Potential and relevance of green hydrogen from biogas

Matching of demand and supply – a show case of Southern Baden

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Summary

- New business models for biogas plants in the post-EEG era.
- Hydrogen from biogas – 5000 existing hydrogen sources distributed over the country – in your region as well.
- Fraunhofer ISE study shows the potential matching for Southern Baden as a show case.
- Certified hydrogen from biogenic waste.
- Turn-key plants from e-flox in industrial standard.

The article demonstrates that producing hydrogen from biogas can make a significant contribution to the establishment of decentralized, local hydrogen hubs in the short to medium term. The authors view this as complementary to the development of a hydrogen gas network ("core network") and local production via electrolysis [8] and support the view of numerous authors that domestic hydrogen production is necessary from both an industrial and an energy policy perspective, in addition to the import strategy.

The GIS-based method combines H2-studies of demand with existing biogenic H2-sources and can be applied to whole Germany by county.

The authors assume that biohydrogen produced from biogas is competitive with electrolytic hydrogen on a decentralized scale. This is primarily because biogas, the feedstock, is available at a cost of less than 10 cents per kWh, and 24/7 operation is possible for over 8,500 hours per year.

Biogas, in conjunction with the Electrolyse Atlas [8] and the H2Hub concept [7], will enable a comprehensive, regional basic supply of hydrogen in the medium term, particularly in regions that cannot expect to be connected to a hydrogen pipeline for some time.

Hydrogen from biogas – more than 5000 potential sources in Germany

There are more than 9,000 biogas plants in Germany. More than 95% generate electricity, while only 2.8% of the plants are equipped with CO2 separation systems to feed 10.5 billion kWh of biomethane into the natural gas grid. Figure 1 clearly illustrates that a biogas plant can be found almost everywhere in the neighborhood, region, or county.

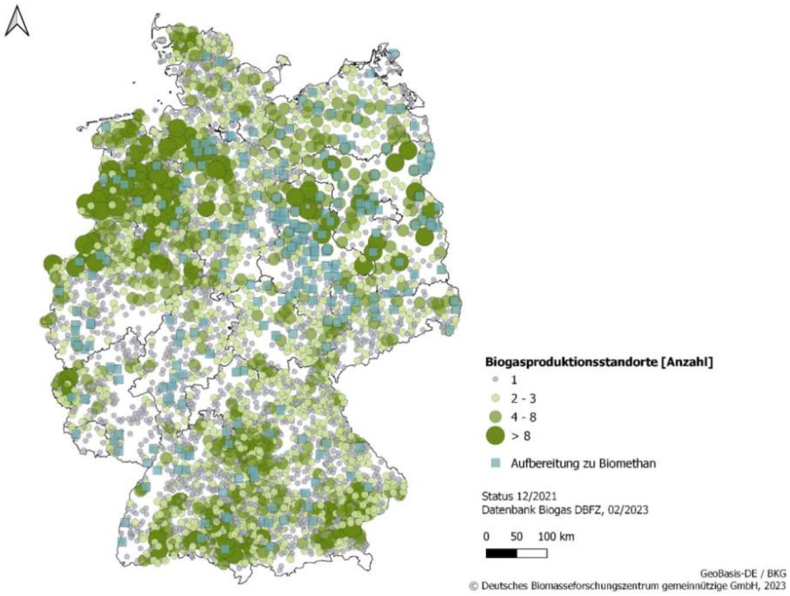


Figure 1: Locations of biogas plants in Germany. Size and color of the data points designate the number of plants per data point. A blue square indicates a plant for upgrading biogas to biomethane.

The massive expansion between 2000 and 2015 (Figure 2) is attributable to the 20-year feed-in tariff under the Renewable Energy Act (EEG) for green electricity. Biomethane feed-in plants were primarily commissioned between 2010 and 2015. The vast majority of these are manure-based plants, although they tend to have lower capacity. Given an electrical efficiency of approximately 40% for the power generators and biogas production costs of 6–8 ct/kWh, it immediately becomes clear that the marginal costs of electricity production exceed 15 ct/kWh and are therefore no longer competitive with PV and wind power.

