

Hydrogen Production from Biogas by Sorption-Enhanced Steam Methane Reforming (SE-SMR)

Demonstration of the Novel Process at the
HyNor Lillestrøm Hydrogen Station

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Outline

- The HyNor project
- The HyNor hydrogen station at the city of Lillestrøm
- The Sorption-Enhanced Steam Methane Reforming process (SE-SMR) for hydrogen production with integrated CO₂-capture
- The SE-SMR pilot unit planned at the Hynor Lillestrøm station



www.hynor.no

The HyNor project

The hydrogen “highway” in Norway



- Demonstration of hydrogen production technologies for the introduction of hydrogen as transportation fuel in Norway
- Make possible driving between the cities of Oslo and Stavanger with hydrogen vehicles

- Sweden, Danmark and Germany also have similar hydrogen road projects
 - Hydrogen Sweden
 - Hydrogen Link
 - Clean Energy Partnership (CEP)



The HyNor Lillestrøm project

www.hynor.no/romerike

<http://hynor-lillestrom.no>



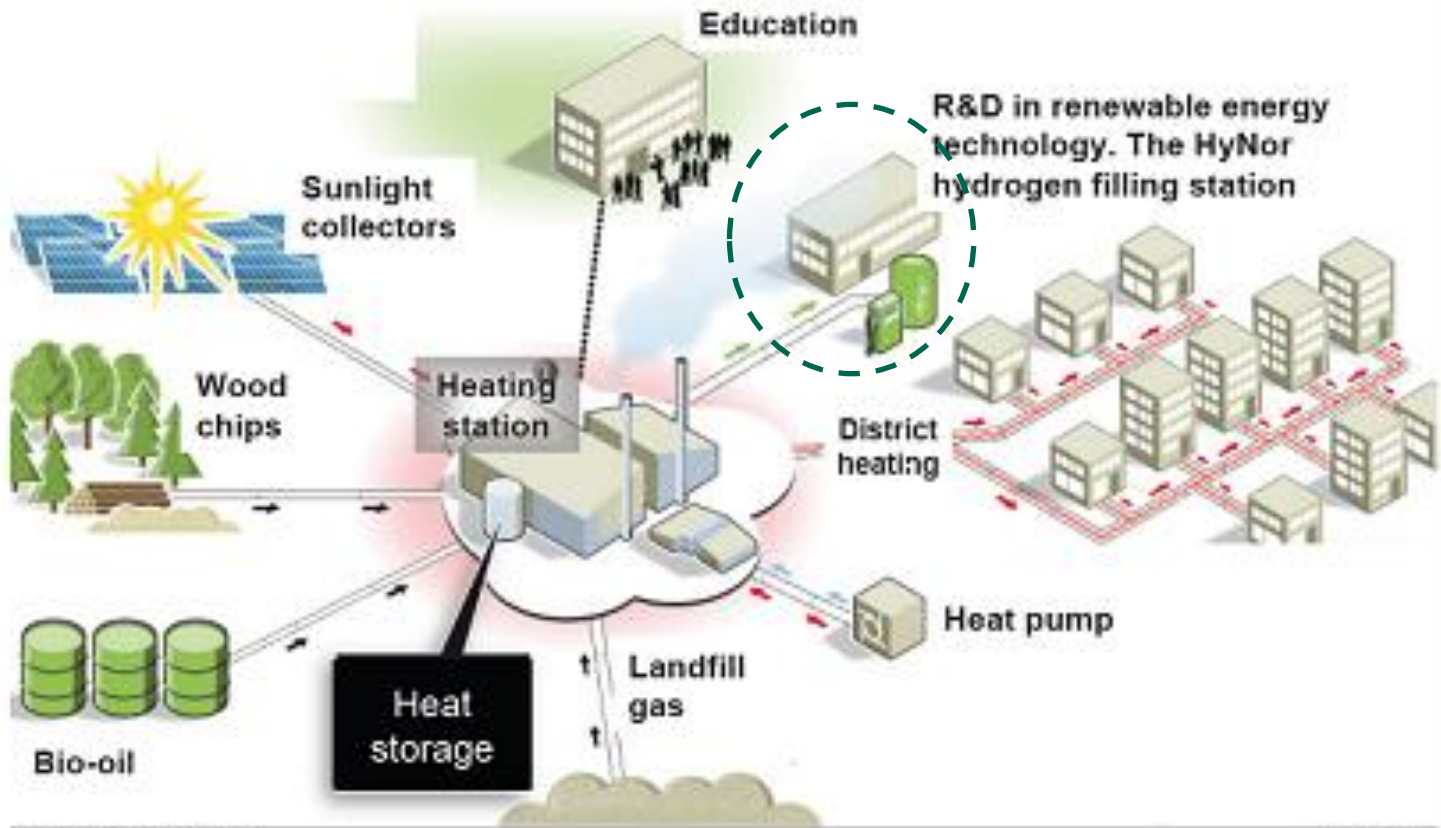
- Hydrogen production based on renewable energy
 - From landfill gas produced at a nearby landfill and transported by pipe to the station
 - From electrolysis using power from the grid and from photovoltaic panels installed at the station
- Hydrogen compression to 700 bar
 - Conventional mechanical compression
 - Demonstration of a metal hydride compressor delivering at 200 bar
- On-site hydrogen delivery (dispenser)
- Hydrogen vehicles fleet: 4 Think Hydrogen

