

Carbon-neutral fuels
&
green hydrogen

JENBACHER … A COMPREHENSIVE POWER GENERATION NETWORK

Supporting H_2 applications worldwide

CHP


CCHP


DC


GH

Biogas


Sewage gas


Landfill gas

37 GW / 25,000 engines delivered; 55% of engines in Europe, 55% thereof running on renewable gas; 12,000 engines digitally connected to myPlant

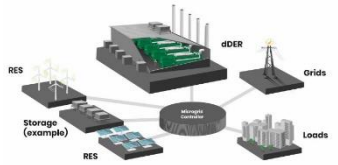
H_2 APPLICATIONS FOR POWER GENERATION

First H_2 movers → **Highly developed H_2 infrastructure**

Datacenter

Plant size: medium (1 to ~100 MW)
Operation: back-up
H_2 consumption: low
H_2 supply: local storage

H_2-Hub & Microgrids



Plant size: medium (1 to ~50 MW)
Operation: balancing
H_2 consumption: medium
H_2 supply: local storage / pipeline

RES balancing

Plant size: medium (1 to ~100 MW)
Operation: balancing
H_2 consumption: low / medium
H_2 supply: pipeline

Industrial H_2

Plant size: small (1 to 100 MW)
Operation: onsite power
H_2 consumption: medium
H_2 supply: from local processes

Islands

Plant size: small/medium (1 to 50 MW)
Operation: baseload / balancing
H_2 consumption: medium
H_2 supply: local storage / pipeline

Flexible CHP

Plant size: medium (1 to ~200 MW)
Operation: balancing
H_2 consumption: medium
H_2 supply: pipeline

PROJECT EXAMPLES

Case studies

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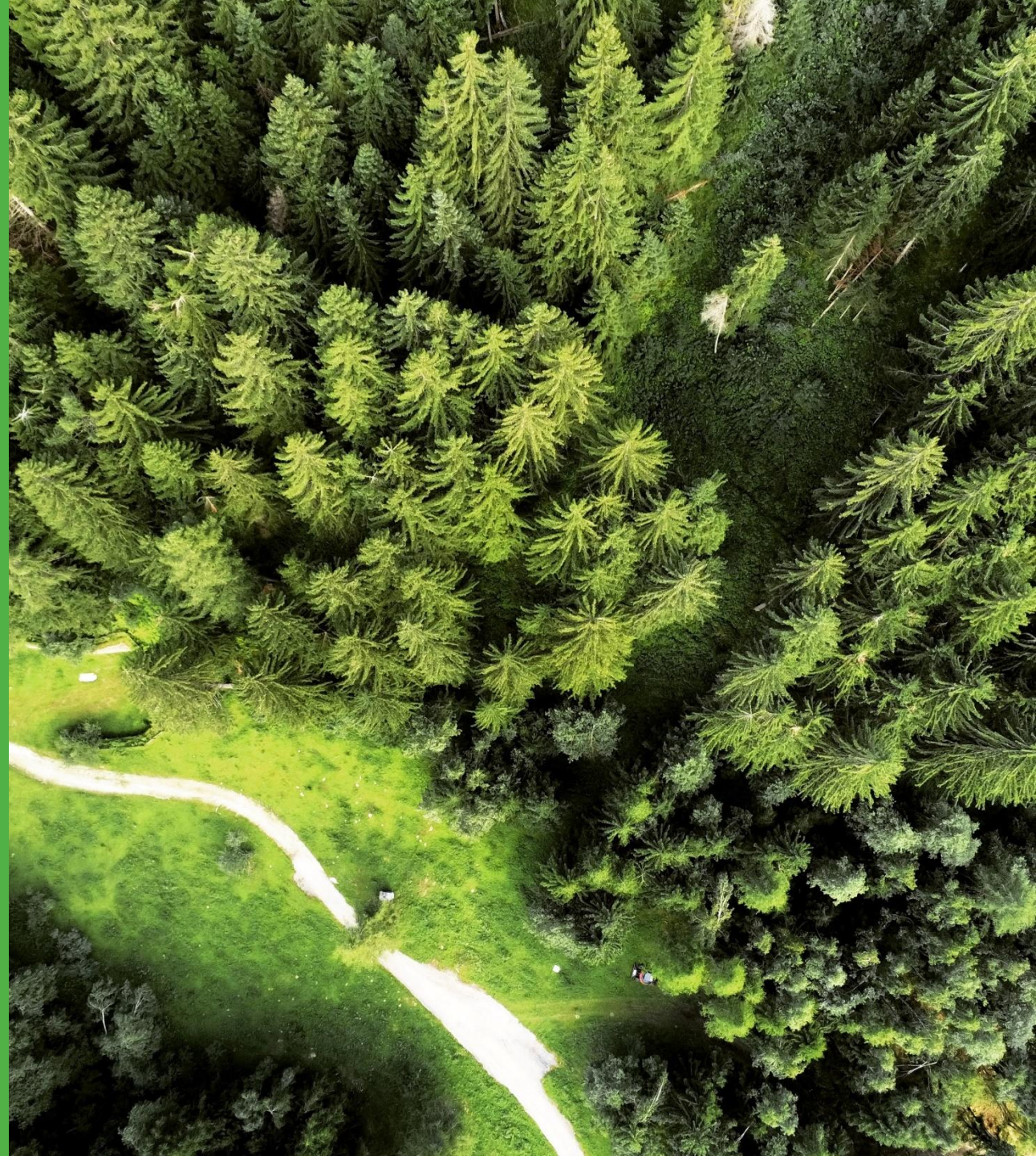