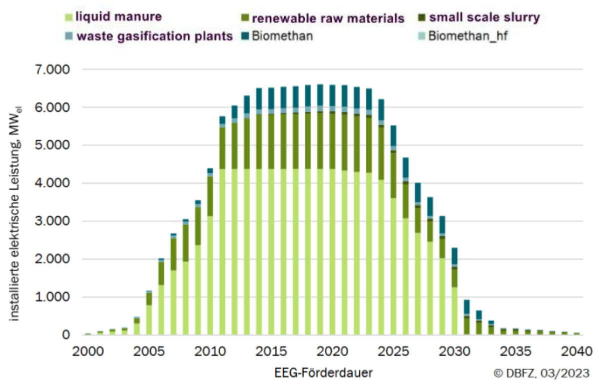


Figure 2: Stock of biogas plants (expressed as electrical power installed) with expected decommissioning resulting from the expiration of the EEG-feed in tariff until 2035.

The sale of thermal energy (heat) is necessary for cost-effective operation, but in many cases is only possible to a limited extent (no district heating networks, no demand in the summer). New business models are therefore urgently needed within this decade. The DBFZ addresses this issue regularly and with increasing emphasis in its status reports [1]. Last year, there was even discussion of using the entire fleet of plants as a “reserve power plant cluster” for periods of low wind and low sunlight [2].

The production of biogenic hydrogen in the existing plants is a further option which has received far too less attention in the opinion of the authors.

Using the electricity generated by biogas plants is not a viable option due to their 40% efficiency, even though this would allow electrolysis to operate 24/7.

The technology of choice is the established steam reforming of methane.

A brief study for Baden-Württemberg conducted by the ZSW [3] confirms the high level of technology and the feasibility of the project, but does not take into account the market environment for existing resources described above. It considers only the newly mobilizable potential of residual and waste materials. If 10% of the newly mobilizable potential is utilized, only a very small contribution of 6% to the expected hydrogen demand in 2030 is projected.

Considering the existing infrastructure, the potential is clearly much greater. From the authors’ perspective, the key advantage in the current situation is the ability to quickly implement and launch numerous local hydrogen hubs. In addition, long-term options, such as biogenic carbon capture [12], should be considered.

Below, we outline a business model for biogas plants in the post-EEG era in the context of developing a hydrogen infrastructure.

Its use as a fuel plays a key role in this context. In the political debate (“Hydrogen only makes sense in the steel industry”), this fact—which has been known for many years [5]—has played hardly any role, despite claims of technological openness by the political actors.

Steam reforming – commercially available module for 400 kg H_2/day

Steam reforming is a proven technology that has been in routine industrial use, for 10 years even on a small scale, in steel and solar panel production.

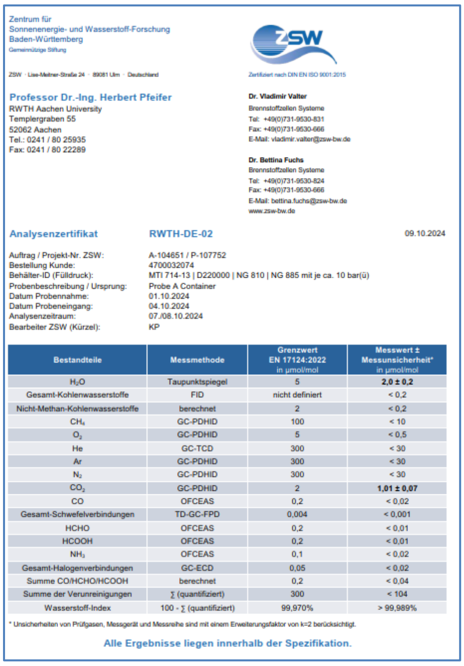
Demonstration plant

As part of the “BioH2Ref” project, the technology was adapted for the direct production of biogas (Figure 3). Through the careful selection of catalysts, the project addressed the requirements of “dry reforming” while also optimizing heat management for typical biogas compositions. The system design specifically addresses the unique operational challenges of a farm setting. The demonstration plant, with a capacity of 100 kg/day and financed with internal funds, will go into production upon completion of the project in 2026.