Project participants and financing

- Hynor Lillestrøm AS: project owner
- Institute for Energy Technology (IFE): project leader
- Akershus Energi AS: building and infrastructure
- Technology suppliers
 - IFE: Reformer unit and system integration
 - HyGear: Landfill gas upgrader and hydrogen purification
 - H2-Logic: Electrolyzer, compression & storage system, dispenser
 - Hystorsys: Metal hydride compressor
 - Scandpower AS: Risk analysis and safety
- Financed by
 - Akershus County (Akershus Fylkeskommune)
 - Research Council of Norway through the Renergi-program
 - Transnova (governmental trial funding program)
 - Innovation Norway

Akershus Energy Park

- energy, research, education



Source: Akershus Energi

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<http://www.aeas.no/pages/akershus-energipark>

The Akershus Energy park



2009

2010

Last
quarter
of 2011

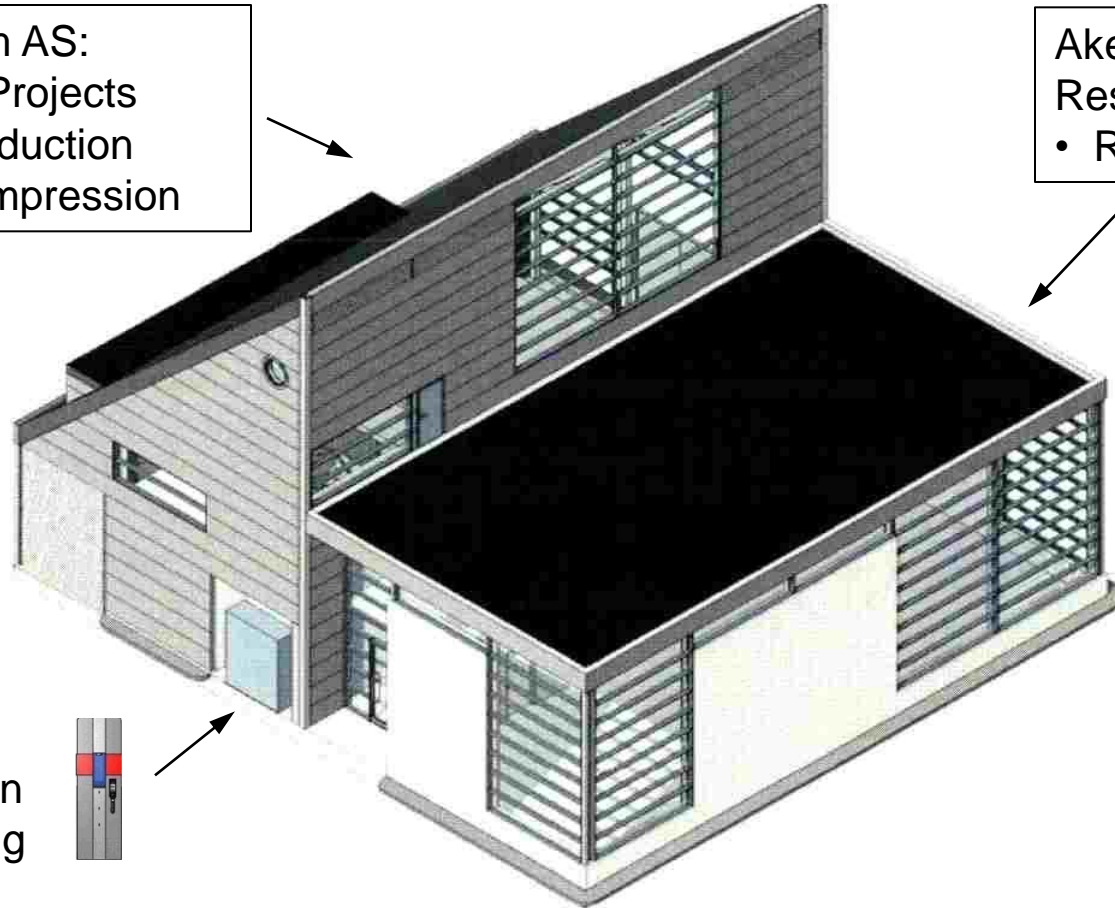
The HyNor building and hydrogen station

HyNor Lillestrøm AS:
Demonstration Projects