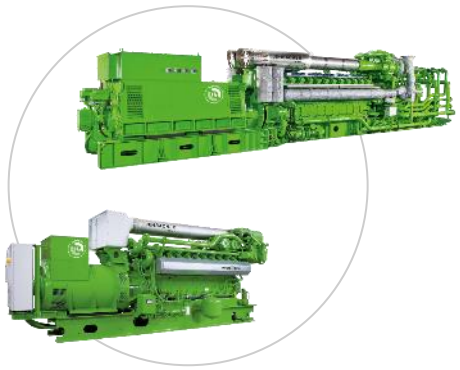
PROVEN EXPERIENCE WITH HYDROGEN & HYDROGEN MIXTURES

>95% H_2 as fuel

4 x 200,000 oph

CO_2 neutral

Traditional gas / hydrogen mixture



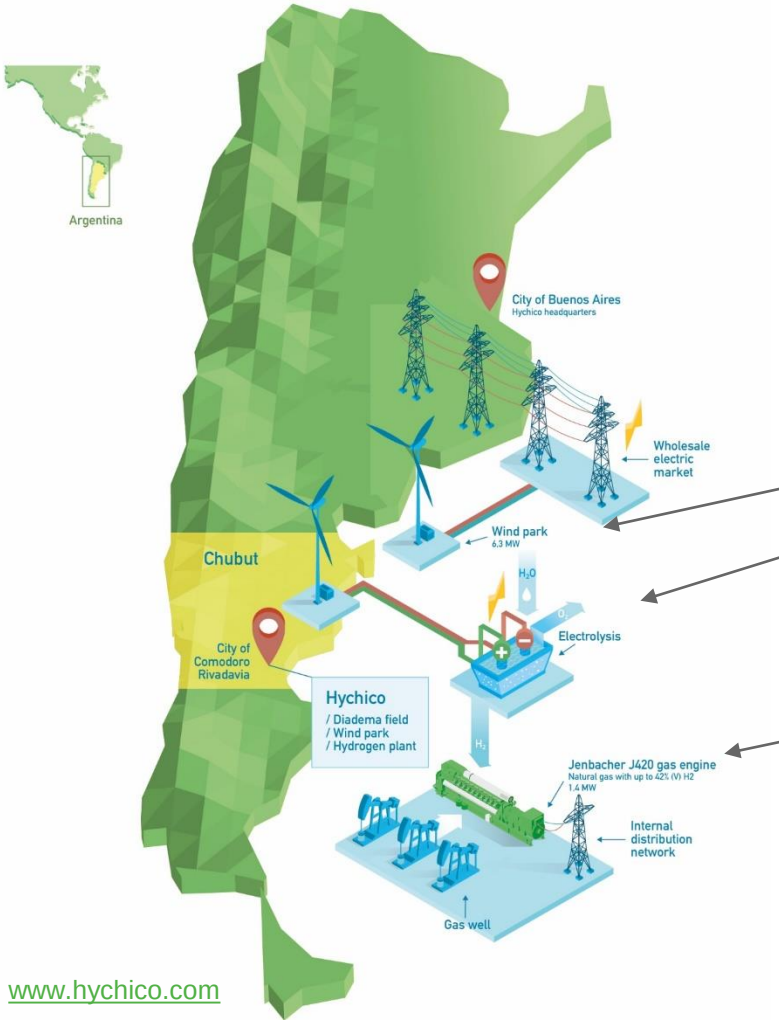
Process gas (Krems) COD 1996	Syngas (Mutsu) COD 2003	Traditional Gas (Hychico) COD 2008	Pure Hydrogen 2021+
H_2: ~15-17 vol% CH_4: ~1.5 vol% LHV: ~0.5 kWh/m³	H_2: ~30-40 vol% CO: ~25-30 vol% LHV: ~2.5 kWh/m³	H_2: ~0-42 vol% CH_4: ~100-58 vol% LHV: ~10-7 kWh/m³	H_2: … 100 vol% Pipeline Gas or Inerts LHV: ~3 kWh/m³

Commercial operation
(Challenges: gas quality variations)

Future

More than 250 MW installed with syngas / process gases, 90 projects, 28 countries

HYCHICO, CHUBUT, ARGENTINA



www.hychico.com

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 H_2 and e-fuels in the future

Green H_2 demo :

6.3 MW wind park with **54.9% CF (2017), avg. >50%**
0.8 MW of Electrolyser (2 units), 120 Nm^3/hr H_2
H_2 with high purity (99.998%), O_2 for local market
Underground H_2 storage research

