Large-scale Deployment of Modular Pressurized Alkaline Electrolysers
Path to a fossil free society
Demand for green hydrogen is surging, requiring significant scale-up of electrolysis capacity

**Estimated future demand for hydrogen in the EU**
From Dansk Energi. Hydrogen demand in million tonnes H₂

<table>
<thead>
<tr>
<th>Year</th>
<th>Grey/blue hydrogen</th>
<th>Green hydrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>2025</td>
<td>12-13</td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td>18-22</td>
<td></td>
</tr>
<tr>
<td>2050</td>
<td>65-70</td>
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</tr>
</tbody>
</table>

**Required electrolysis capacity to meet EU demand**
From Dansk Energi. Electrolysis capacity in GW

- In 2025, 6 GW is estimated to produce 1.5 million tonnes H₂, with price per kg H₂ estimated at 22.43 DKK/kgH₂ (~3.0 EUR/kgH₂) in 2025 which multiplied yields an expected market size of EUR ~4.5bn.
- In 2030, 80 GW is estimated to produce 20 million tonnes H₂, with price per kg H₂ estimated at 17.61 DKK/kgH₂ in 2030 (~2.4 EUR/kgH₂) which multiplied yields an expected market size of EUR ~47bn.

Notes: 1) EU-27; 2) EA Energianalyse (2020); 3) calculated from Dansk Energi (2020) (volume estimate) and EA Energianalyse (2020) (price estimates): 6 GW is estimated to produce 1.5 million tonnes H₂, price per kg H₂ estimated at 22.43 DKK/kgH₂ (~3.0 EUR/kgH₂) in 2025 which multiplied yields an expected market size of EUR ~4.5bn by 2025. In 2030, 80 GW is estimated to produce 20 million tonnes H₂, with price per kg H₂ estimated at 17.61 DKK/kgH₂ in 2030 (~2.4 EUR/kgH₂) which multiplied yields an expected market size of EUR ~47bn. 4) Recharge News – Gigawatt scale: the world’s largest 13 green-hydrogen projects (2020). 5) Goldman Sachs – Green Hydrogen – the next transformational driver of the Utilities industry (2020). Source: Dansk Energi – Anbefalinger til en dansk strategi for Power-To-X (2020); EA Energianalyse – Brint og PtX i fremtidens energisystem (2020); Recharge News – Gigawatt-scale: the world’s 13 largest green-hydrogen projects (2020).
Hydrogen electrolysis splits water into hydrogen and oxygen using electricity. If the electricity is derived from renewable energy sources, the produced hydrogen is considered green. The process of green hydrogen electrolysis is completely fossil-free, as the only by-product is oxygen and the power used in electrolysis is generated from renewable sources.
Platform system architecture and sub-systems

<table>
<thead>
<tr>
<th>System Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aux. systems</strong></td>
<td>• Core electrolyser technology supported by pressure equalising system and other BOP components</td>
</tr>
<tr>
<td></td>
<td>• Reliable technology with no stack issues since prototype launch in 2015¹</td>
</tr>
<tr>
<td><strong>BOP</strong></td>
<td>• Smart software control system, HyProManager™, under development by GHS</td>
</tr>
<tr>
<td></td>
<td>• Flow system consists of sourced components</td>
</tr>
<tr>
<td></td>
<td>• Altogether named BOP</td>
</tr>
<tr>
<td><strong>N2 purge system</strong></td>
<td></td>
</tr>
<tr>
<td><strong>H2O supply system</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Cooling system</strong></td>
<td></td>
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<tr>
<td><strong>Power supply</strong></td>
<td></td>
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<tr>
<td><strong>Flow system</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Monitoring &amp; control software</strong></td>
<td></td>
</tr>
</tbody>
</table>

¹ System architecture and mature subsystems working in unison enable a robust electrolyser platform.

GHS-developed system architecture

- Systems connected to the HyProvide™ rack (composed of the Balance of Plant (BOP) and stack)
- Compatible power supply system delivered by GHS
- Located on-site as part of a complete green hydrogen production system
GHS will realise LCOH reduction through initiatives across key cost factors focused on cost optimisation and output scale-up.