- Hydrogen Production
- Hydrogen Compression

Akershus Energy AS:
Research Projects

- Renewable Energy



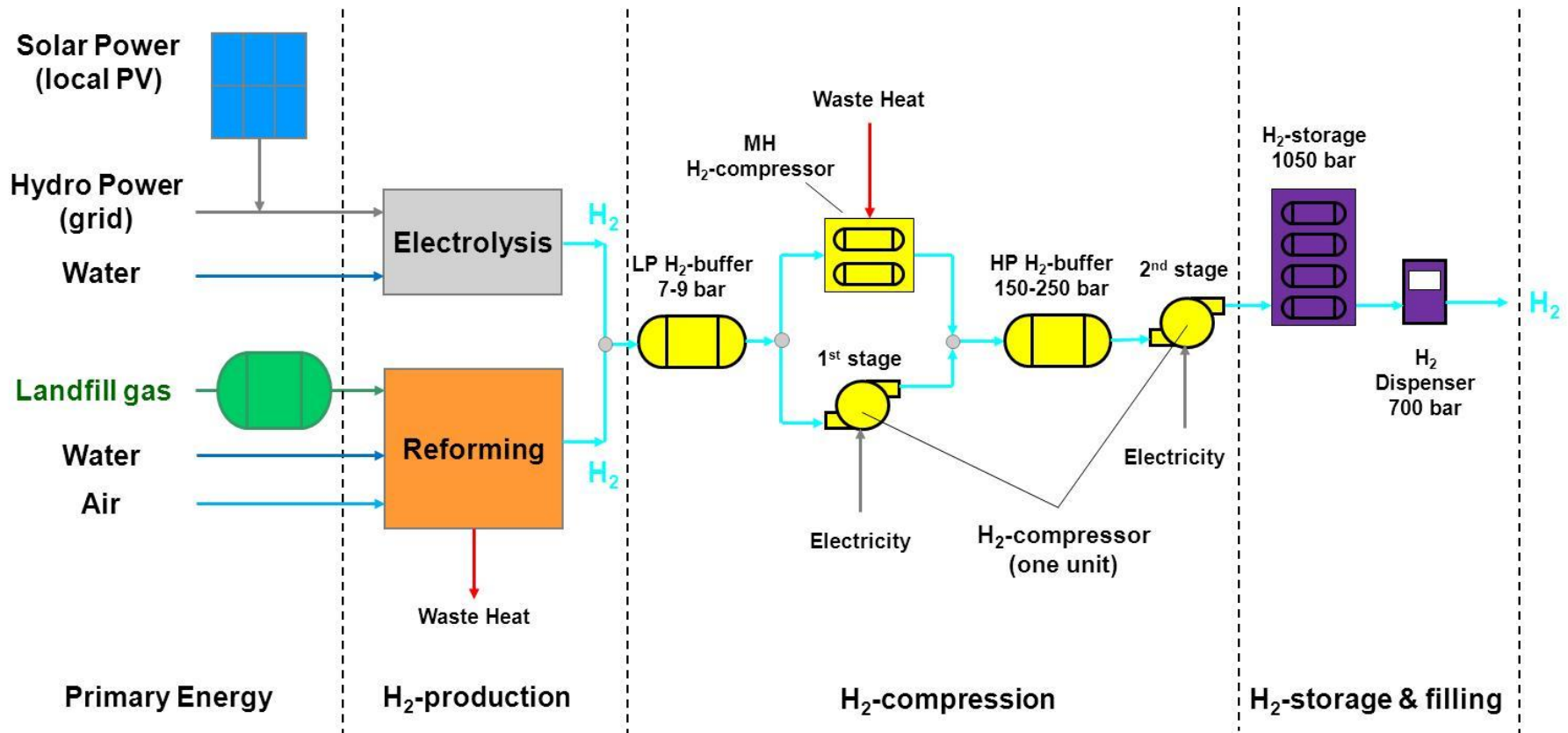
Hydrogen
Refuelling



Hydrogen
Fuel Cell Vehicles

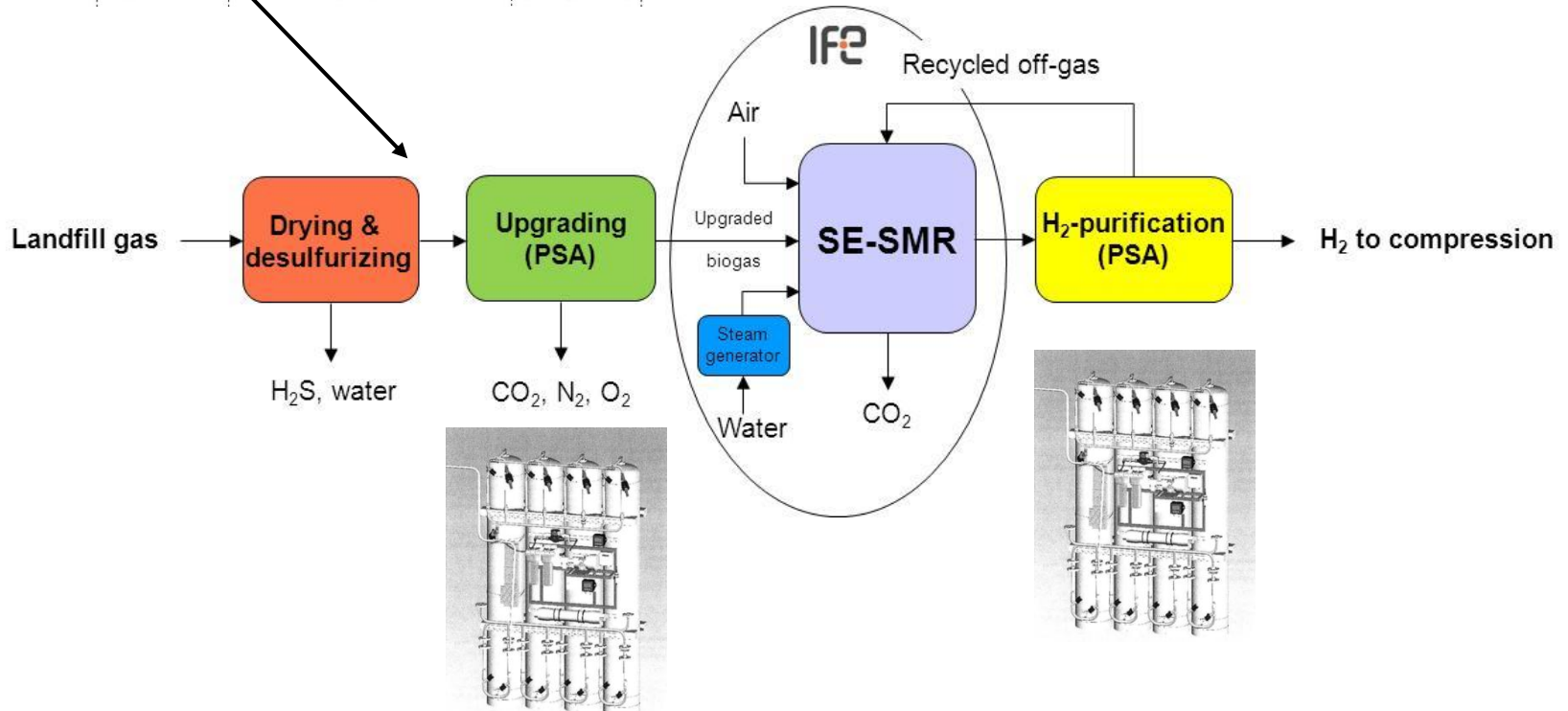
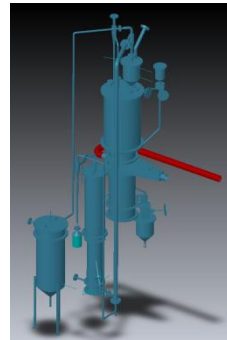
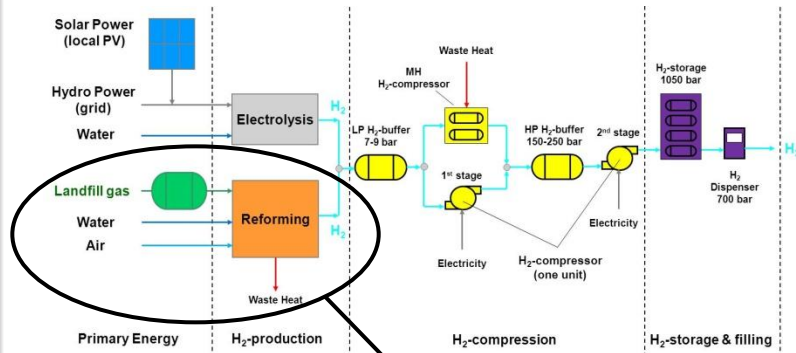


HyNor Lillestrøm System Concept



- Production capacity
 - 10 Nm³/h H₂ from the electrolysis line
 - 10 Nm³/h H₂ from the reforming line
 - Purity of 99.99% minimum