J420 converts H_2 back to power

Output 1,415 kW_{el}
Main Fuel: NG MN >90
Operation with **controlled H_2 blending**
0-27 v% H_2 1,415 kW
28-42 v% H_2 1,415 to 1,180 kW

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HANSEWERK NATUR - OTHMARSCHEN, HAMBURG, GER

Retrofit Demo 2020: First MW gas engine with field conversion from natural gas to hydrogen operation

J416	Pipeline Gas (design 2019)	20%v H_2 admixing example (after retrofit)	100% H_2 operation (after retrofit)
Electrical output	999 kW	999 kW	>600 kW
Electrical efficiency	42%	~42%	~40%
Total efficiency	93.5%	~93.5%	~93%
NO_x emissions	<250 mg/Nm³ @ 5%O_2	<250 mg/Nm³ @ 5%O_2	<100 mg/Nm³ @ 5%O_2
CO_2 emissions	216 g/kWh$_{el}$	201 g/kWh$_{el}$ (-7%)	0 g/kWh$_{el}$ (-100%)

Technology

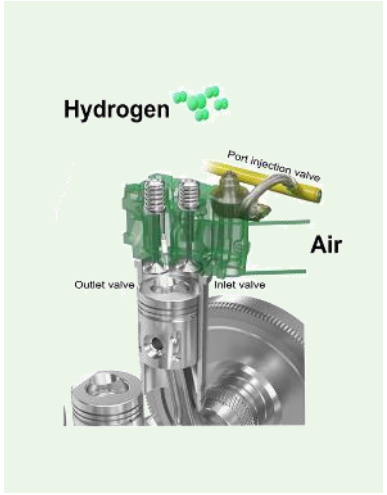
- Port injection (gas pressure 8+bar)
- Cylinder selective combustion control
- Wastegate for turbo charger

CO_2 Emissions calculated with heat bonus method

HYOSUNG, ULSAN, SOUTH KOREA

First 100% hydrogen engine for the Asia-pacific region

J420	Pipeline Gas	100% H_2
Electrical output	1.060 kW	1,060 kW
Electrical efficiency	38.4%	~38.4%
Total efficiency	~89%	~85%
NO_x emissions	<250 mg/Nm^3 @ 5%O_2	<100 mg/Nm^3 @ 5%O_2
CO_2 emissions	226 g/kWh$_{el}$	0 g/kWh$_{el}$
H_2 consumption		~83 kg/h



Largest 60 Hz H2-Engine IPP in Asia

- Hydrogen as a byproduct from chemical production at Hyosung
- Hyosung Heavy Industry demonstrating the use of hydrogen for an IPP plant as an industrial application
- H2-Engine delivered in 2023
- H2-Engine installation and service provided by INNIO Group's authorized Jenbacher distributor RNP

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*Note: Special generator design

NORTHC DATACENTERS, EINDHOVEN, NL

First data centre with H2-Engines for emergency back-up

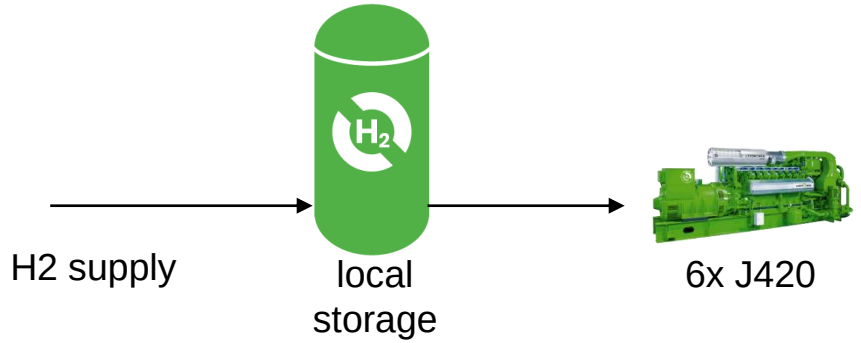
NorthC Eindhoven

NorthC Datacenters

- Small scale regional DC in Netherlands, Germany & Switzerland
- 15 local DC's, whereof 10 in NL
- Carbon neutral by 2030
- DC Groningen (2022) first with standby H_2 Fuel Cell
- **DC Eindhoven (2023)** first with 6x INNIO's Jenbacher JGC420 H2-Engines
- Going forward … new and replacement standby power based on H_2

Datacenter Eindhoven – 6 H2-Engines

- 6 MWe … standby power based on **6 x 1 MWe H2-Engines** (JGC420)
- Replacing concept with multiple 1,5 – 2,0 MWe standby diesel generators
- Re-designing concept for UPS & Cooling/chillers
- Dual fuel H2-Engines (pipeline gas as back-up fuel)
- H_2 as main fuel from local H_2 storage until H_2 pipeline is available
- Pipeline gas as back-up fuel in case of longer grid failures



https://www.northcdatacenters.com/en/about-us/sustainable-data-centers/

Containerized solution for Jenbacher Type 4 engines - example only for illustration purposes

RAG UNDERGROUND HYDROGEN STORAGE, AUT

First of its kind in Europe - world's first 100% hydrogen storage facility in a porous underground reservoir