Extensive experimental studies, conducted in conjunction with and based on the theoretical predictions of a dynamic process simulation [9], were carried out and have contributed to a deep understanding of the process.

Figure 3: Demonstration plant for the production of 100 kg biogenic hydrogen / day

The quality of the hydrogen produced was verified, and a method for continuous monitoring was developed. Both Quality 5.0 and the fuel cell standard (EN 17124-2022, see Figure 4) have been met. Finally, a certification process in accordance with REDcert-EU was methodically developed and successfully obtained.



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Analysenzertifikat RWTH-DE-02 09.10.2024

Auftrag / Projekt-Nr. ZSW: A-104651 / P-107752
Bestellung Kunde: 4700032074
Behälter-ID (Fülldruck): MTI 714-13 | D220000 | NG 810 | NG 885 mit je ca. 10 bar(ü)
Probenbeschreibung / Ursprung: Probe A Container
Datum Probennahme: 01.10.2024
Datum Probeneingang: 04.10.2024
Analysenzeitraum: 07./08.10.2024
Bearbeiter ZSW (Kürzel): KP

Bestandteile	Messmethode	Grenzwert EN 17124:2022 in µmol/mol	Messwert ± Messunsicherheit* in µmol/mol
H_2O	Taupunktspiegel	5	**2,0 ± 0,2**
Gesamt-Kohlenwasserstoffe	FID	nicht definiert	< 0,2
Nicht-Methan-Kohlenwasserstoffe	berechnet	2	< 0,2
CH_4	GC-PDHID	100	< 10
O_2	GC-PDHID	5	< 0,5
He	GC-TCD	300	< 30
Ar	GC-PDHID	300	< 30
N_2	GC-PDHID	300	< 30
CO_2	GC-PDHID	2	**1,01 ± 0,07**
CO	OFCEAS	0,2	< 0,02
Gesamt-Schwefelverbindungen	TD-GC-FPD	0,004	< 0,001
HCHO	OFCEAS	0,2	< 0,01
HCOOH	OFCEAS	0,2	< 0,01
NH_3	OFCEAS	0,1	< 0,02
Gesamt-Halogenverbindungen	GC-ECD	0,05	< 0,02
Summe CO/HCHO/HCOOH	berechnet	0,2	< 0,04
Summe der Verunreinigungen	∑ (quantifiziert)	300	< 104
Wasserstoff-Index	100 - ∑ (quantifiziert)	99,970%	> 99,989%

* Unsicherheiten von Prüfgasen, Messgerät und Messreihe sind mit einem Erweiterungsfaktor von k=2 berücksichtigt.

Alle Ergebnisse liegen innerhalb der Spezifikation.

Normec Zertifizierung

REDcert EU

Certificate

EU-REDcert-548-Z71089923

By means of an audit on **18.03.2024**, documented in a report

Normec Zertifizierung Umweltgutachter GmbH
Kapellenweg 8, 48683 Ahaus, Germany

confirms to

BtX energy GmbH
REDcert-ID: 4570
Am Lefkeshof 22, 47839 Krefeld
Latitude 51.3874162; longitude 6.5003028

the compliance with the requirements of the certification scheme

REDcert-EU

a scheme for demonstrating compliance with the sustainability criteria under the Directive (EU) 2018/2001 of the European Parliament and of the Council

This certificate serves as proof of compliance with the requirements of Directive (EU) 2018/2001 for the following scope(s):
*(**420**) Plant for the production of biogenic hydrogen / (**502**) supplier (dealer/ware-house/logistic center - after the last interface)*

Date of certification decision: 28/03/2024
This certificate is valid from 28/03/2024 to 27/03/2025

Ahaus, 28.03.2024
Place, Date

Normec Zertifizierung
Umweltgutacher GmbH
Kapellenweg 8 · 48683 Ahaus
Stamp, Signature

The Certification Body is responsible for the accuracy of the certificate. Edition: 01/2024
Decisive for the validity of the certificate is exclusively the information given on the website of REDcert GmbH. Deviations can result for example from the withdrawal or suspension of an issued certificate. Since this certificate is property of the certification body, in eligible cases it must be returned on request.