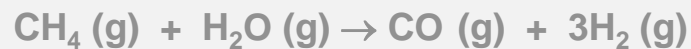
The reformer unit



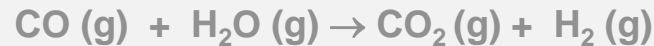
Sorption enhanced steam methane reforming

H₂-production with integrated CO₂-capture in one single step

Reforming



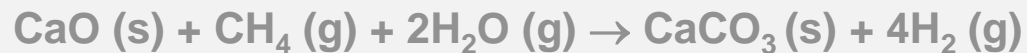
Water gas shift



Carbonation



Total reaction (SE-SMR)

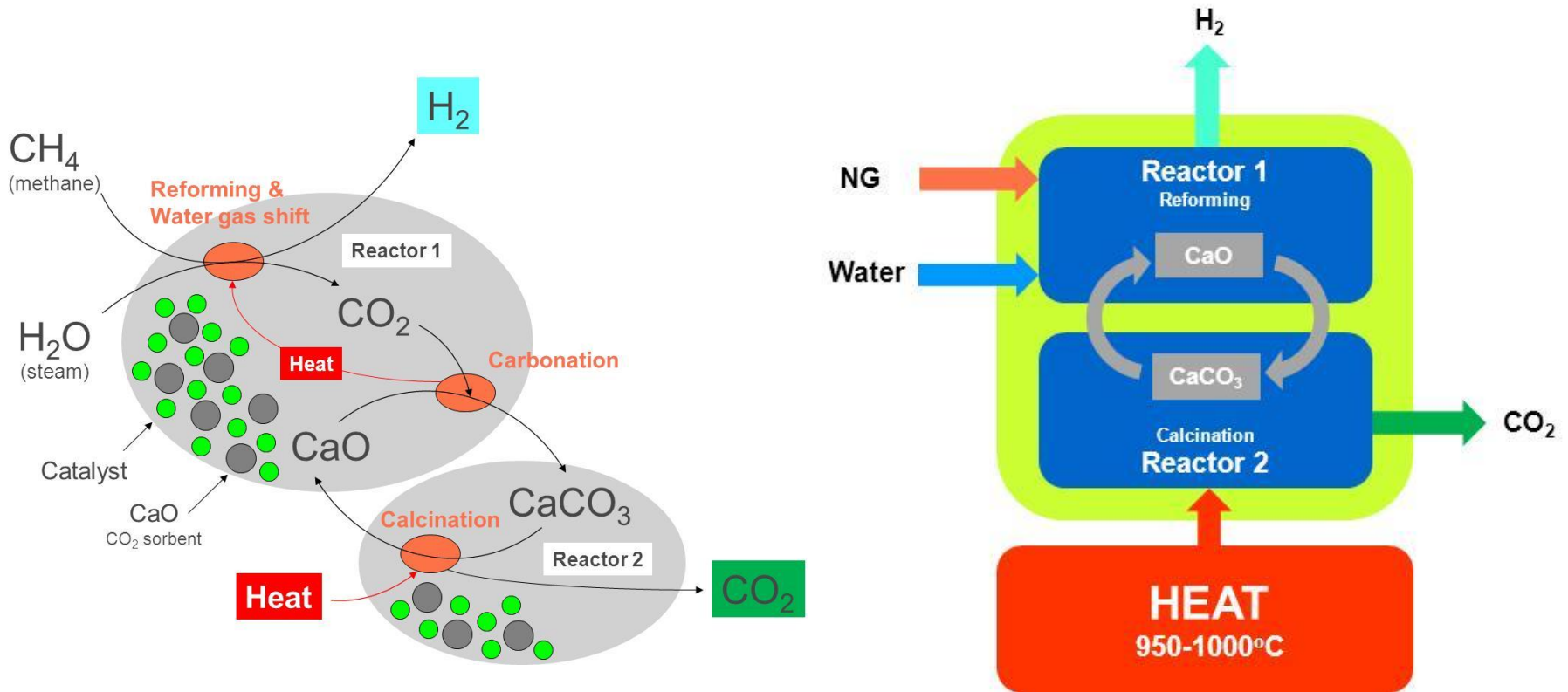


Calcination (regeneration)