Summer operation

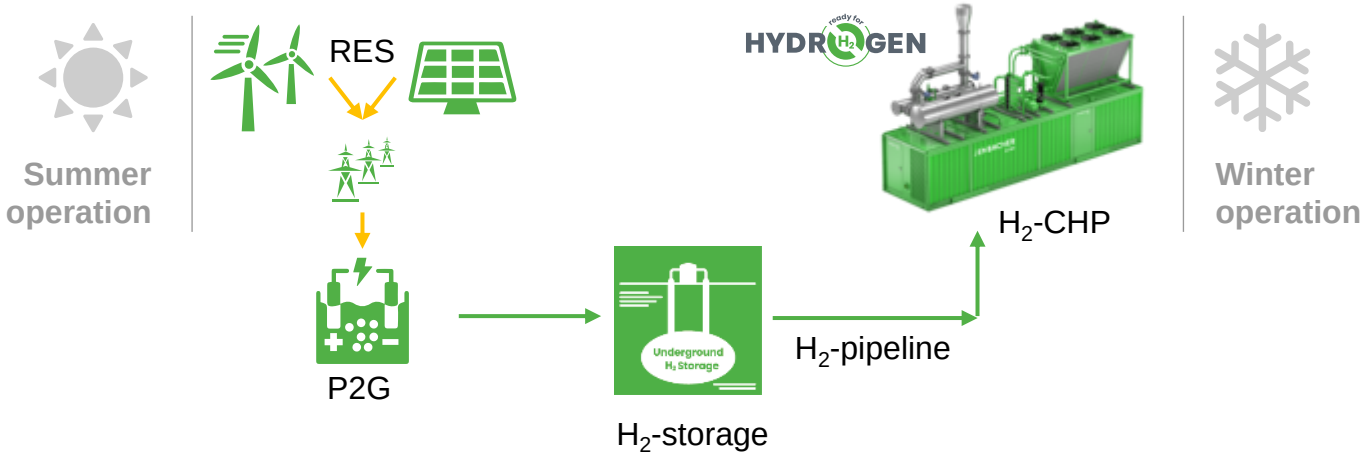
- Solar PV overcapacity
- 2 MW electrolyzer for green H_2 production
- H_2 compression

Seasonal storage

- 1.2 mio. Nm^3 H_2 storage in modified NG storage
- Gas chromatograph at H_2 discharge
- 8 km H_2-pipeline from H_2-storage to CHP unit
- Up to 600 Nm^3/h H_2-pipeline capacity

Winter operation

- J412 containerized CHP
- 530 kW electrical output and 550 kW heat output
- 100% H_2 and up to 40% NG / 60% H_2 mixture
- Commissioning date early 2024
- ~2,000 bis 4,000 oh/yr



Containerized solution for Jenbacher Type 4 engines - example only for illustration purposes

Source: INNIO Group to deliver innovative hydrogen technology... Press Release

GREEN HYDROGEN INVESTMENT IN JENBACH

H2-engine development

H_2 infrastructure investment

Project

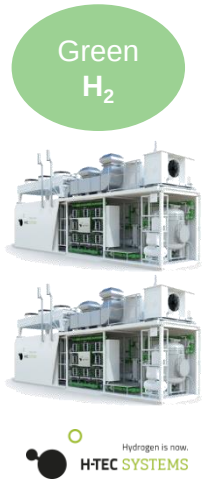
• Project start	Q4 2021
• Commissioning	2025

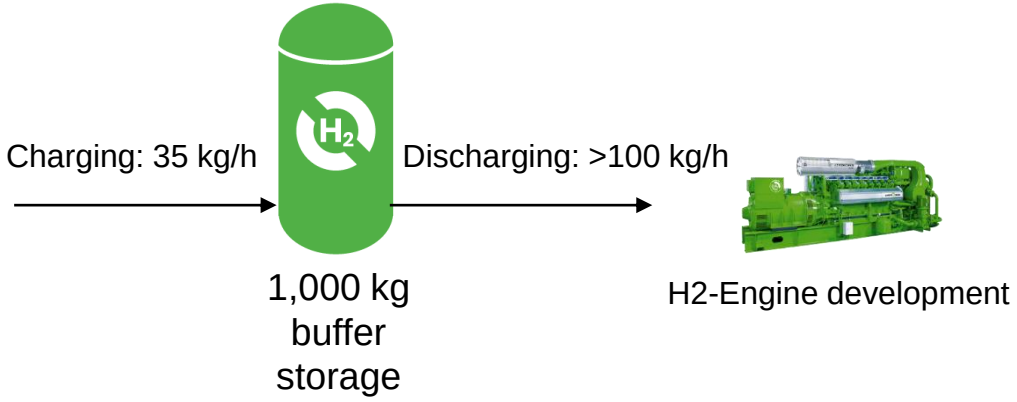
H2 production

• Nom. el. power	2 x 1 MWe
• H2-production	35 kg/h total
• Annual capacity	200 – 300 t/a

