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Electrified Steam Reforming of Biogas

13 July 2022

Sofia

Bayerngas Group

bayerngas

Bayerngas GmbH, Munich, Germany

bayerngas energy

Bayerngas Energy GmbH,
Munich, Germany

Bayerngas Stake: 100 %

bayernservices Technische Dienstleistungen

bayernservices GmbH,
Munich, Germany

Bayerngas Stake: 50 %

bayernugs untergrundspeicher

bayernugs GmbH,
Munich, Germany

Bayerngas Stake: 100 %

bayernets erdgas transport systeme

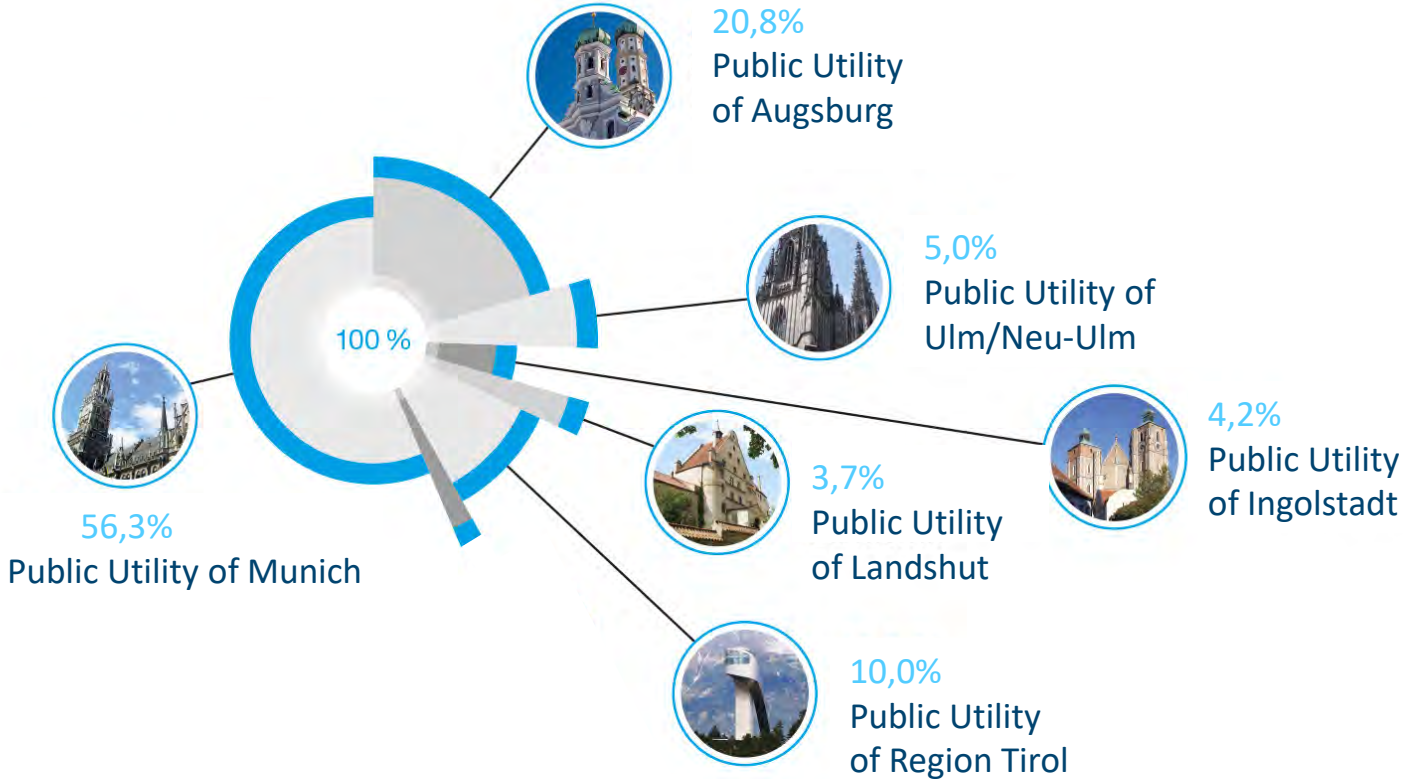
bayernets GmbH,
Munich, Germany

Bayerngas Stake: 59.1 %

- The Bayerngas Group was established in Munich in 1962.
- To date, the Bayerngas Group is exclusively backed by municipal and public shareholders.
- The Bayerngas Group is active in gas sales, pipeline and storage operations and technical services.

