DECENTRALIZED H2 BASED ELECTRICITY STORAGE

IEWT 2023 – Internationale Energiewirtschaftstagung

Dr. Klaus Payrhuber

15-17th of Feb. 2023

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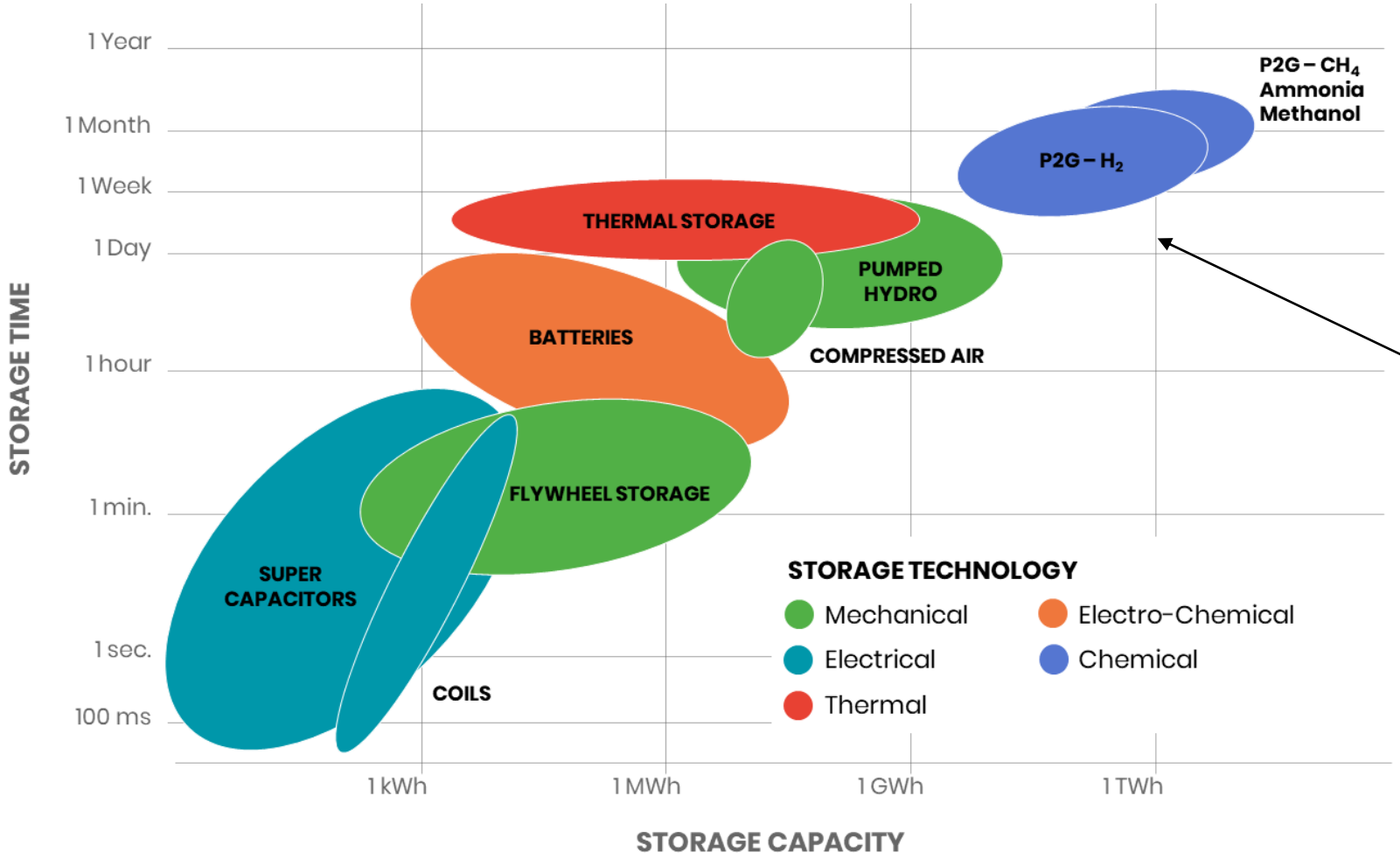
ELECTRICITY STORAGE OPTIONS



Batteries vs. Hydrogen

Example from Germany:

20 GW over 2 days balancing power

20 GW over 48 hrs

960 GWh

~1 TWh

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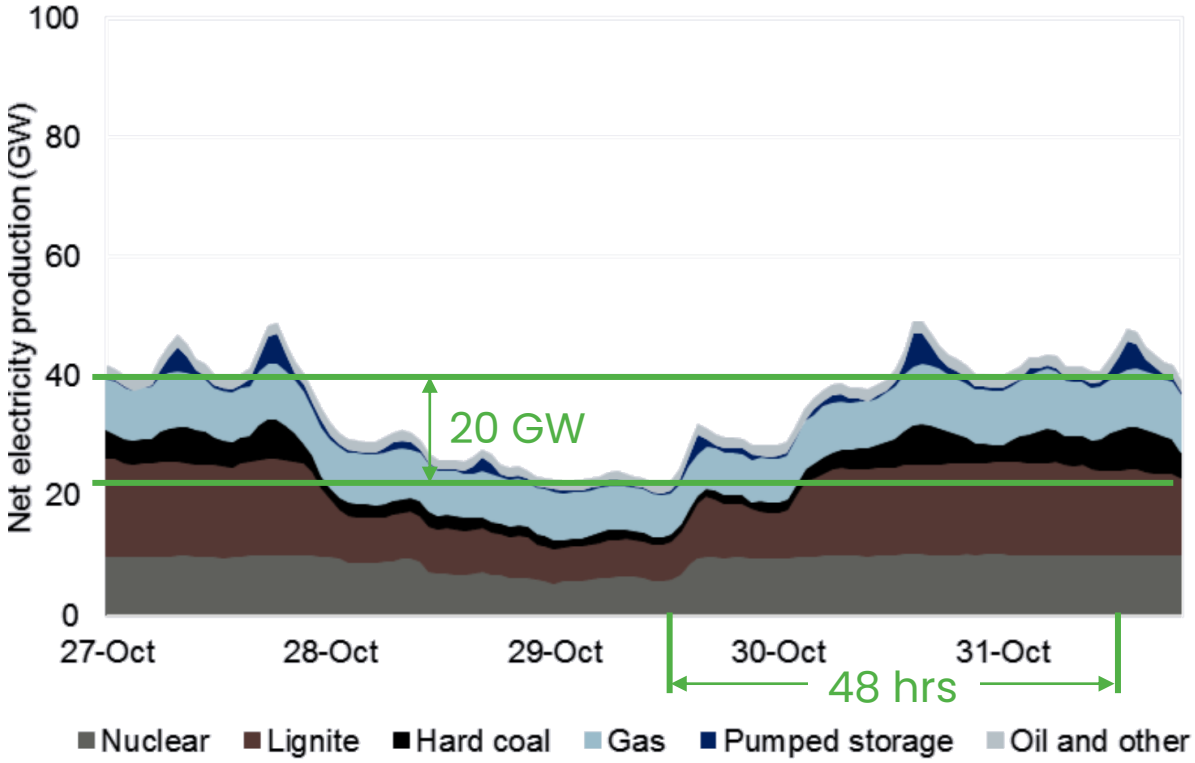
Source: INNIO Jenbacher

BATTERIES VS. HYDROGEN

An example from Germany

Net power generation by conventional energy sources, 27 to 31 October 2017, German grid



20GW Batteries vs. Hydrogen

Example:
20 GW over 2 days balancing power
20 GW over 48 hrs
960 GWh **~1 TWh**

Batteries:

20 GW with 4 hr storage = 80 GWh
12 x 20 GW @4 hrs (48 hrs) = 960 GWh

~500 €/kWh **CAPEX** (Full Turnkey)
500 x 960 000 000 kWh = **480 000 Mio. €**

Hydrogen Power Plant:


1/30

~800 €/kW **CAPEX** (Full Turnkey)
800 x 20 000 000 kW = **16 000 Mio. €**

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Source: Agora Energiewende and INNIO Jenbacher