H2 storage

• H2 tank capacity	1,000 kg
• Pressure	500 bar
• Time to re-charge tank	~23 h





~~Gray hydrogen price delivered at site @ 10 – 20 €/kg~~

Green hydrogen production at site @ 6 – 8 €/kg

KIEL PLANNING FOR HYDROGEN

SW Kiel and INNIO announced to convert 190 MW CHP from pipeline gas to hydrogen by 2035

2019

5 min
from 0 to 100% Load

2035

Old: HARD COAL PLANT

323 MW	net electric output
295 MW	heat output
>50 %	total efficiency

Inflexibel in operation

Design	low # of starts
AGE:	~50 yrs

New: PIPELINE GAS

190.4 MW	plant net el. output
191.8 MW	thermal output
91 %	total efficiency

Highly flexible operation

5 min.	start up time
4 MW	minimum load

Future: HYDROGEN

target	**2035**
balancing renewables	
high efficiency H2-CHP	

Highly flexible operation

5 min.	start up time
4 MW	minimum load

Source: Stadtwerke Kiel und INNIO setzen weltweit Maßstä... Pressemitteilung

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“READY FOR H_2”

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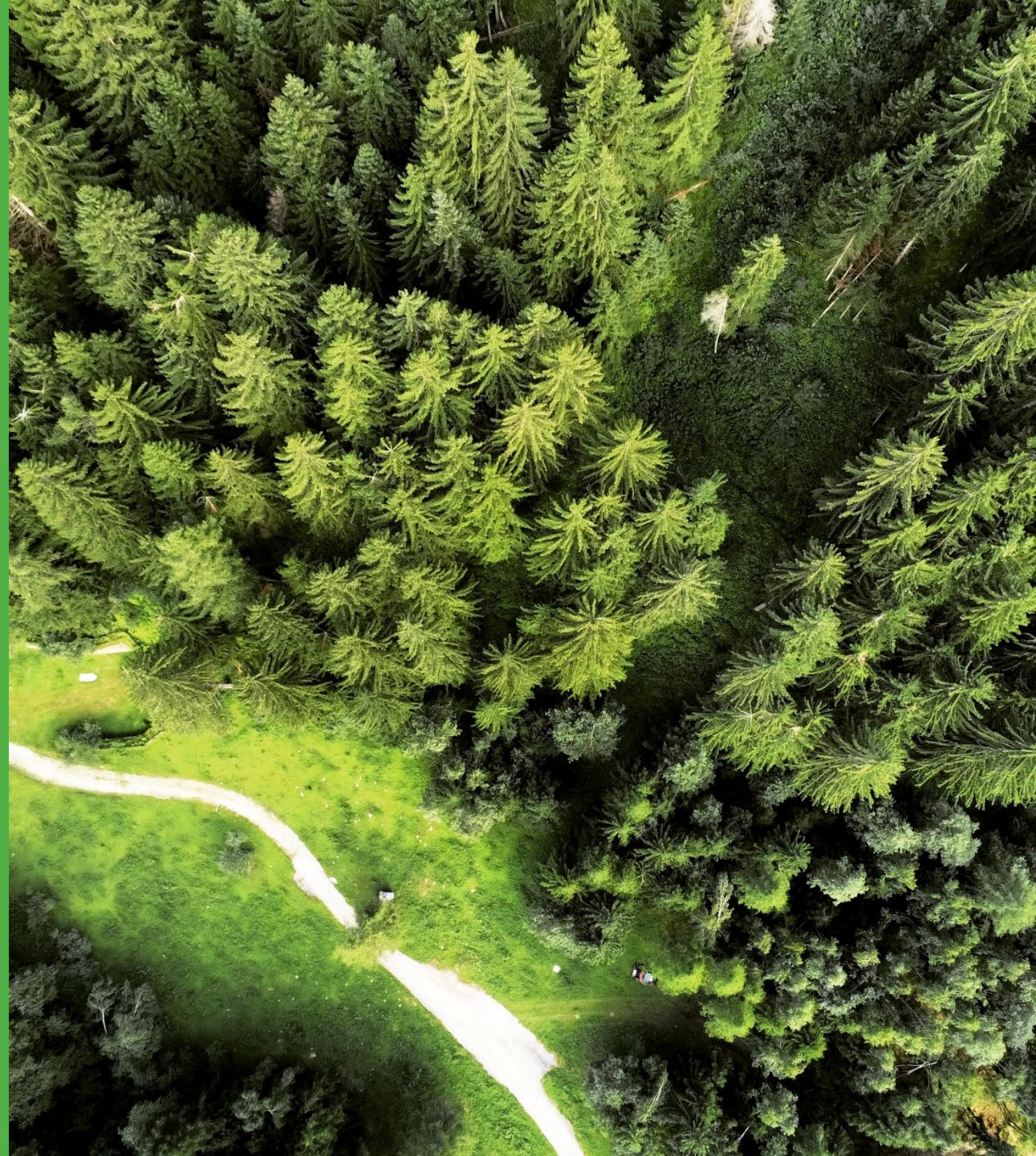
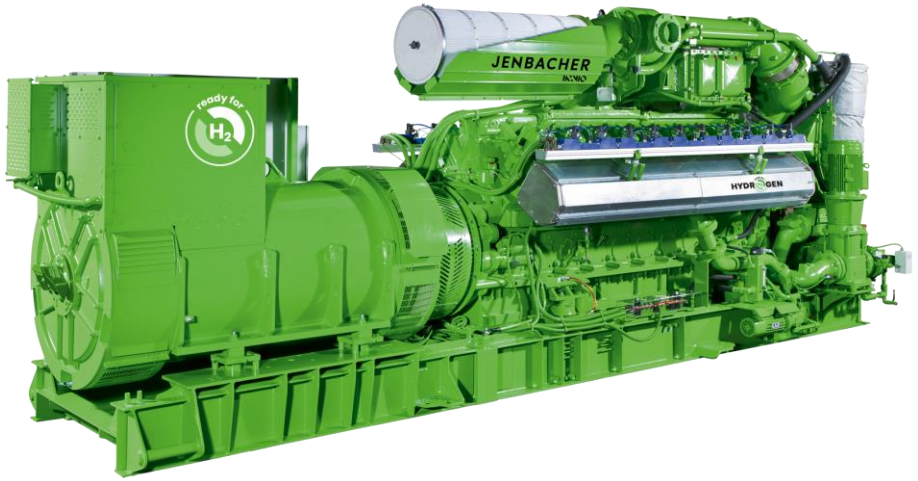