Sorption enhanced steam methane reforming

Principle and basic concept



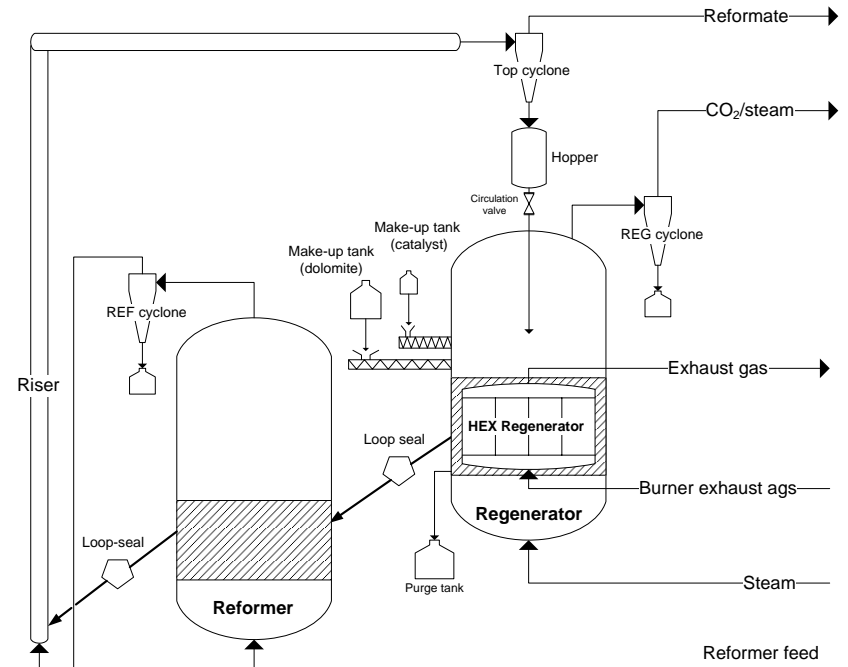
Sorption Enhanced Steam Methane Reforming

Advantages of the novel H₂-production route

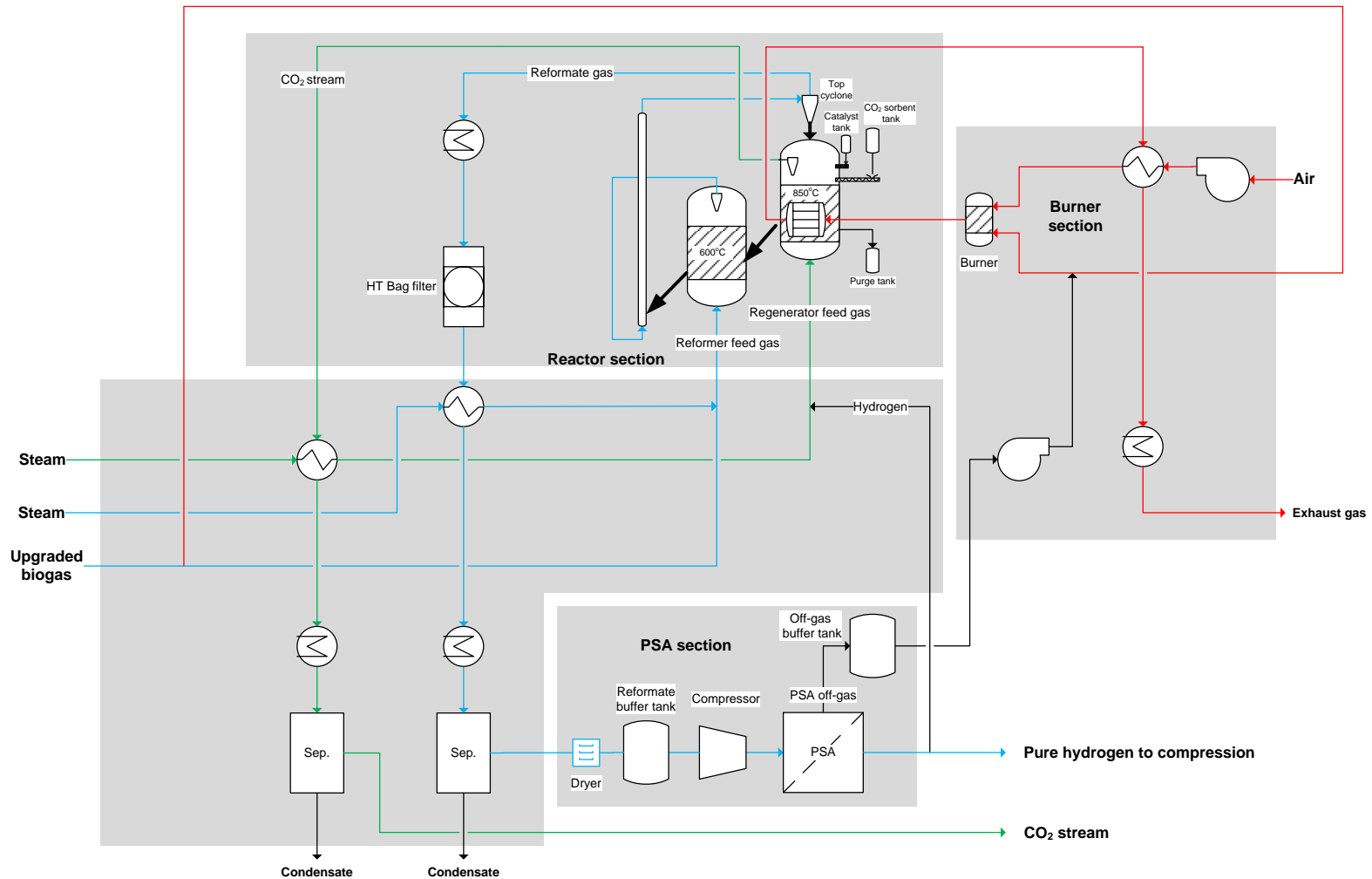
- Higher H₂-yields (95% +) than in conventional SMR, in one single step, and at lower temperature (500-600 C)
- Simplified process layout (fewer vessels)
- No need for shift catalyst
- Reduced needs for downstream H₂-purification
- Potential for lower production costs and energy savings

