HYDROGEN TO MAGNUM H2M

European Turbine Network

Bucharest 2018.03.14

Geert Laagland – Head of Engineering – BA Heat – OU Heat Projects

VATTENFALL

PURPOSE STATEMENT

As Vattenfall we exist to:

POWER

… 100% free from using fossil fuel throughout the entire value chain of energy production in one generation

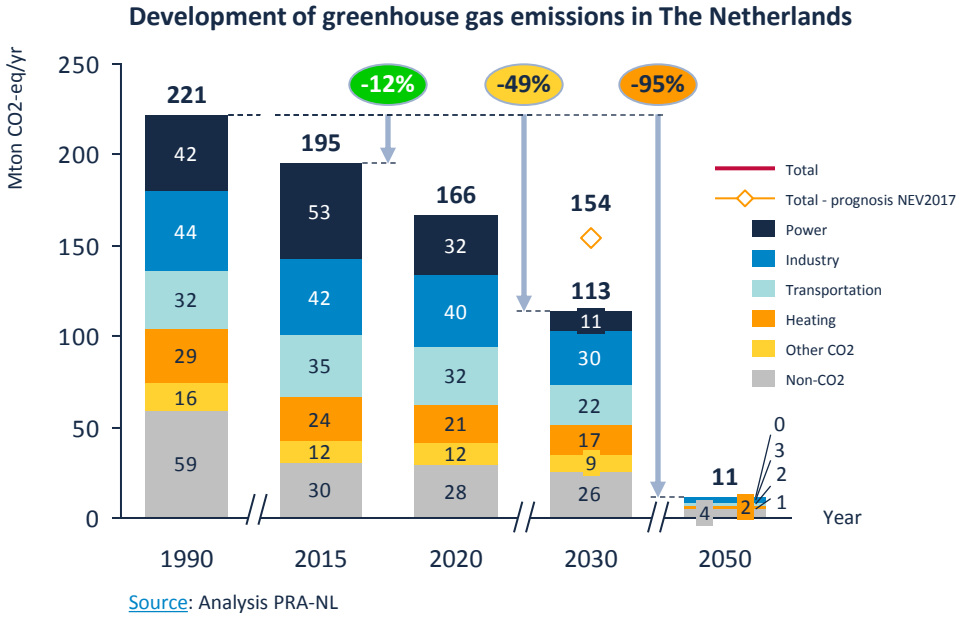
CLIMATE SMARTER

… using the word "smarter" indicates continuous improvements

LIVING

… for everyone; a way of working, a way of living today and for the future

TOWARDS A CO_2-FREE ENERGY SYSTEM IN THE NETHERLANDS



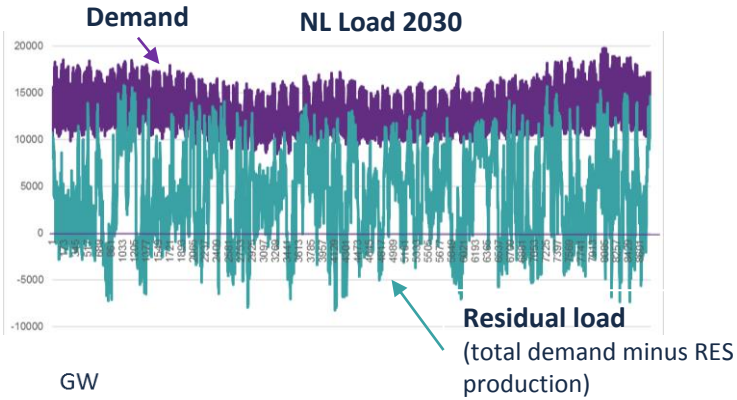
Source: Analysis PRA-NL

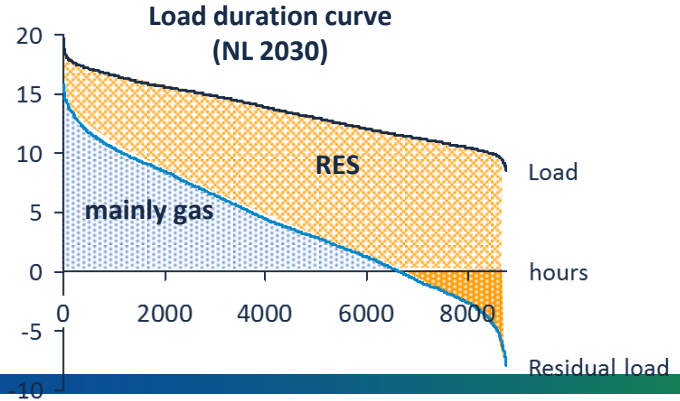
Key challenges:

- Fast CO_2-emission reduction required in all sectors
  - Power sector: 50-75% reduction in 2030; carbon free before 2050
- Integration of strongly increasing amounts of wind and solar in the energy system
  - Requirement for flexible capacity
  - Requirement for large-scale energy storage
- Availability of CO_2-free energy in NW-Europe