READY FOR H_2 – WHAT DOES IT MEAN?

INNIO Definition



All new Jenbacher engines are **"Ready for H_2"**.

In general, **„Ready for H_2"** Jenbacher units can be converted to operate on up to 100% hydrogen in the future. Details on the cost and timeline for a future conversion may vary and need to be clarified individually.

Furthermore, models can be offered with the option to operate with up to **25% (vol) H_2** in the pipeline gas.

Type 4 engines are offered for **100% H_2** operation.

Type 6 engines will be offered for **100% H_2** operation in 2025

Jenbacher technology then covers the full range of **500 kW to 4 MW** of hydrogen products.

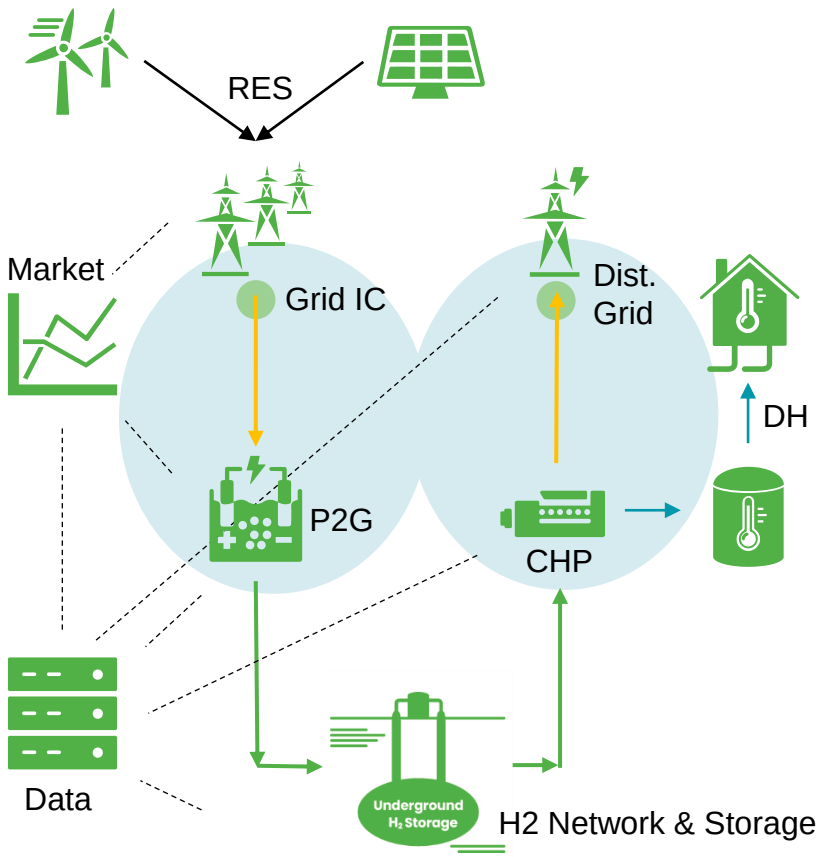
“READY FOR H_2” — JENBACHER PRODUCT PORTFOLIO

Available products today and tomorrow

[1] Subject to required modifications for the certification of the fuel gas components — a modification of the maintenance schedule for such components may be required