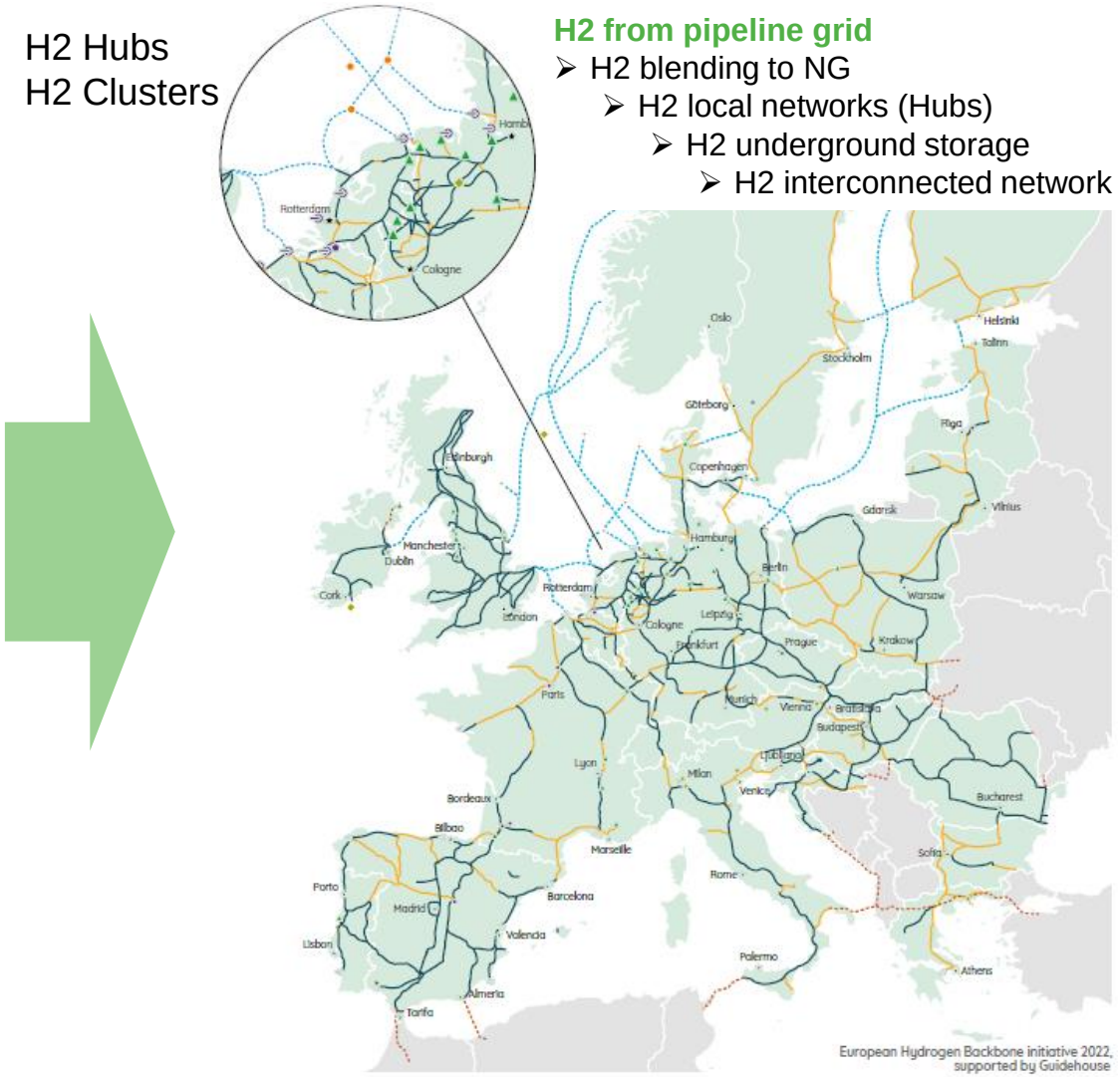
H2 SUPPLY CHAIN AND STORAGE

H2 from local storage
- Local H2 production
- Local storage as compressed H2 (technical storage)
- Local re-use of H2


Source: Hydrogen storage - DLR Portal

H2 Hubs
H2 Clusters

H2 from pipeline grid
- ➢ H2 blending to NG
  - ➢ H2 local networks (Hubs)
    - ➢ H2 underground storage
      - ➢ H2 interconnected network



Source: EU Hydrogen Backbone

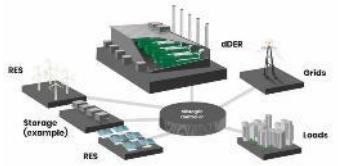
H2 APPLICATIONS FOR POWER GENERATION

First H2 movers → Highly developed H2 infrastructure

Datacenter

Plant size: medium (1 to ~100 MW)
Operation: back-up
H2 cons.: low
H2 supply: local storage

H2-Hub & Microgrids



Plant size: medium (1 to ~50 MW)
Operation: balancing
H2 cons.: medium
H2 supply: local storage / pipeline

RES balancing

Plant size: medium (1 to ~100 MW)
Operation: balancing
H2 cons.: low / medium
H2 supply: pipeline

Industrial H2

Plant size: small (1 to 100 MW)
Operation: onsite power
H2 cons.: medium
H2 supply: from local processes

Islands

Plant size: small/medium (1 to 50 MW)
Operation: baseload / balancing
H2 cons.: medium
H2 supply: local storage / pipeline

Flexible CHP

Plant size: medium (1 to ~200 MW)
Operation: balancing
H2 cons.: medium
H2 supply: pipeline