Transition to a hydrogen based economy is a possible solution

GAS PLANTS WILL OPERATE IN THE FAR MAJORITY OF HOURS, EVEN WITH HIGH AMOUNTS OF RES INSTALLED

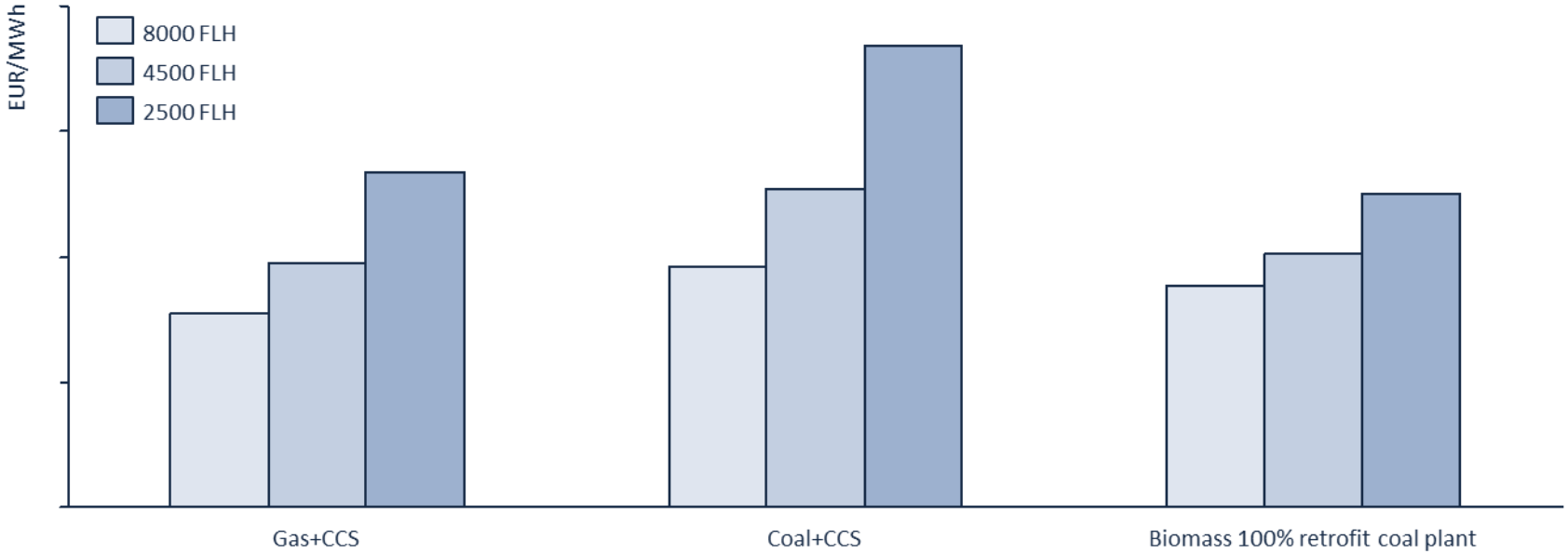




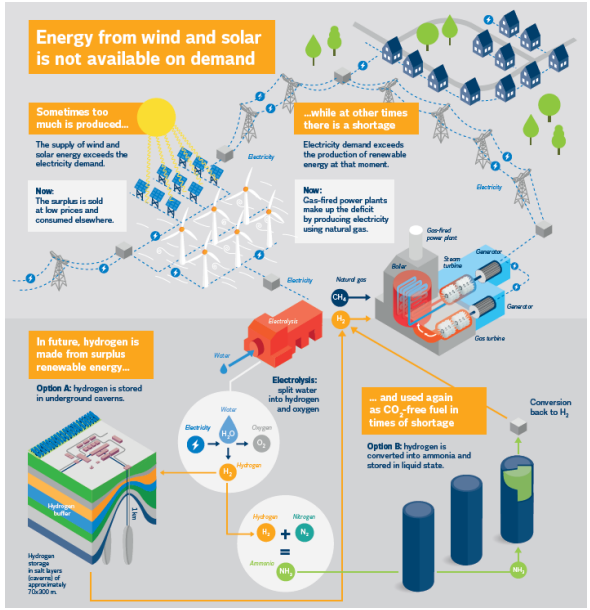
- Even with high amounts of RES in the system, in the far majority of hours a residual load remains
  - As coal will be phased out after 2030, it will be mostly gas plants that will serve this load
- The resulting CO_2 emission for the electricity sector is ca. 20 Mton/yr in 2030
  - This is a 55% reduction (Ref: 1990), and the lower limit of required emission reduction for the power sector
- In order to meet deeper emission reductions, emissions of gas plants must be reduced:
  - Post-combustion CCS is disqualified as an option due to high costs at reduced amount of FLH and continued dependence on fossil fuels
  - H_2-firing is a solution, offering important synergies in the energy system