Reactor technology

- Fluidized bed reactor technology
 - Liquid like behaviour makes transport of solids possible
 - Very good heat transfer
- Dual bubbling fluidized bed reactor (DBFB)
 - 2 dedicated reactors connected with loop seals and transport riser
 - Continuous mode
 - Bubbling regime
 - Circulation rate regulated with a slide valve
 - High temperature tube heat exchanger in the regenerator

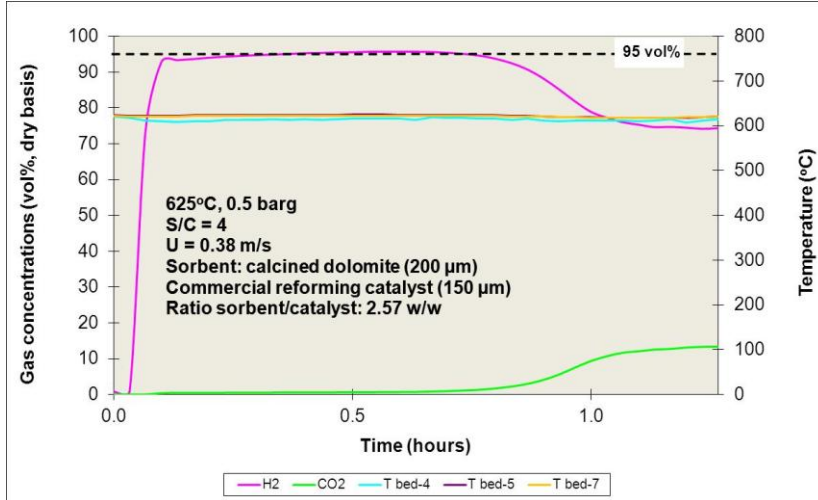
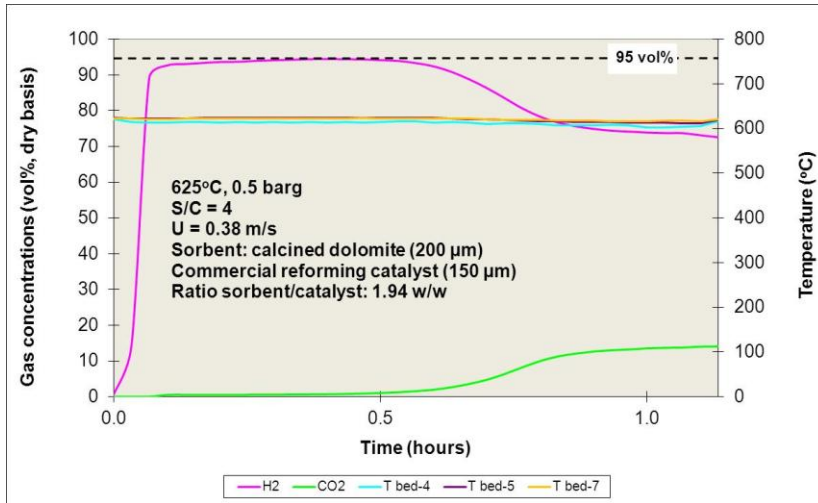