Figure 4: Quality certificate and exemplary certification in accordance with RED II

Commercial plant

The results of the research project were incorporated into the development of a commercial system. Product development is guided by the concept of a modular standard module built in a container design. The first question that needed to be answered was which power class would cover the broadest possible market segment. The ongoing studies by the DBFZ and DVGW-EBI provide the answer. Figure 5 shows that most systems fall within the performance class up to 500 kW; a more detailed analysis reveals that there are approximately 4,000 systems in the 350–500 kW_el performance class, most of which are agricultural systems with limited or no access to the natural gas grid or a district heating network.

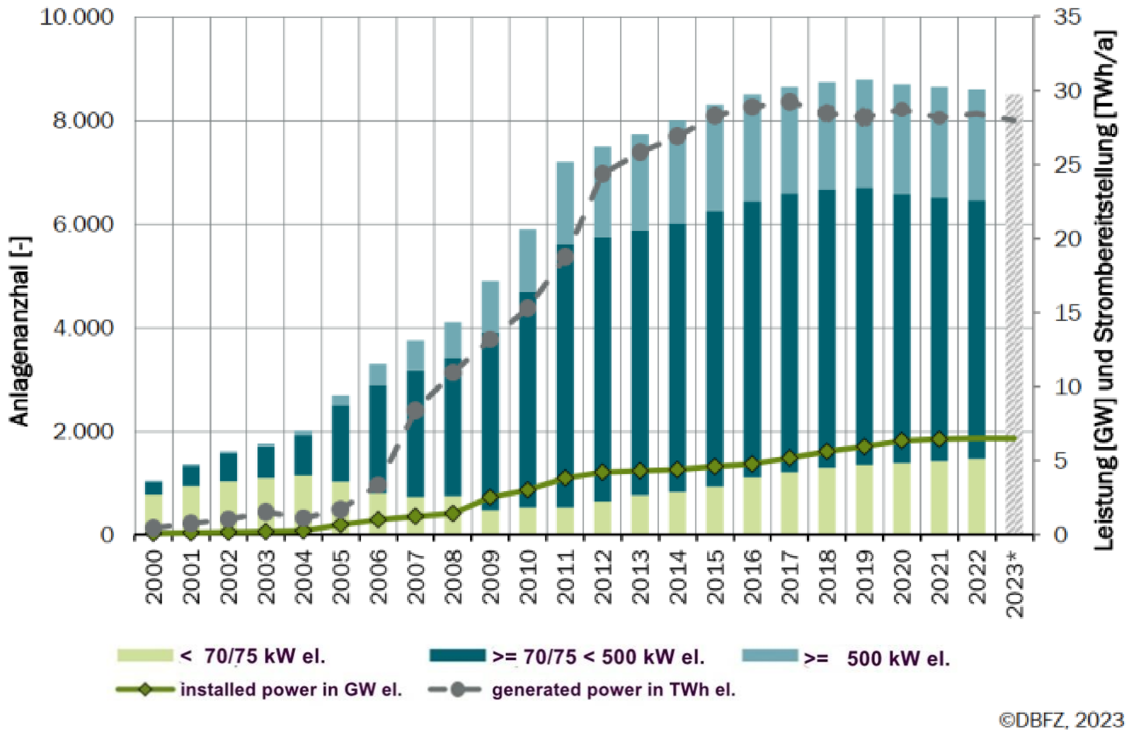

Figure 5: Stock of biogas plants in units, sorted by class of electrical power, development by year

An analysis of the steam reforming process shows that approximately 10 Nm³ of raw biogas is required to produce 1 kg of pure hydrogen. A 400 kW biogas plant requires approximately 200 Nm³/h of raw biogas (1 MW thermal output). This means that a typical standard biogas plant with a capacity of 400 kW supplies biogas for the production of 400 kg of hydrogen per day.