LCOE ANALYSIS BASED ON TODAY'S MARKET PRICES

Dispatchable CO_2 free technologies



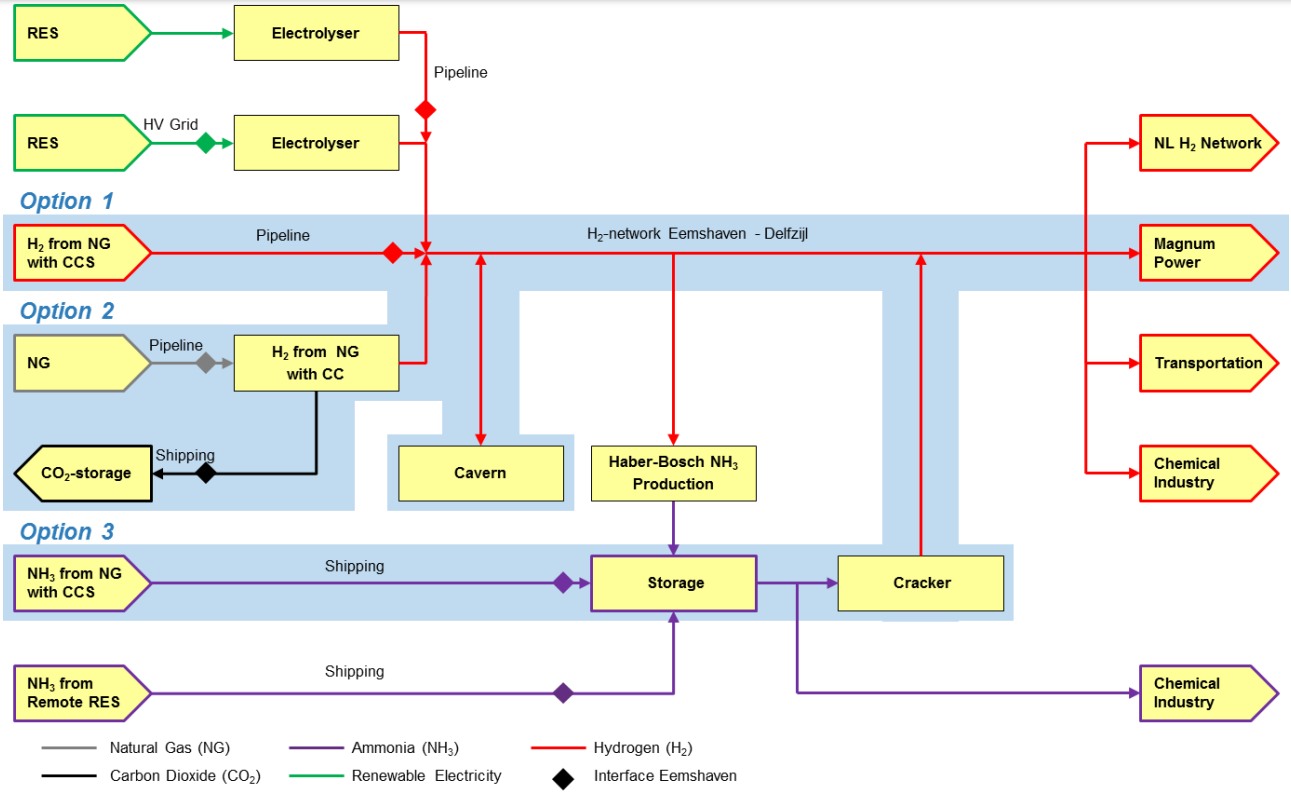
Our vision: Magnum as a superbattery



- 3x MHPS 701F4 gas turbine combined cycles (CCGT)
- Output 3x437 MW_e, (2 million households)
- State of the art, year of commissioning 2013
- Flexible (daily start/stop) and high efficient
- Good logistic options (seaways)
- Excellent grid connection (2x1400 MW_e, 380 kV)
- Engineered for coal gasification (declined) and so:
  - Multi fuel turbines
  - 45 ha plant area, 40% occupied
  - Oversized $DeNO_x$

