StormGeo

Part of Alfa Laval

THE FUTURE OF POWER - MARKET OUTLOOK 2050

RENEWABLES

SPRING 2024

SAMPLE

Contents

Carbon Capture and Sequestration (CCS)

- What it is: Technologies to capture CO2 from emissions (usually using chemicals) and store it safely.
- How it works (main method):
  - » Amine gas treating: A liquid traps CO2 from the emissions.
  - » Heating separates the CO2, which is then stored (often injected deep underground).
- CCS in Europe:
  - » Norway is a leader, with projects like Northern Lights aiming to capture, transport, and store CO2 at scale.
- Impact on Blue Hydrogen: CCS is what makes hydrogen "blue" (low carbon). The cost of CCS is a major factor in the price of blue hydrogen, along with natural gas prices.
- Uncertainty: There's still uncertainty about the long-term costs of CCS, both for the capture process and the transportation/storage.

Blue Hydrogen: Capital Expenditure (CAPEX) and Operational Expenditure (OPEX) Analysis

CAPEX

The capital expenditure (CAPEX) of blue hydrogen production has two main components: the steam methane reforming (SMR) plant and the carbon capture unit (CCU). SMR is a mature technology, so its capital costs are relatively stable and range from 800-900 € per kilowatt of hydrogen (kW H2) in Europe. The CCU offers more potential for cost reduction through innovation and economies of scale. Currently, adding carbon capture increases CAPEX by 60-70%, but this is expected to decrease as CCU technology improves. For long-term cost projections, we align with the International Energy Agency's (IEA) expectations of a 9% CAPEX reduction by 2030 and a 15% reduction by 2050.

OPEX

Blue hydrogen's operational costs (OPEX) include operation and maintenance, fuel (natural gas), and CO2 management. Since 90% of CO2 emissions are captured, the main CO2-related cost comes from transportation and storage, with the remaining 10% subject to European Union Allowance (EUA) pricing. Transportation and storage costs are uncertain and estimates range from 15-55 € per ton of CO2. We assume a standardized cost of 20 € per ton of CO2 for our analysis. Operation and maintenance costs are fixed at 4.7% of the initial investment annually.

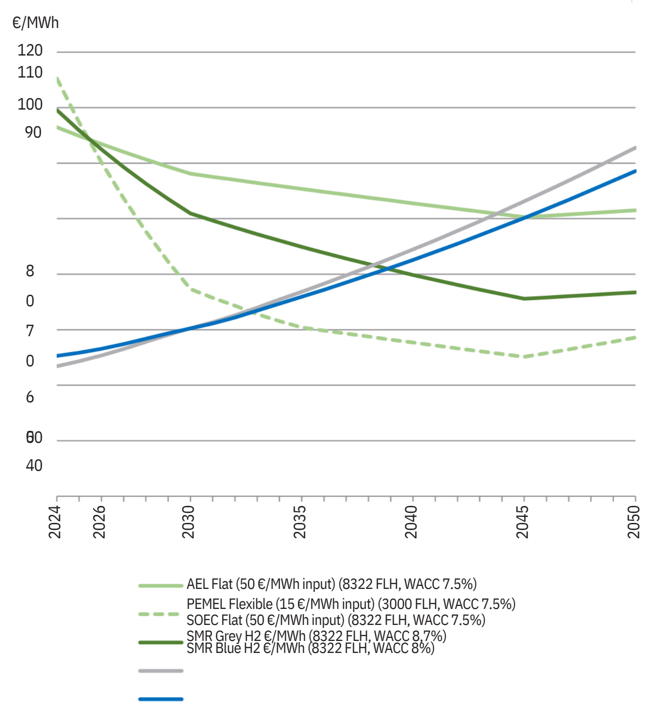
Load Hours/Operation Time

We assume a 95% load factor (8,322 hours per year) and a 25-year operational lifetime for a blue hydrogen plant.

LRMC Analysis and the Competitiveness of Green Hydrogen

We've calculated the long-run marginal cost (LRMC) for different hydrogen production technologies from 2022 to 2050, taking into account CAPEX trends and load hours. The figure below compares the LRMCs of steam methane reforming (SMR), with and without carbon capture and storage (CCS), alongside alkaline (AEL), proton exchange membrane (PEM), and

LRMCs green vs grey and blue



Source: StormGeo Nena Analysis

Hydropower in the Nordic Region: Potential, Costs and Prospects

Hydropower is a cornerstone of the Nordic energy landscape, accounting for a remarkable 50% of the region's total electricity output on average. This is largely driven by the extensive hydropower resources in Norway and Sweden. While the construction of large new hydropower projects has slowed in recent years, efforts are underway to modernize and optimize existing plants. These enhancements aim to increase efficiency and flexibility, ensuring hydropower remains a vital asset for grid balancing as other renewable energy sources continue to grow.

Overall, hydropower remains a cornerstone of the Nordic energy mix. Continued optimization and its ability to provide on-demand power make it crucial for a reliable and increasingly renewable energy system.

While hydropower remains important, finding economically feasible new projects is increasingly challenging due to competition from wind, solar, and emerging storage technologies. Sweden faces environmental constraints on further expansion, but Norway has untapped potential in upgrading existing facilities and developing small-scale hydropower.

Overall, some potential hydropower investments may struggle to compete with the falling costs of wind and solar. However, we anticipate a significant increase in small-scale hydropower development in Norway by 2050.

Hydropower projects under construction

Owner/Developer	Name	Type of investmentArea	GWh	COD	MW	FLH	Indicative LCOE €/MWh
Eviny Fornybar As	Tverrelvi kraftverk	New hydro > 25MWNO5	26.4	11/24	9.8	2694	45
Feios Kraftverk As	Feios kraftverk	New hydro > 25MWNO3	98.0	03/25	28.8	3403	48
Kilandsfoss As	Kilandsfoss kraftverk	New hydro > 25MWNO2	40.0	03/26	7.6	5263	40
Småvoll Kraftverk As	Småvoll kraftverk	New hydro > 25MWNO3	40.0	02/25	15.7	2548	45
Småkraft As	Dalaåna kraftverk	New hydro > 25MWNO2	37.2	08/24	9.9	3758	41
Lyse Produksjon As	Maudal Nedre kraftverk	Upgrade NO2	50.0	10/24	8.5	5882	35
Godfarfoss Kraft As	Godfarfoss kraftverk	New hydro > 25MWNO5	54.0	06/24	16.0	3375	48
Statkraft Energi As	Rana	Upgrade NO4	37.5	06/24	15.0	2500	50
Sunnhordland Kraftlag As	Løkjelsvatn	Upgrade NO2	163.0	06/24	60.0	2717	50
Hydro power under construction/FID			**546.1**				
Expected Projects <25 GWh			**380.266**				
Total Capacity Under Construction (GWh)			**926.366**				

Source: StormGeo Nena Analysis

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This document is part of the

StormGeo The Future of Power - Market Outlook 2050.

For the latest version of the Outlook, please contact us.

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