PROJECT EXAMPLES

Case studies

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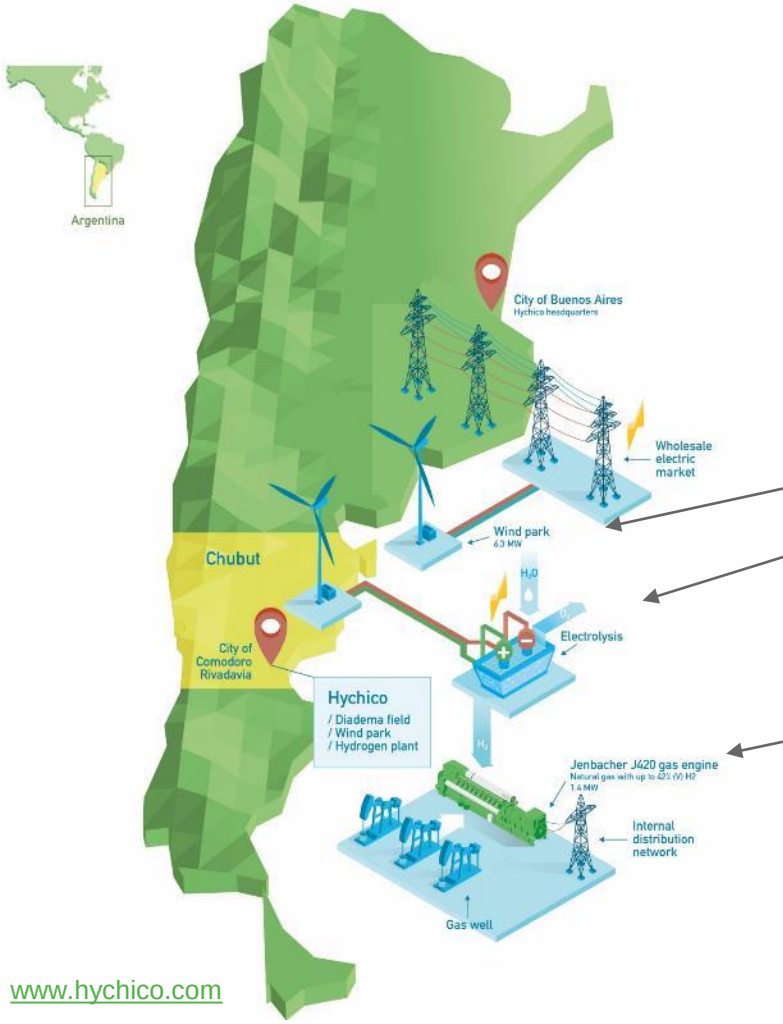
HYCHICO, CHUBUT, ARGENTINA



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

~80,000 oh
since 2008

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HWN OTHMARSCHEN, HAMBURG, GER

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

J416	Nat. 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

CO2 Emissions calculated with heat bonus method

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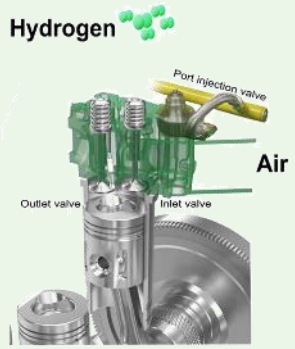
HYOSUNG, ULSAN, SOUTH KOREA H2-ENGINE CHP

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/Nm³ @ 5%O_2	<100 mg/Nm³ @ 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 CHP in Asia

- Hydrogen as a byproduct from polypropylene production from Hyosung chemical
- Hyosung heavy industry demonstrating the use of hydrogen for an IPP plant as an industrial CHP (with steam boiler)
- H2-Engine delivery in mid 2022
- H2-Engine installation and service provided by INNIO Jenbacher's authorized distributor RNP