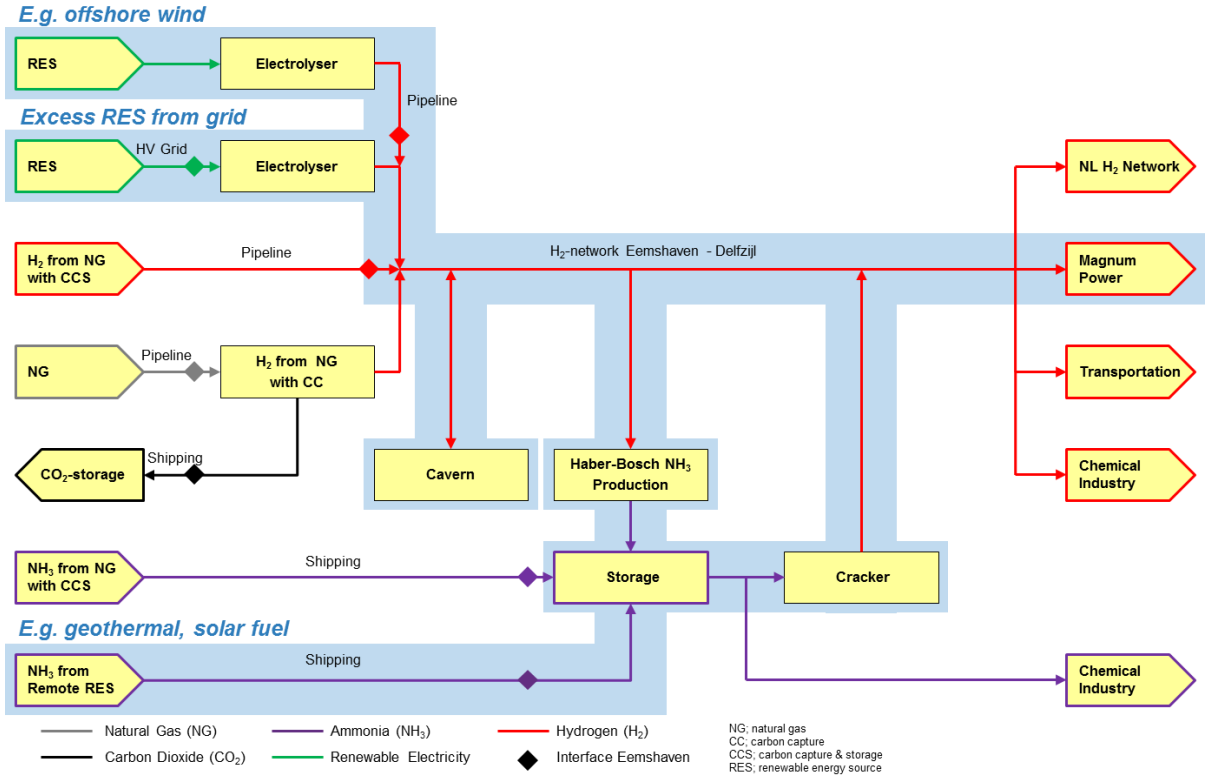
VATTENFALL

BLUE HYDROGEN VALUE CHAINS



VATTENFALL

Future Green Hydrogen Value Chains



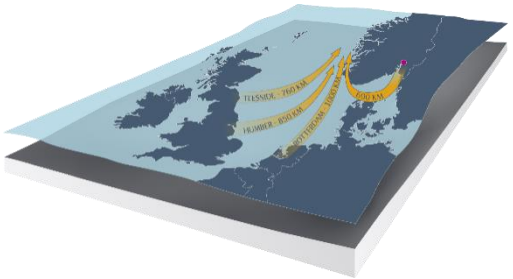
VATTENFALL