**GHS' LCOH reduction over time**

- **LCOH reduction initiatives across key cost factors**
  - **Initiatives**
    - **Cost-out actions**
    - **LCOH impact**
  - **Cost-out actions**
    - **LCOH impact**

**Year**
- 2021
- 2023
- 2025

**Table:**

<table>
<thead>
<tr>
<th>Year</th>
<th>Initiatives</th>
<th>Cost-out actions</th>
<th>LCOH impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>2021</td>
<td>A (Cost-out programme)</td>
<td>• Should-cost analysis, sourcing optimisation and design to cost</td>
<td>All cost factors</td>
</tr>
<tr>
<td>2023</td>
<td>B (Serial production)</td>
<td>• Optimisation of technology, design and processes to increase system suitability for serial production</td>
<td>CAPEX, other OPEX</td>
</tr>
</tbody>
</table>
| 2025 | C (Increased system energy efficiency) | • R&D to achieve higher system energy efficiency  
  i. System design for higher temperatures (higher efficiency per electric current density)  
  ii. Cell resistance reduction (reducing slope of linear part of efficiency curve) | Electricity |

**Graph:**

1. **A90**
2. **A120**
3. **X-Series**

**Legend:**
- **LCOH reduction**
- **Incremental cost optimisation**
- **Output scale-up**

**Notes:**
- LCOH (EUR/kg H₂)
- Model version upgrade
- System platform development

**Efficiency of HHV:**
- Current density, mA/cm²
- Temperature: Low, Medium, High

**Electricity:**
- CAPEX, other OPEX
- All cost factors
High system delivery pressure is an advantage as it affects versatility through efficiency and LCOH

Energy losses for the multi-stage mechanical compression of hydrogen

Compression losses as a fraction of hydrogen LHV (%)

Energy penalty for compressing from 1 to 30 bar is about 3.5% to 4% equivalent of hydrogen lower heating value

Source: IRENA analyses based on BNEF (2019)
Modular system design enables targeting of increasingly large projects

**Modular system design**

- Standardised and pre-tested "plug-and-play" electrolyser modules
- Quick and easy addition/installation of new modules on-site like building blocks
- Fully automated operation with minimal manpower requirements
- Modular in-a-box design allowing for clustered solutions and incremental project build-out
- Small footprint/MW consumption increasing number of applications

**Scalable and footprint efficient offering**

**Multi-MW projects**

- To be announced 2021
- 30 x A90
- 12 MW
- GHS electrolysers
- Electrolysis capacity

**Future GW-scale projects**

- X-Series ready for commercialisation in 2023
- Beyond 2025
- ~133 x 7.5MW
- GW scale
- GHS electrolysers
- Electrolysis capacity

**Increasingly large projects over time, delivering solutions with high efficiency per sqm.**
HyProvide X-series in a clustered version

**Dynamic utilisation**
Load balancing to achieve specified production output is critical when energy source is variable

**Automated redundancy**
Secure stable production if one unit is temporarily down

**Easy service and maintenance**
Production can continue during service and maintenance on specific parts

**Rapid system diagnostics**
Precise system diagnostics and problem-solving enabled by monitoring of individual units

**HyProManager™ software**
Enables control of individual units, clustered units and all units as a group, bringing ultimate flexibility

**Standardised & pre-tested modules**
Quick and easy to add/install new modules on-site like building blocks

**Illustrated clustered solution**

- max module power consumption
- daily hydrogen production
GreenHyScale

Project start: Oct. 2021 duration 5 years
Total budget: 53M€
Funding: 30M€

Key milestones
Nov 22: Prototype operational at GreenLab Skive
Oct 23: Go/No Go milestone
Oct 24: 100 MW fully operational At GreenLab Skive
Nov 25: First operation of high-pressure 7.5 MW electrolyser at GreenLab Skive

100 MW installation at GreenLab Skive
GreenHyScale concept

Figure 2: GreenHyScale concept scheme
GreenLab Skive
GreenLab Skive Energy Park – SymbiosisNet™
A National Test Zone for Integrated Energy and Open Innovation