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* Special generator design

NorthC DATACENTERS, EINDHOVEN, NL

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

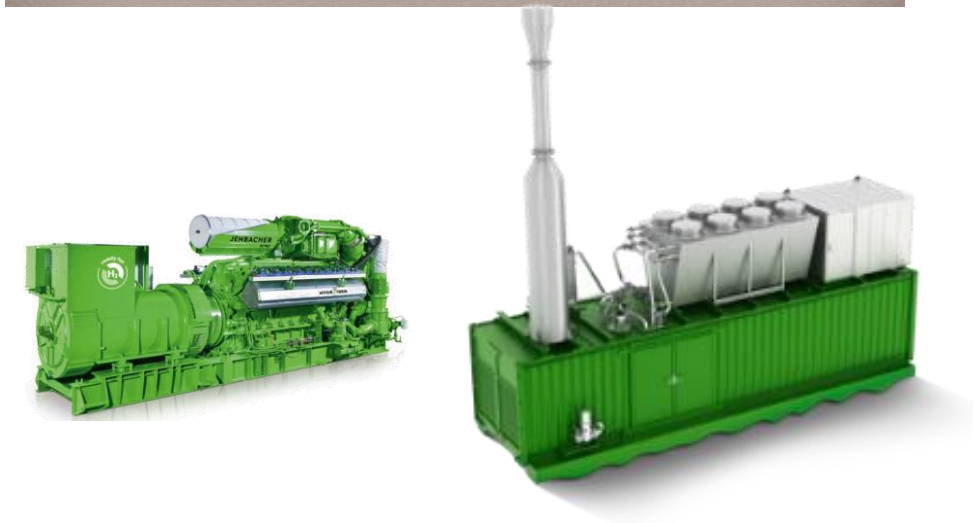
NorthC Datacenters

- 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 H2 Fuel Cell
- **DC Eindhoven (2023)** first with 6x INNIO Jenbacher JGC420 H2-engines
- Going forward … new and replacement standby power based on H2


NorthC Eindhoven

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 (NG as back-up fuel)
- H2 as main fuel from local H2 storage until H2 pipeline is available
- NG as back-up fuel in case of longer grid failures



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

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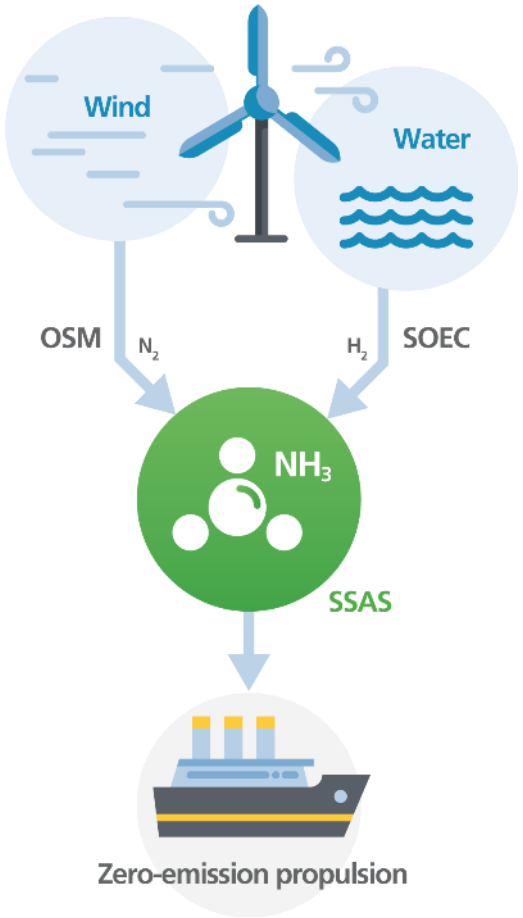
NH3 FOR STATIONARY GAS ENGINE APPLICATIONS

Wind & Water to Ammonia



Home-en - Campfire (wir-campfire.de)

JENBACHER INNIO · LEC · ZBT · INP · autosoft · YARA Knowledge grows

Aim of this sub-project:

- Development of a container-based NH3 CHP plant for a stationary application
- Power range of 1 MW
- Remote off-grid application

Including

- various evaluation steps of critical components of the gas engine
- detailed design
- implementation of the container CHP plant
- integration of the NH3 cracker and necessary safety equipment
- various test runs
- stationary and flexible start/stop operation
- optimizing efficiency and minimizing exhaust emissions

Stationäre Energie - Campfire (wir-campfire.de)

READY FOR H_2* — JENBACHER PRODUCT PORTFOLIO

Available products today and tomorrow

Power Output (kWel)

Generator Output @ 50 Hz operating on pipeline gas

0 | 1,000 | 2,000 | 3,000 | 4,000 | 5,000 | […] | 10,000

	A	B	C
	H_2 in pipeline gas	NG/H_2 engine	Pure H_2 engine
	<5% (vol) <25% (vol)[1] optional	0–100% (vol)	100%
Type 9	J920 FleXtra	✓ ✓	25%	2025+
Type 6	J612 J616 J620 J624	✓ ✓	60%	2025
Type 4	J412 J416 J420	✓ ✓	100%	✓
Type 3	J312 J316 J320	✓ ✓	60%	2025+
Type 2	J208	✓ ✓	60%	2025+