Hydrogen from biogas: commercial system BTH400

Figure 6 shows the standard system designed for this market. The developers believe that standardization is necessary to meet cost targets and ensure sufficient production capacity to meet the market's clearly substantial potential.

The system consists of three containers, is largely prefabricated at the factory, and is suitable for transport by road. On-site work is kept to a minimum. At full production capacity of 400 kg of hydrogen per day, the system requires 200 Nm³/h of biogas, 40 kW of electric power (primarily for the biogas compressor), and 3,200 liters of water per day.

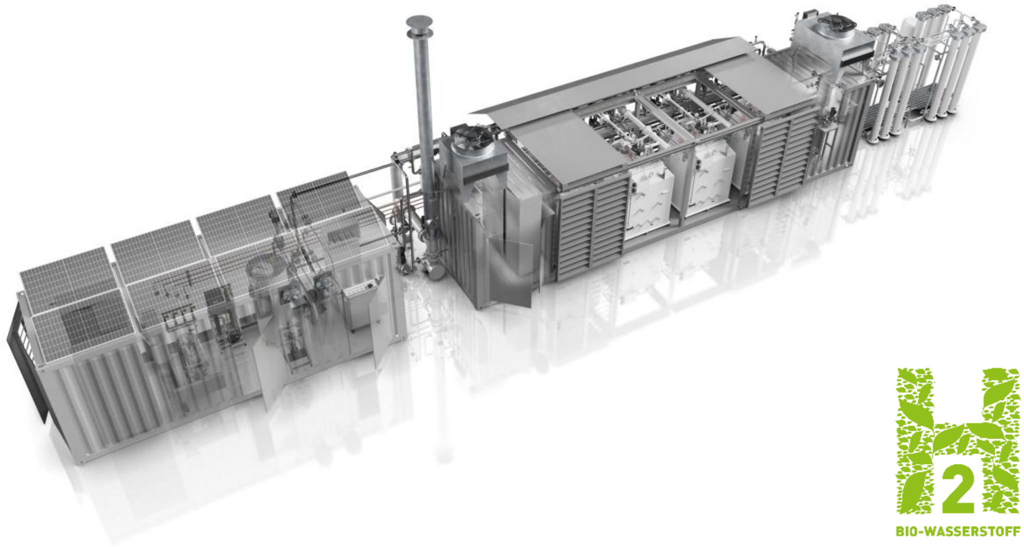

Figure 6 BTH400: Media supply (Container left), Reformer (Container middle), PSA (Skid right)

Biogas is available 24/7 and, provided the feedstocks are properly qualified and documented in accordance with RED II, is certified as “**ABF—advanced biofuel**.” The methodology is established; the additional revenue from GHG emissions trading ranges from €2 to €10 per kg of H2 at CO2 prices between €100 and €400 per ton of CO2. Similar figures apply to electrolytic hydrogen, which is certified and traded as “RFNBO” as long as the multiple counting is the same.

Comparison with electrolysis

If we examine the consumption figures for the steam reformer plant in detail and compare them with those for electrolysis, it becomes clear that:

1. The energy input per produced kg of hydrogen is similar, 50 kWh biogas or 50 kWh renewable electricity.
2. The water consumption of steam reforming is half as high: 50% of the hydrogen is generated thermochemically from water and 50% from the methane in the biogas.

Local hydrogen hubs: do local demand and production match?

With over 9,000 biogas plants in Germany, there are intuitively two opposing answers to this question. The first: Biogas plants are located in rural areas, where there is no demand. The second and opposing view: You will always find a biogas plant near demand.