H_2-BASED ELECTRICITY STORAGE

Seasonal electricity storage



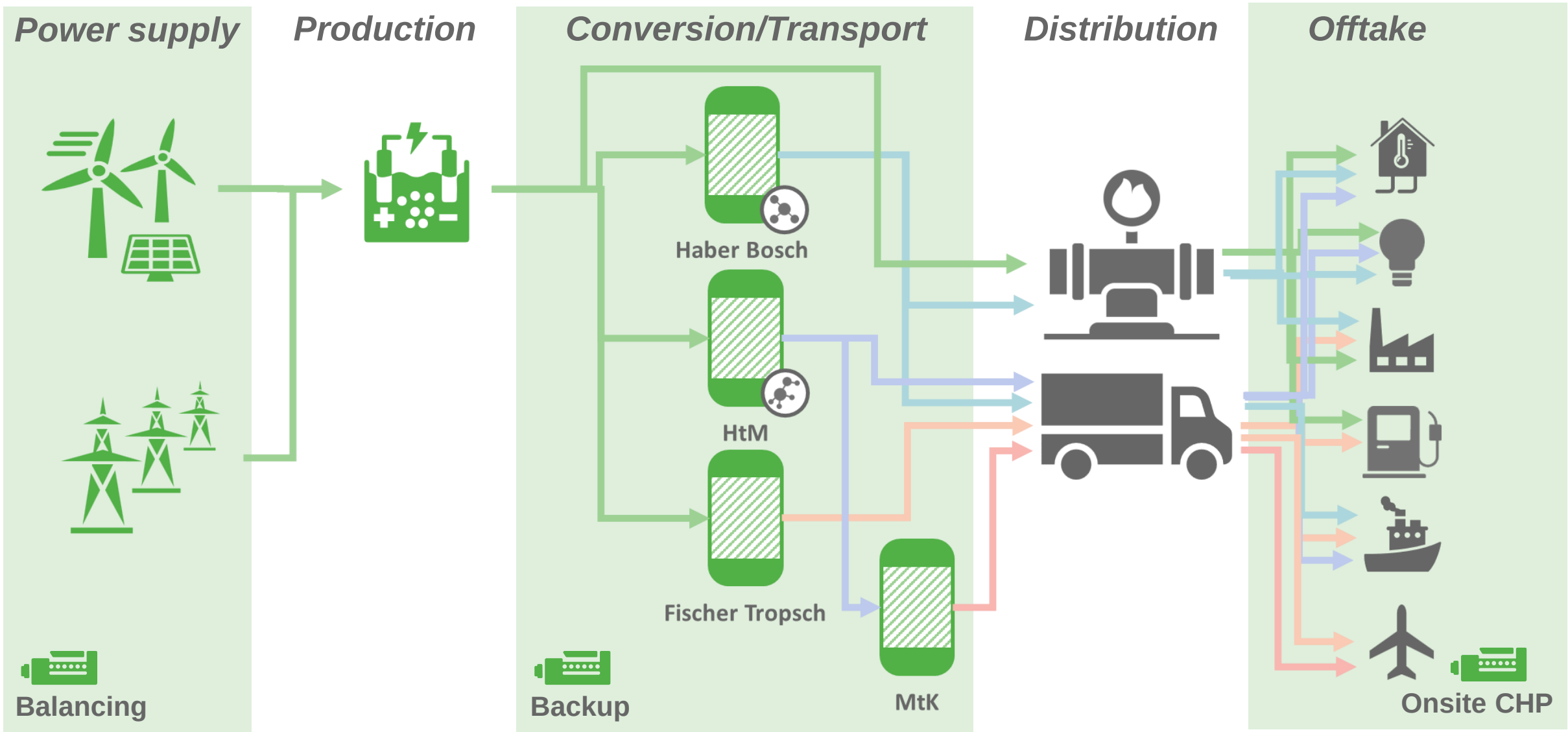
Seasonal H_2 storage:

- allows TWh storage capacity
- needs H_2 underground storage
- needs a H_2 network

- P2G at oversupply of RES (mainly in summer)
- G2P at undersupply of RES (mainly in winter)
- **Semi-decentralized H_2-CHP (90% efficiency)**
  - ✓ Allows the use of heat for district heating
  - ✓ Avoids electrical grid bottlenecks
  - ✓ Ideal for cities, microgrids and hubs

The solution for a fully decarbonized energy system with an interconnected H2 grid

FUEL FLEXIBLE H_2 (-DERIVATES) POWER SOLUTIONS FOR P2X VALUE CHAIN



TÜV SÜD CONCEPT CERTIFICATE – H_2 READINESS

INNIO Group is the first company worldwide to offer energy solutions based on the TÜV SÜD-certified "H_2 readiness" concept

Concept for new engine plants and for converting existing plants to run on 100% hydrogen.

Certification offers municipalities and companies a high level of investment security due to subsequent convertibility of the engine.

Bridge until relevant norms and standards for the planning and construction of hydrogen engine power plants are available.

INNIO Group received certificate for Jenbacher Type 4 and 6 of the Jenbacher hydrogen product line in 2023.

Certification covers all relevant components and systems - both for new plants and for plants already in operation.