[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

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* Optional scope on demand

H2 BASED ELECTRICITY STORAGE

The concept

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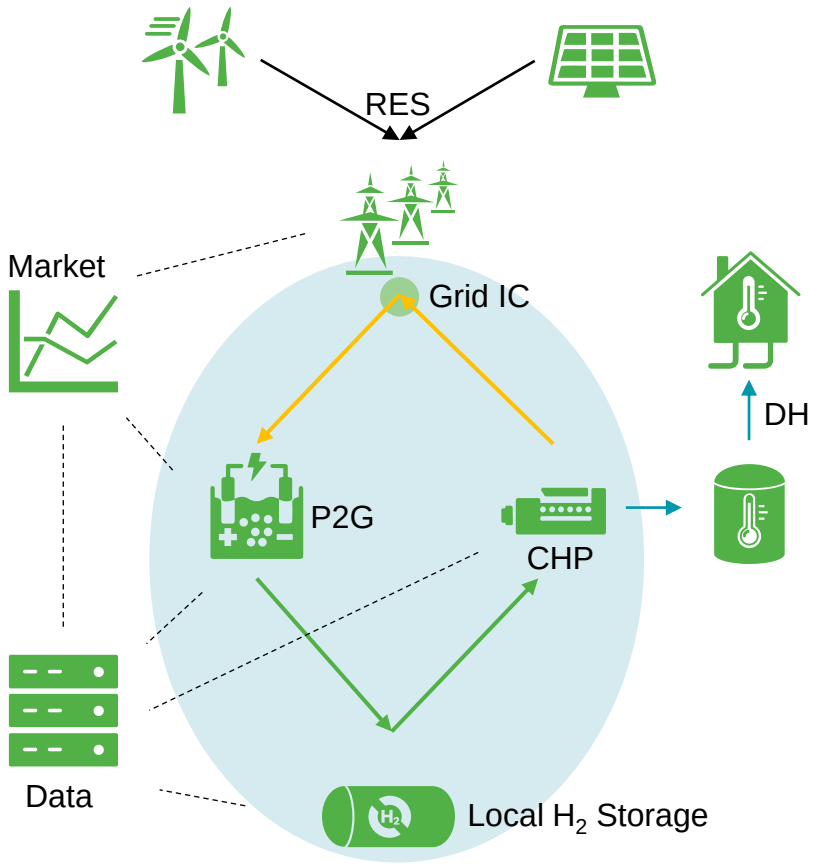
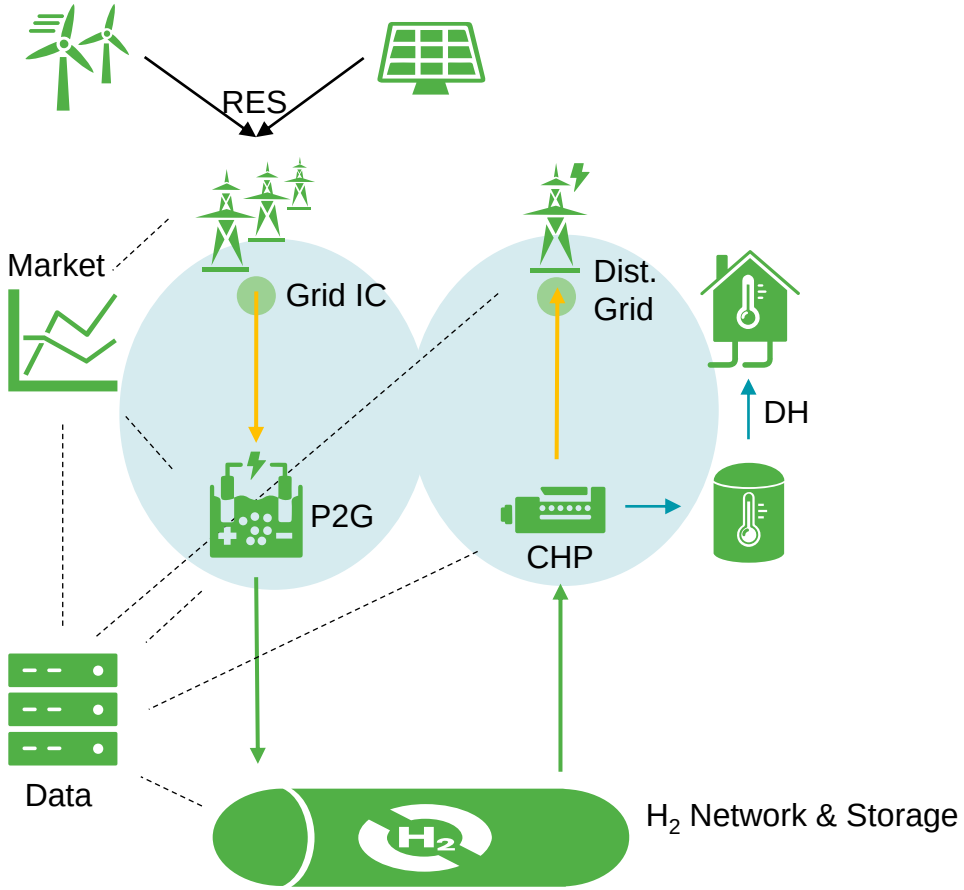
H2-BASED ELECTRICITY STORAGE