Simplified SE-SMR process

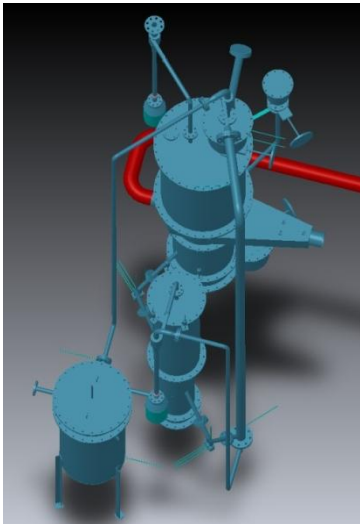
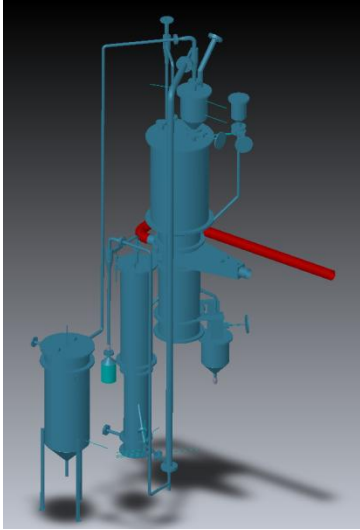


Experimental results

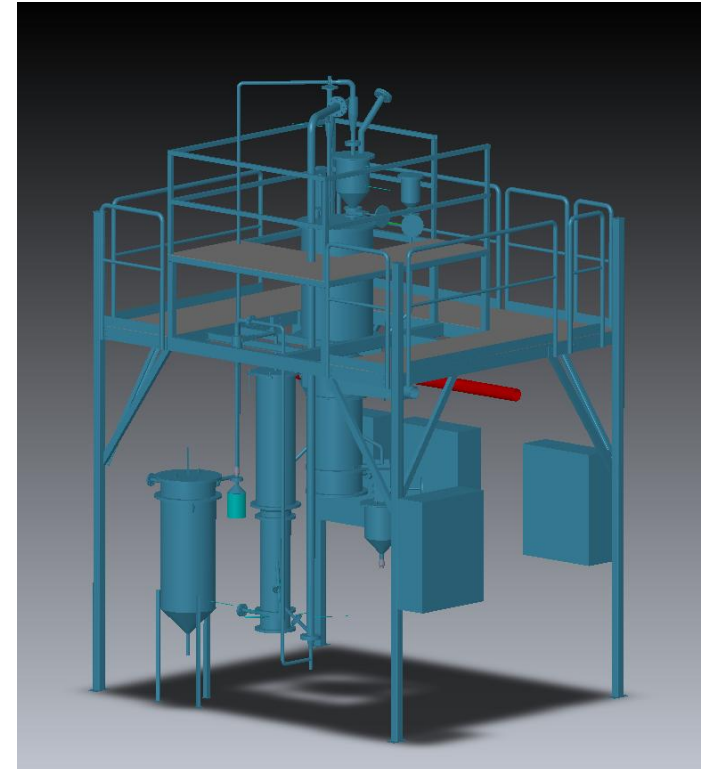
Bubbling bed batch reformer/regenerator



The DBFB SE-SMR pilot



- **H₂ production capacity**
 - 12.5 Nm³/h
- **Reformer**
 - 625°C; 0.5-1 barg
 - 0.29 m/s; S/C ratio: 4
 - Upgraded biogas (Swedish standard)
- **Regenerator**
 - 850°C; 0.5-1 barg
 - 0.10 m/s
 - Steam + 2 vol% hydrogen
- **Solids**
 - Arctic dolomite from Franzefoss
 - 200µm
 - Commercial reforming catalyst
 - 150µm
 - Ratio sorbent/catalyst: 2.5 – 3 w/w
 - Solids circulation rate: 75 kg/h

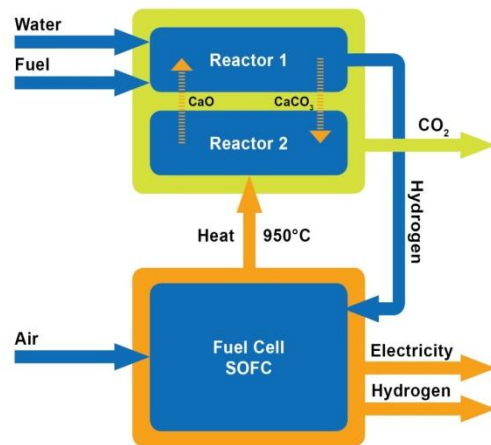


- Installation in the last quarter of 2011
- Testing and commissioning in first quarter of 2012

Other applications of the SE-SMR process

Power production and co-production

- H₂-production with CO₂-capture and steam boilers
- H₂-production with CO₂-capture and CC power plant
- H₂-production with CO₂-capture and SOFC
 - ZEG-Power concept



- Co- production of electricity and hydrogen with integrated CO₂- capture
- Electricity from high temperature solid oxide fuel cells (SOFC)
- Hydrogen production by sorption enhanced steam methane reforming
- High total energy efficiency

ZEG Power 
www.zegpower.com

Thank you for your attention !