Shareholders of the Bayerngas Group

The Bayerngas Group is entirely owned by public utilities located in southern Germany and Austria.



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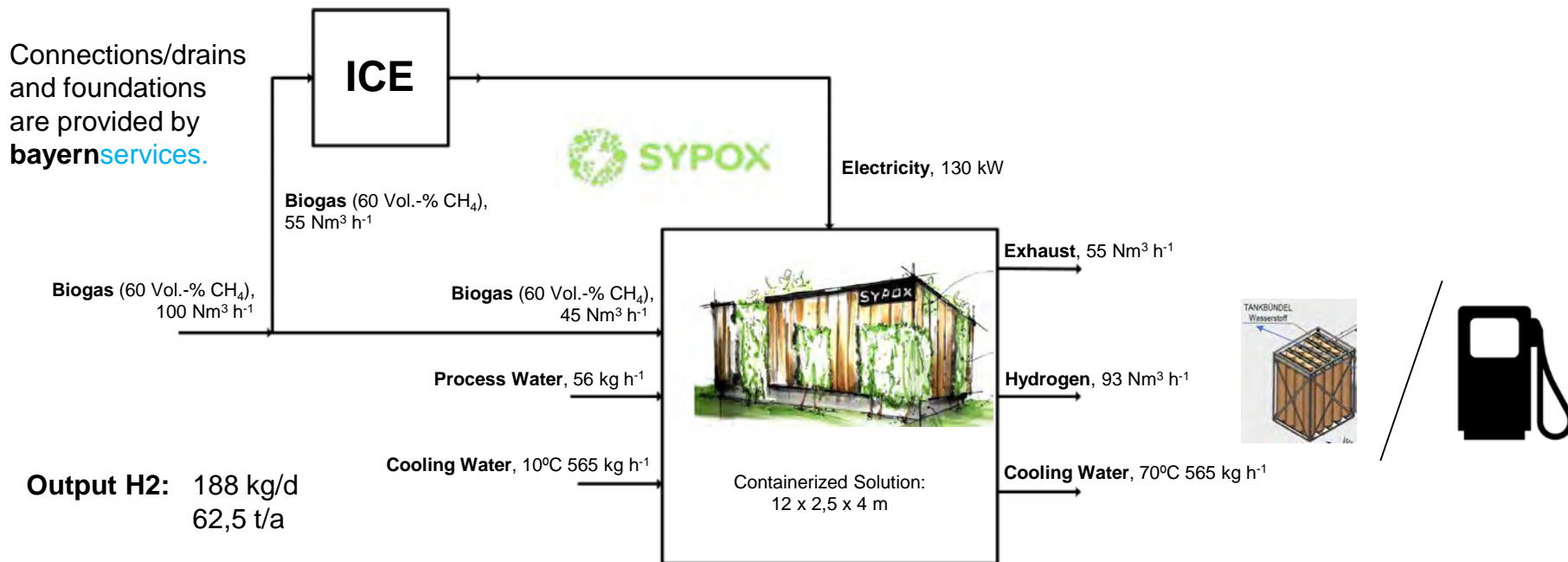


1. Technology

2. Value Creation

3. Projects

- The company SYPOX is a spin-off of the Technical University of Munich.
- The SYPOX process is a further development of steam reforming in which the thermal energy is supplied by **integrated, electrified heating wires** rather than by combustion from outside.
- By using biogas for power generation **and** as a raw material for the SYPOX process, the resulting hydrogen is CO₂ - neutral.



Hydrogen can be stored, transported and refueled in vehicles in different states of aggregation:

- Gaseous (compression required)
- Liquid (cooling to -253 degrees Celsius required)
- Liquid stockpiling via LOHC
- Mixed forms (e.g. hydrogen paste)
- Current standard at hydrogen refueling stations in Germany: **Gaseous refueling**
 - 350 bar for trucks
 - 700 bar for cars



- Fuel cell trucks in different sizes (up to 44 tons gross combination weight) exist in the prototype stage.
- The first **serial use** of Hyundai hydrogen trucks in Europe has been taking place in Switzerland since 2020.
- While Hyundai has already launched the second edition of the XCIENT Fuel Cell truck in 2021, German manufacturers have announced the start of serial production from 2023 onwards.
- The fundamental question: "fuel cell or H2 combustion engine" has not yet been decided - but the majority of vehicle manufacturers are pursuing the fuel cell concept.