To provide a more informed answer to this question, the authors commissioned a study from Fraunhofer ISE. The study was intended to examine a specific region in Germany as a case study and to develop a methodological approach. The Southern Baden region was an ideal choice for this purpose, as a demand assessment had already been conducted through local hydrogen networks and is largely transparent:

- What is the current status of biogas plants in the South Baden region?
- How is the local distribution of potential hydrogen demand?
- Could local demand be met, and what distribution logistics would be required?
- When will biogas plants face pressure to develop new business models after the 20-year EEG feed-in tariff expires?

The findings are intended to highlight potential business models for both biogas plant operators and regional customers. No filtering has yet been performed based on market price targets and specific production costs.

The methodology was rigorous and based on freely available data. It was grounded in mapped survey data on hydrogen demand, broken down by location and application [7]. In the next step, existing biogas plants—segmented by plant size (only plants larger than 350 kW_el were considered)—were added to the map using data from the market master data registry. The logistics concept developed in the BioH2Log project [10] demonstrates that regional distribution can be economically viable. In the study, we opted for a distribution radius of 10 km around the biogas site as a worst-case scenario and took planned larger electrolysis plants (>10 MW) into account. Finally, a temporal classification of the plants was performed following the expiration of the EEG feed-in tariff for the periods 2027–2030 / 2030–2035 / 2030–2024. When making investment decisions, it must be taken into account that these must be made several years in advance in order to build up the necessary reserves within the operation.

Conclusions:

Figure 7 shows the overall picture for the next 15 years (all existing biogas plants are covered by EEG subsidies).

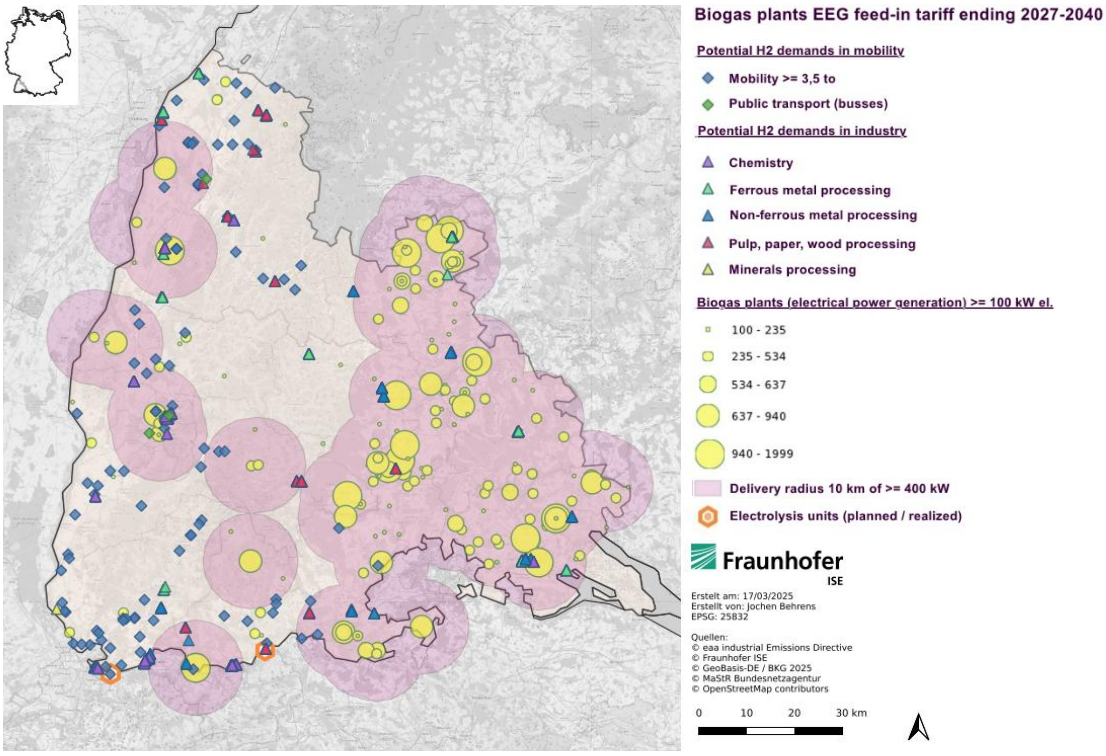

Figure 7: Existing biogas plants by size, with a 10-kilometer supply radius, and the local distribution of projected hydrogen demand.