COOPERATING WITH OTHER PARTIES IS KEY TO SUCCESS

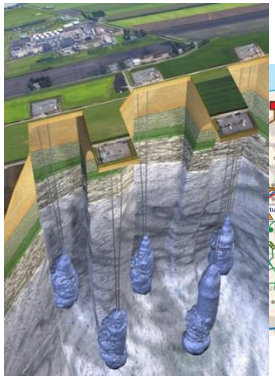
Statoil

gasunie

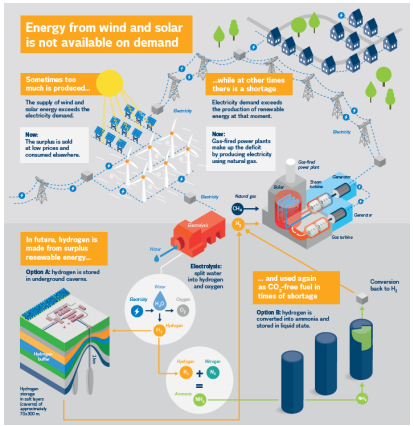
NUON



Source picture: Statoil



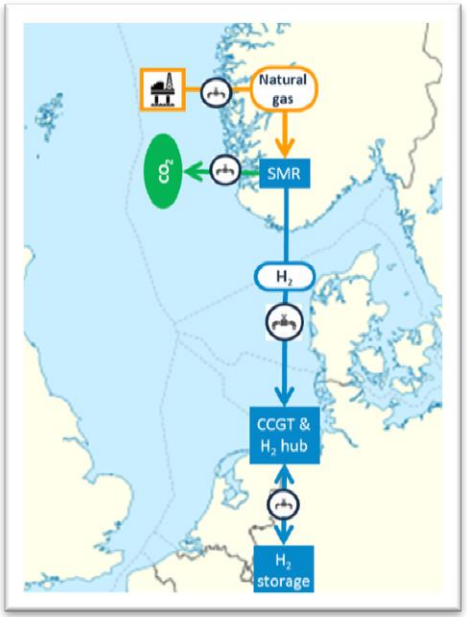