Source: Paul Nutzfahrzeuge



Source: Hyundai Hydrogen Mobility

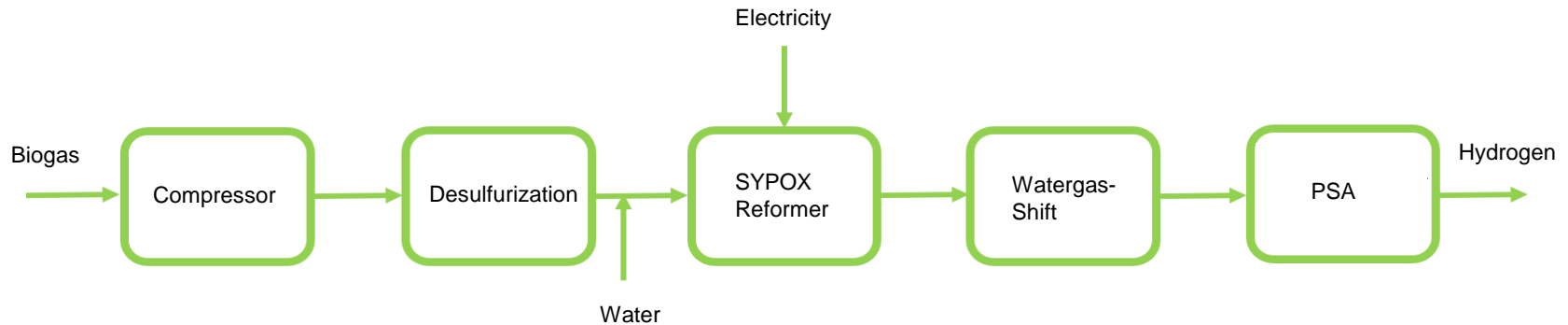
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1. Technology

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- The SYPOX process requires 16.6 kWh electricity for 1 kg of hydrogen and thus approx. 65% less electricity than electrolysis.
- Compared to conventional steam reforming, SYPOX requires about 35% less energy.
- Pressure swing adsorption achieves a purity level of 99.999%.
- The hydrogen production plant shall be owned by the biogas plant operator.
- The process of hydrogen production thus takes place directly at the biogas plant.
- The integration of the SYPOX - plant at the biogas plant and maintenance work are carried out by bayernservices.

- The role of Bayerngas Energy GmbH in this business model :
 - 1) Sales of SYPOX plants
 - 2) Commercialization/Marketing of hydrogen
 - 3) Trading of GHG reduction quotas (in German mobility)
- The marketing of hydrogen includes the organization of the transport from the producer to the consumer (here: refueling station).
- Since, from Bayerngas' point of view, hydrogen will primarily be used in the truck sector, compression to a maximum of 500 bar is planned.
 - Refueling at 350 bar
 - Overpressure in the storage medium shortens the refueling time (target: full refueling of a truck during refueling by means of overflow takes 10 minutes max.)

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1. Technology

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3. Projects

3.1 First Project at a Biogas Plant

- Biogas plant in Upper Bavaria
- Project „EReTech“ funded by the European Union
- 14 partners from industry, research institutes and universities involved
- Coordinator: Technical University of Munich
- Hydrogen production capacity: 130 t / a
- Project start: 01.06.2022
- Planned start date of hydrogen production: 2025



The EReTech project has received funding from the European Union's HORIZON-CL4-2021-RESILIENCE-01 under Grant Agreement No. 101058608

- As a preliminary stage to the first project, SYPOX, TU Munich, Bayerngas and bayernservices (Schandl) will build a demo reformer this summer, which will produce approx. 30 liters of hydrogen-containing synthesis gas per hour from biogas.
- This reformer will be integrated into a transportable container and will be commissioned at a biogas plant in Upper Bavaria within 2022.