The results can be summarized as follows:

1) The chemical industry cluster in the Basel area does not present an opportunity; moreover, demand is likely far greater than the relatively low typical production capacity (150 tons/year) of a single plant.
2) For medium-sized industrial companies requiring small quantities of over 50 kg, an economical delivery radius is achieved.
3) The density of biogas plants in the Upper Rhine region is somewhat too low. To meet demand, priority should be given to expanding the core hydrogen network and connecting it to the French pipeline in the south.
4) The Freiburg area and the eastern Black Forest are key regions in terms of demand; there are plenty of biogas plants and many small and medium-sized businesses in these areas
5) An H2 corridor along the A81 could likely be powered largely by biogenic hydrogen.

Similar maps were created to provide a short-term overview as a basis for establishing local hydrogen hubs. This provides a data foundation for counties, municipalities, biogas plant operators, and technology providers alike, enabling them to make project-based and strategically oriented decisions.

BioH2Log – Connecting local hubs via an intelligent distribution system at competitive prices

The goal of the BioH2Log [10] funded project is to develop and test an innovative, AI-supported process control system for the demand-driven and cost-effective production and distribution of hydrogen from biogas to regional customers. The project is being carried out under the leadership of TakeOff Engineering GmbH in close collaboration with BioH2Ref. The application focus is on the German market as well as relevant international markets that have a large existing stock of biogas plants or high potential for the installation of biogas plants. The innovative concept of BioH2Log is based on serving many regional customers with numerous decentralized biogenic hydrogen production facilities via a flexible storage and transport system at attractive prices (Figure 8). The vision of BioH2Log logistics, including the process chain and simulation, is shown in Figure 9. With this, the project partners are breaking new ground in the field of industrial gas production and gas distribution, which has previously been based on a relatively small number of larger production plants with corresponding logistics.

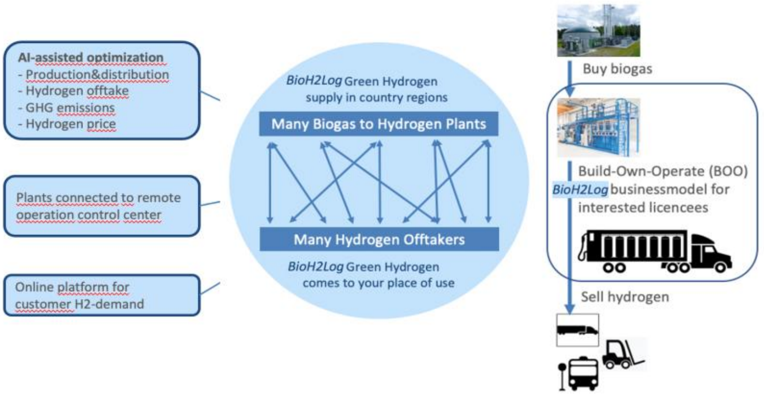

Figure 8: BioH2Log- Concept for the optimal management of biogenic hydrogen production and logistics

Figure 9: BioH2Log- Logistics Target Model with Process Chain and Simulation

The BioH2Log project is at an advanced stage, with hydrogen supply scenarios being categorized into “individual supply” and “cluster supply” and optimized using AI methods. While the analysis and calculation of supply scenarios in Germany have been completed, the focus is now on the relevant European hydrogen markets. Internationally, the North American and parts of the South American markets, as well as the Chinese and Indian markets, are being examined. Particular attention is being paid to the South Korean market, which currently has approximately 1,000 H2 buses. An additional 600 buses are planned for 2026, with the number of H2 buses expected to rise to 21,000 by 2030.

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