Source pictures: Gasunie



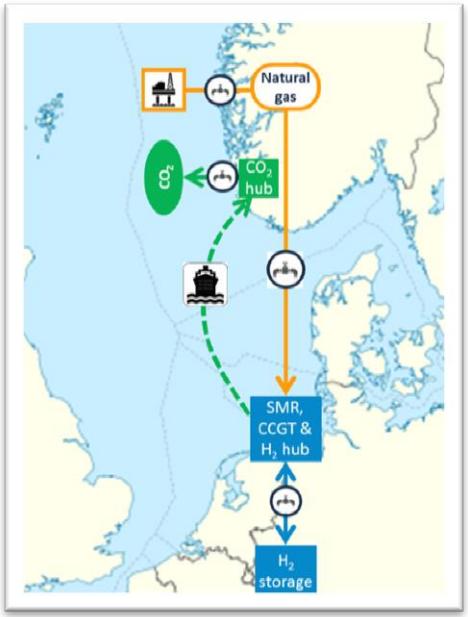
VATTENFALL

SUPPLY OPTIONS H_2 FROM CH_4 + CCS

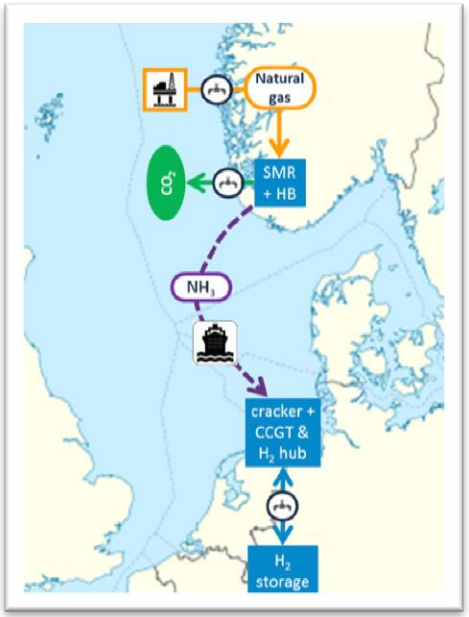
Option 1:
H_2 production in Norway



Option 2:
H_2 production in NL

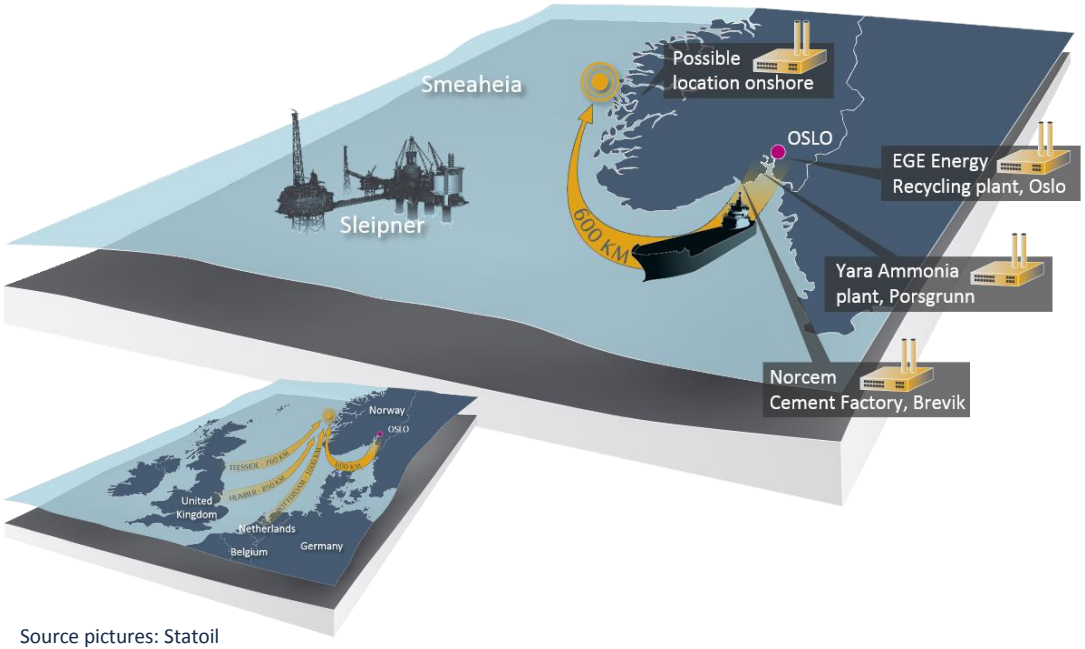


Option 3:
NH_3 production in Norway



VATTENFALL

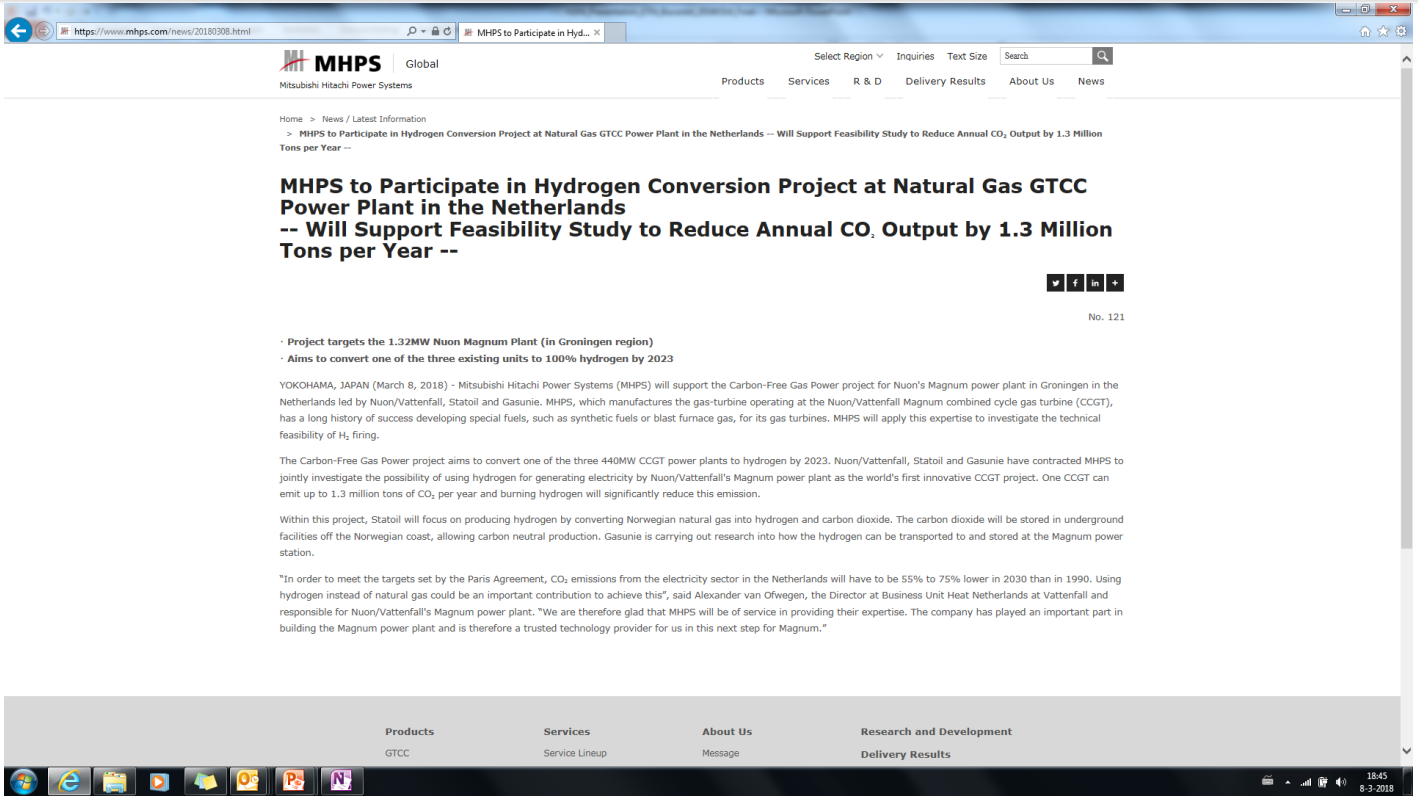
CO2 TRANSPORT AND STORAGE – NORWEGIAN CCS PROJECT