SymbiosisNet™

Industrial Cluster

Electrolysis

Synthesis

Proces industry, Biogas, Pyrolysis, Proteins, Fiberboard, Waste handling

O₂ Oxygen

N₂ Nitrogen

H₂ Hydrogen

+CO₂ Carbon dioxide

+N₂ Nitrogen

Green products

H₂ Hydrogen

NH₃ Ammonia

CH₄ Methanol

CH₄ Methane

Jetfuel

Naphtha

Proteins

Transport
Agriculture
Industry
Materials
Food
Energy

Digital Optimization Platform

TSO connection

HV transformer

Storage-Chemical Thermal CCU

Heat-Dam Storage

Heat upgrading

Waterprocessing

CO₂ Carbon dioxide

O₂ Oxygen
Local infrastructure

Unique location

We are close to national gas and electricity grids as well as Batum Salt Cavern for potential seasonal storage.
Thank you
Why choose our electrolysers?

Selected technological benefits
- Builds on mature and commercially proven pressurised alkaline technology
- Flexible with ability to handle variable loads suitable for renewable energy
- High efficiency (HHV) and system delivery pressure (bar)
- Modular and versatile solutions that are suited for scale-up and serial production
- Significant cost-out potential

Selected commercial benefits
- “Plug-and-play” units with modular in-a-box design allowing for clustered solutions
- Small footprint due to compact modular design increasing number of applications
- Fully automated operation with minimal manpower requirements
- Standardised and pre-tested components and design for lower S&M costs
- High durability (10+ year stack durability) and system uptime

Notes: 1) GHS’ HyProManager smart control system is currently under development
Source: Company information
One of the most efficient pressurised alkaline electrolysers on the market

HyProvide™ A-Series

<table>
<thead>
<tr>
<th>Power consumption (kW)</th>
<th>A30</th>
<th>A60</th>
<th>A90</th>
<th>A120</th>
<th>A150</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>150</td>
<td>300</td>
<td>450</td>
<td>600</td>
<td>750</td>
</tr>
</tbody>
</table>

HyProvide™ X-Series

<table>
<thead>
<tr>
<th>Power consumption (kW)</th>
<th>X-versions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 – 7,500</td>
</tr>
</tbody>
</table>

Ancillary solutions and supporting services

- Containerised solutions for rapid installation and deployment
- Installation and engineering services
- Global Service and Maintenance for installed units
Solution for every scale

**HyProvide™ A-Series**
Containerised solution

- 1 MW
- 2x A90
  (total A90 max module power consumption of 450 kW)

20-foot or 40-foot containers comprising 1-2x A90
(includes auxiliary systems) or factory floor solution

**HyProvide™ X-Series**
Containerised solution

- 6 MW

Upcoming 40-foot container comprising 1x X-Series
(excludes auxiliary systems) or factory floor solution
Green Hydrogen Systems is a leading provider of **alkaline electrolyzers**. Our technology is required to build an energy supply system solely based on renewable energy - and we are committed to help our customers **decarbonise their operations** and increase their independence from fossil-fuels through onsite production of green hydrogen.
Ongoing scale-up of production expansion

**Suppliers**
Robust supplier base in place, allowing for efficient scaling of production input

**GHS production**
Facilities for both assembly and manufacture need to scale continuously

**Customers**

Nordager (Kolding) production site

New production facilities inaugurated in November 2020; 6x larger than previous site

Will go through expansion in multiple phases

Estimated to be able to reach total capacity of more than 1,000 MW p.a. with further facility expansion

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**Nordager site**
4,500 m²
(of which ~2,000 m² admin)

2021 year-end run-rate capacity could triple by introducing additional production shifts

75 MW p.a. ▶▶ 150 MW p.a.

The Company expects to expand its facilities ahead of reaching maximum capacity, making it unlikely that production output will be limited by the above estimates

**Expansion potential**
30,000 m²
(acreage availability)

+1,000 MW p.a.
(estimated potential based on full expansion of facilities)²

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The Nordager production site is designed to be a standardised factory blueprint for establishing potential additional production sites

New production sites to be considered if commercially substantiated by order pipeline
The versatile design of our solutions allows for application across many different market segments for green hydrogen production. Below selected customer cases.