Exterior view of the container

The containers in the three different sizes can be connected modularly.



Output H₂:
93 Nm³ h⁻¹
(188 kg/d)



Output H₂:
200 Nm³ h⁻¹
(400 kg/d)

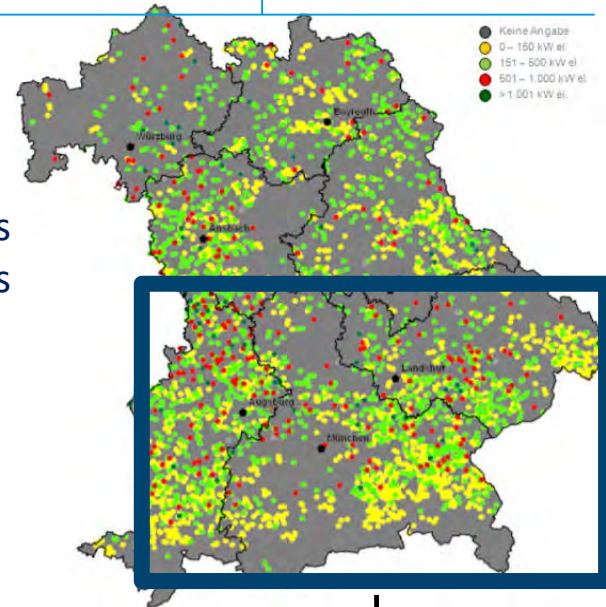


Output H₂:
400 Nm³ h⁻¹
(800 kg/d)

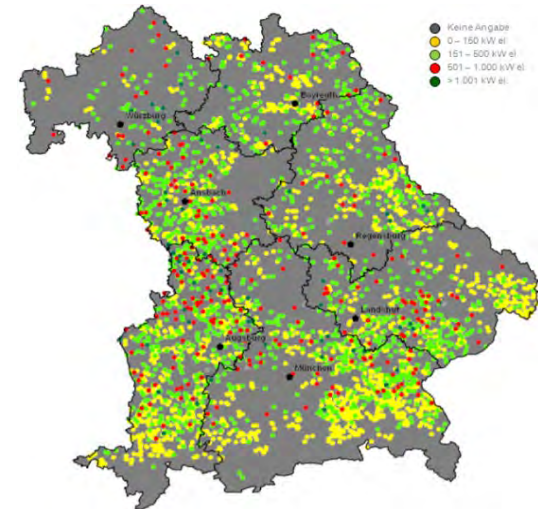
3.4 Feedback from the Biogas Industry

3. Projects

- With the help of an external consultant, who himself operates a biogas plant in the greater Munich area, sales work is currently being intensified in the south of Bavaria.
- Result so far :
 - 15 signed LOIs from biogas plant operators
 - Distinct planning of a first project



- Currently, there are more than 2,500 biogas plants in Bavaria, generating a total of 9.25 billion kWh of electricity per year.
- As of today, Bayerngas has 15 signed LOIs from the biogas industry.
- In relation to these 15 biogas plants, the following scalability can be applied:



Case 1: Electricity not from ICE (e.g. solar PV)	
Ø – Biogas quantity per plant in MWh per year	11,100
Hydrogen quantity per plant in MWh	11,000
Hydrogen quantity per plant in t	333
Total hydrogen quantity per year in t	4,994
Total hydrogen quantity in MWh	166,439
Driveable distance H2 truck in km	62,420,889
Number of trucks at 100,000 km / truck / year	624

Case 2: Electricity from ICE	
Ø – Biogas quantity per plant in MWh per year	11,100
Hydrogen quantity per plant in MWh	4,993
Hydrogen quantity per plant in t	150
Total hydrogen quantity per year in t	2,247
Total hydrogen quantity in MWh	74,898
Driveable distance H2 truck in km	28,089,400
Number of trucks at 100,000 km / truck / year	281

Scaled to all of Bavaria	
Driveable distance H2 truck in km	8,553,973,640
Number of trucks at 100,000 km / truck / year	85,540

Scaled to all of Bavaria	
Driveable distance H2 truck in km	3,849,288,138
Number of trucks at 100,000 km / truck / year	38,493

Thank you for your attention!



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