Source pictures: Statoil

- CO_2 storage is foreseen in a saline aquifer on the Norwegian Continental Shelf
- Norwegian CCS project is driven by Norwegian Ministry of Petroleum and Energy and coordinated by Gassnova
  - Statoil has been awarded contract to develop storage scope Project is in development, FID planned for 2019
- Storage complex has sufficient capacity to store Magnum volumes

INVOLVEMENT OF THE OEM - HTTPS://WWW.MHPS.COM/NEWS/20180308.HTML



MHPS Global
Mitsubishi Hitachi Power Systems

Select Region | Inquiries | Text Size | Search

Products | Services | R & D | Delivery Results | About Us | News

Home > News / Latest Information
> MHPS to Participate in Hydrogen Conversion Project at Natural Gas GTCC Power Plant in the Netherlands -- Will Support Feasibility Study to Reduce Annual CO_2 Output by 1.3 Million Tons per Year --

MHPS to Participate in Hydrogen Conversion Project at Natural Gas GTCC Power Plant in the Netherlands -- Will Support Feasibility Study to Reduce Annual CO_2 Output by 1.3 Million Tons per Year --

No. 121

- **Project targets the 1.32MW Nuon Magnum Plant (in Groningen region)**
- **Aims to convert one of the three existing units to 100% hydrogen by 2023**

YOKOHAMA, JAPAN (March 8, 2018) - Mitsubishi Hitachi Power Systems (MHPS) will support the Carbon-Free Gas Power project for Nuon's Magnum power plant in Groningen in the Netherlands led by Nuon/Vattenfall, Statoil and Gasunie. MHPS, which manufactures the gas-turbine operating at the Nuon/Vattenfall Magnum combined cycle gas turbine (CCGT), has a long history of success developing special fuels, such as synthetic fuels or blast furnace gas, for its gas turbines. MHPS will apply this expertise to investigate the technical feasibility of H_2 firing.

The Carbon-Free Gas Power project aims to convert one of the three 440MW CCGT power plants to hydrogen by 2023. Nuon/Vattenfall, Statoil and Gasunie have contracted MHPS to jointly investigate the possibility of using hydrogen for generating electricity by Nuon/Vattenfall's Magnum power plant as the world's first innovative CCGT project. One CCGT can emit up to 1.3 million tons of CO_2 per year and burning hydrogen will significantly reduce this emission.

Within this project, Statoil will focus on producing hydrogen by converting Norwegian natural gas into hydrogen and carbon dioxide. The carbon dioxide will be stored in underground facilities off the Norwegian coast, allowing carbon neutral production. Gasunie is carrying out research into how the hydrogen can be transported to and stored at the Magnum power station.

"In order to meet the targets set by the Paris Agreement, CO_2 emissions from the electricity sector in the Netherlands will have to be 55% to 75% lower in 2030 than in 1990. Using hydrogen instead of natural gas could be an important contribution to achieve this", said Alexander van Ofwegen, the Director at Business Unit Heat Netherlands at Vattenfall and responsible for Nuon/Vattenfall's Magnum power plant. "We are therefore glad that MHPS will be of service in providing their expertise. The company has played an important part in building the Magnum power plant and is therefore a trusted technology provider for us in this next step for Magnum."

Products: GTCC
Services: Service Lineup
About Us: Message
Research and Development: Delivery Results

VATTENFALL

Key benefits of the use of Hydrogen in CCGTs

- Direct significant reduction of CO_2 emissions (Mton/a) in The Netherlands by replacing CO_2 emitting fossil fuel by CO_2 neutral fuels
- Facilitating integration of wind and solar capacity in the energy system by means of flexible capacity
- Optimal use of already existing capacity of natural gas fired power stations
- Catalyst for a H_2 based economy, facilitating transition to CO_2 neutral fuels and feedstocks in other sectors (industry, transport and heating)
- Technology fitting in the end objective: facilitating the growth of a CO_2-free H_2 economy and facilitating the feed-in of H_2 from renewable sources in time within the same system


THANK YOU FOR YOUR ATTENTION!
VATTENFALL