2 options

Common Grid Interconnection



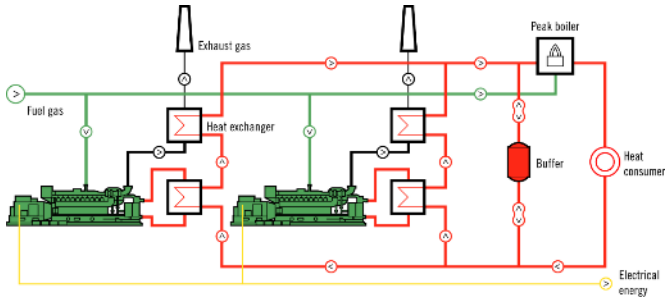
Decoupled Solution



BALANCING PLANT (CHP) - PIPELINE GAS MAIN FUEL WITH READY FOR H2

Pipeline gas

Flexible CHP
(for electricity balancing)



Highly flexible
Highly efficient

90% total efficiency, ~225 g/kWh CO2

Hydrogen benefits:

0% pipeline gas savings

0% CO2 savings

CHP benefits:

~33% pipeline gas savings

~33% CO2 savings

Conversion to 100% H2
at a later stage

Costs for conversion
to H2:
~25% of total CAPEX

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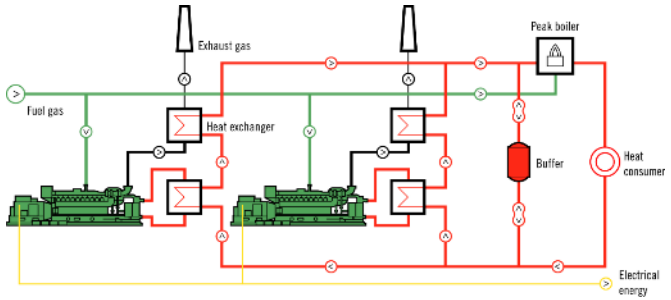
BALANCING PLANT (CHP) – PIPELINE GAS MAIN FUEL WITH H2 BLENDING

Up to 20-30%(vol) H2 in pipeline gas

Pipeline gas
(with up to **25%(vol) H2**)

Flexible CHP
(for electricity balancing)



Highly flexible
Highly efficient

90% total efficiency, ~198-225 g/kWh CO2

Hydrogen benefits with 25%(vol) :

~10% pipeline gas savings

~10% CO2 savings

CHP benefits:

~33% energy source savings

~33% CO2 savings

Conversion to 100% H2
at a later stage

Costs for conversion
to H2:
~25% of total CAPEX

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BALANCING PLANT (CHP) – PIPELINE GAS MAIN FUEL WITH H2 LOCAL ADMIXING

Up to 60%(vol) H2 from a dedicated H2 source

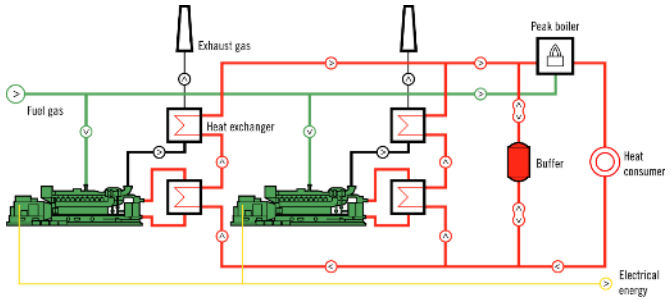
main

Pipeline gas
(up to 100%)

admixing

H2 (up to 60%(vol))

Flexible CHP
(for electricity balancing)



Highly flexible
Highly efficient

90% total efficiency, ~155-225 g/kWh CO2

Hydrogen benefits with 60%(vol) :

~30% pipeline gas savings

~30% CO2 savings

CHP benefits:

~33% energy source savings

~33% CO2 savings

Conversion to 100% H2
at a later stage

Costs for conversion
to H2:
~25% of total CAPEX

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BALANCING PLANT (CHP) – PIPELINE GAS MAIN FUEL WITH H2 OPTIONAL

Up to 100% (vol) H2 from a dedicated H2 source

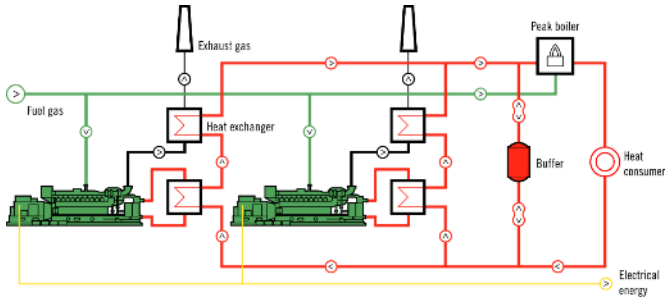
main

optional

Pipeline gas
(up to 100%)