EU Clean Hydrogen Alliance roadmap on standardisation

DocsRoom - European Commission (europa.eu)

Press release: Another world's first:
INNIO receives 'H2-Readiness' certification from TÜV SÜD for engine power plant concept

THANK YOU

Decentralized H_2-based electricity Storage

Mag.(FH) Markus Strömich-Jenewein

20th June 2024

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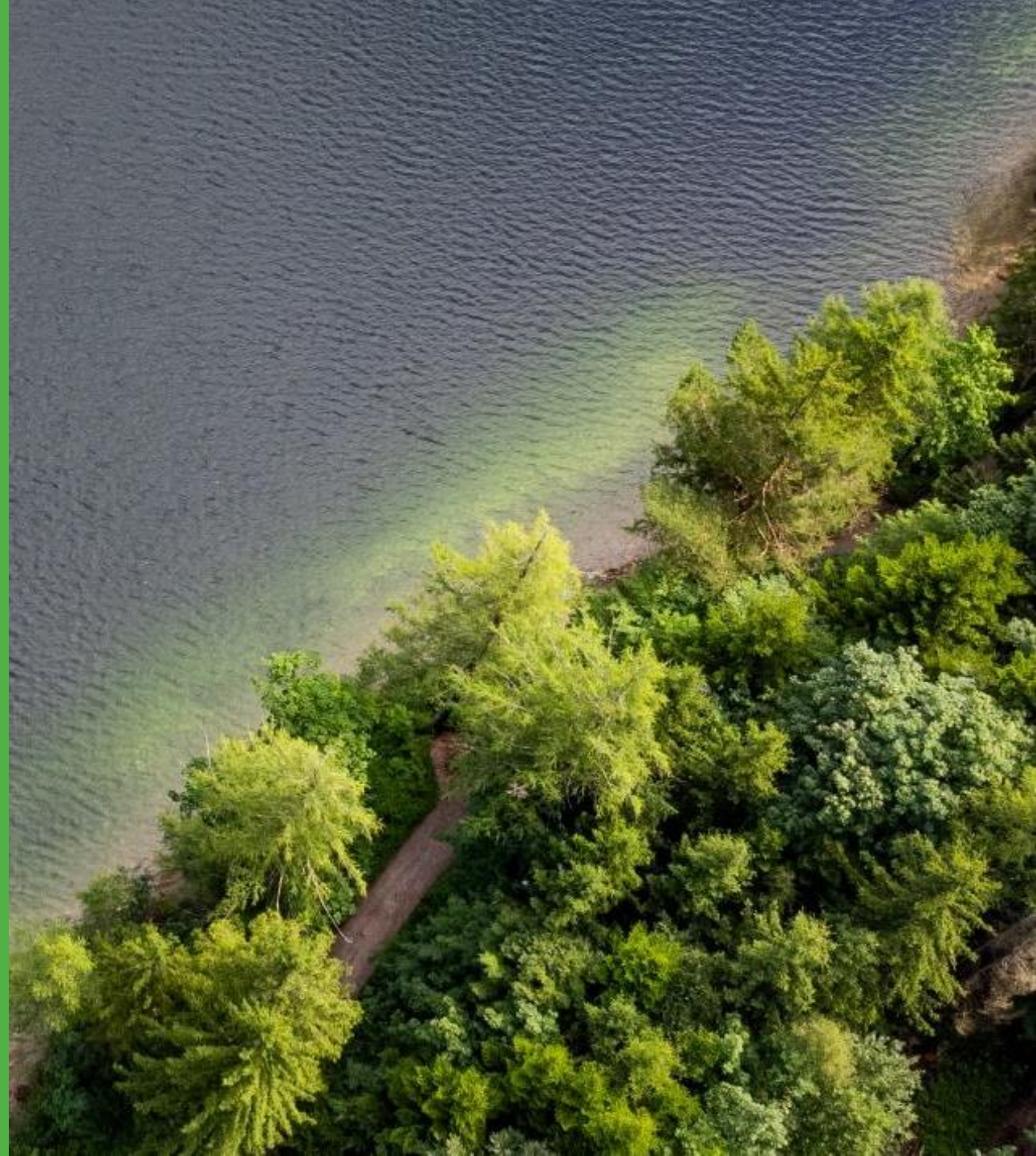

INNIO Group is a leading energy solution and service provider that empowers industries and communities to make sustainable energy work today. With its Jenbacher and Waukesha product brands and its AI-powered myPlant digital platform, INNIO Group offers innovative solutions for the power generation and compression segments that help industries and communities generate and manage energy sustainably while navigating the fast-changing landscape of traditional and green energy sources. INNIO Group is individual in scope, but global in scale. With its flexible, scalable, and resilient energy solutions and services, INNIO Group enables its customers to manage the energy transition along the energy value chain wherever they are in their transition journey.

INNIO Group is headquartered in Jenbach (Austria), with other primary operations in Waukesha (Wisconsin, U.S.) and Welland (Ontario, Canada). Through a service network in more than 100 countries, a team of more than 4,000 experts provides life-cycle support to the more than 57,000 engines that INNIO Group has delivered globally.

INNIO Group's ESG strategy has been recognized and awarded by esteemed rating agencies such as Sustainalytics and EcoVadis. Additionally, the company's near-term climate targets until 2030 have been validated by the Science Based Targets initiative (SBTi).

For more information, visit INNIO's website at www.innio.com. Follow INNIO Group and its brands on X (formerly known as Twitter) and LinkedIn.

In general, "Ready for H2" Jenbacher units can be converted to operate on up to 100% hydrogen in the future. Details on the cost and timeline for a future conversion may vary and need to be clarified individually.

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Jenbacher is part of the INNIO Group