H2 (up to 100%)

Flexible CHP
(for electricity balancing)



Highly flexible
Highly efficient

90% total efficiency, 0-225 g/kWh CO2

Hydrogen benefits:

up to 100% pipeline gas savings

up to 100% CO2 savings

CHP benefits:

~33% energy source savings

~33% CO2 savings

Costs for conversion to H2:
~10% of total CAPEX

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BALANCING PLANT (CHP) – H2 MAIN FUEL WITH PIPELINE GAS AS OPTIONAL

100% H2 from a dedicated H2 source

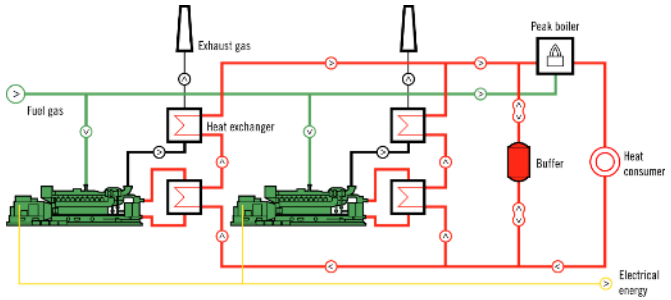
main

optional

H2
(up to 100%)

Pipeline gas
(up to 100%)

Flexible CHP
(for electricity balancing)



Highly flexible
Highly efficient

90% total efficiency, 0-225 g/kWh CO2

Hydrogen benefits:

up to 100% pipeline gas savings

up to 100% CO2 savings

Additional costs to a dedicated H2-engine: ~5% of total CAPEX

CHP benefits:

~33% energy source savings

100% CO2 savings

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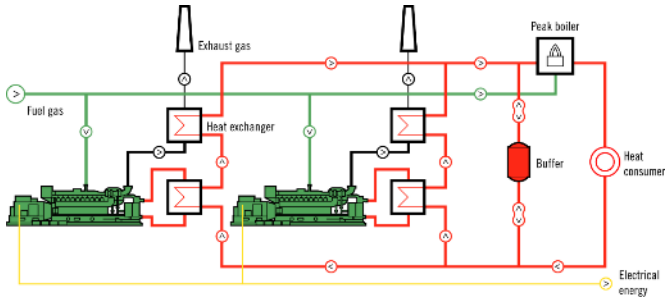
BALANCING PLANT (CHP) – WITH H2 AS MAIN FUEL

100% H2 from a dedicated H2 source

H2

Flexible CHP
(for electricity balancing)



Highly flexible
Highly efficient

90% total efficiency, 0 g/kWh CO2

Hydrogen benefits:

0 pipeline gas

0 CO2

CHP benefits:

~33% energy source savings

100% CO2 savings

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SELECTING THE RIGHT SOLUTION TODAY … WITH FLEXIBILITY FOR THE FUTURE

NG and H2 CHP

100% NG plant, ready for H2

With CHP:
33% NG saving
33% CO2 saving

100% NG plant, 30v% H2 in NG, ready for H2

With CHP:
>33% NG saving
>33% CO2 saving

100% NG plant, 60v% H2 admixing, ready for H2

With CHP:
>33% NG saving
>33% CO2 saving

100% NG plant, 100% H2 optional (dual gas)

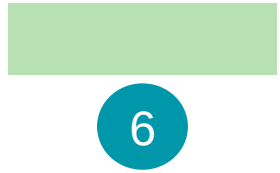
With CHP:
>33% NG saving
>33% CO2 saving

100% H2 plant, 100% NG back-up (dual gas)

With CHP:
33% H2 saving
100% CO2 savings

H2 plant

With CHP:
33% H2 saving
100% CO2 savings



INNIO is a leading energy solution and service provider that empowers industries and communities to make sustainable energy work today. With our product brands Jenbacher and Waukesha and our digital platform myPlant, INNIO 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. We are individual in scope, but global in scale. With our flexible, scalable, and resilient energy solutions and services, we are enabling our customers to manage the energy transition along the energy value chain wherever they are in their transition journey.

INNIO is headquartered in Jenbach (Austria), with other primary operations in Waukesha (Wisconsin, U.S.) and Welland (Ontario, Canada). A team of 4,000 experts provides life-cycle support to the more than 54,000 delivered engines globally through a service network in more than 100 countries.

INNIO's ESG Risk Rating places it number one of more than 500 worldwide companies in the machinery industry assessed by Sustainalytics.

For more information, visit INNIO's website at **www.innio.com**

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