Latest Hydrogen Achievements and Trends in the Netherlands

Energy research Centre of the Netherlands

- Independent research organization
- Bridge between fundamental research and industrial products
- 550 - 600 employees
- Annual turnover 75-80 M€
- Active in the field of:
  - Wind Energy
  - Solar Energy
  - Biomass (incl. CCS technology)
  - Energy Efficiency
  - Policy Studies
  - Environment & Energy Engineering

**ECN’s mission:**

*With and for the market ECN develops knowledge and technology that enable a transition to a sustainable energy system*
Research at ECN Policy Studies:

**Techno-economic**
- Assessment of technology, cost, ...

**Quantitative**
- Monitoring, projections, scenarios

**Social science**
- Consumer behaviour, public acceptance

**Policy instruments**
- Design and evaluation

Effective & cost efficient policy
- Emission reduction
- Energy saving
- Alternative energy sources & carriers
- Better air quality

Combination of technical, economic and social expertise
IEA HIA Task 28:
Large-scale Hydrogen Delivery Infrastructure

Operating Agent: Marcel Weeda

Team

Netherlands: ECN, Shell
USA: ANL and Proton OnSite (GM)
Japan: Tokyo Gas and Nissan
Denmark: Danish Gas Technology Centre and H2Logic
Australia: GreenCollar Climate Solutions / AAHE
France: GdF-SUEZ, TOTAL and Air Liquide
Germany: NOW (many options but no final decisions)
Contents

- Drivers for $H_2$ and FC in the Netherlands
- Overview Hydrogen and Fuel Cell activities
- Arnhem $H_2$ and FC technology cluster
- Light House projects in the Netherlands
- Latest Developments in the Netherlands
Drivers for Hydrogen and Fuel Cells

• At present automotive is main driver:
  - No OEM in the Netherlands
  - Competition from battery electric

• However, other drivers present
  - Innovation
  - Air quality issues
  - Large industrial hydrogen complex
Overview Hydrogen and Fuel Cells activities

Amsterdam: Hydrogen transport projects

Rotterdam: Hydrogen Production

Eindhoven: High-tech and automotive cluster

Arnhem: Hydrogen & Fuel Cell technology cluster

WaterstofNet

Energy research Centre of the Netherlands
Hydrogen & Fuel Cell technology cluster

• Nedstack

• HyGear

• HyET
Nedstack overview

Founded in 1998
• Independent spin-off from Akzo Nobel

Today
• Major global PEM fuel cell producer
• Global installed base including emerging market in Europe, US, Africa, Asia
• Partner in a sustainable eco system

Partnering for reliable, sustainable, affordable green energy solutions

Development and manufacturing of:
PEM Fuel Cell Stacks
PEM Power Plants
Nedstack’s PEM fuel cell stacks are unique

- Hydrogen, pressure 100-300 mbarg
- Ambient air, pressure 50-150 mbarg
- Liquid cooled

- Power range 1 – 10 kW
- Stacks can be combined to 20 – 2000 kW

- Lifetime in stationary applications: 20,000 h
- Proven reliability
- Robust, easy to integrate
- Recyclable
- CE
Nedstack has an extensive track record

Over 700 telecom back-up stations with Nedstack stacks installed with untroubled operation since 2007

5 kW off-grid telecom power supply
4 Installations running smoothly since early 2010

70kW demonstration power plant running >25,000 hrs since August 2007

1MW plant at Solvay chlorine plant

1 MW full power reached Nov. 2012
Current decay rates suggest Nedstack’s stacks will survive over 20,000 hours

Extrapolation of actual measurements at AkzoNobel Delfzijl PEM Power Plant
HyGear

• A Product and Services provider
  – Hydrogen Generators
  – BioGas upgrading
  – Gas to Liquid systems (in development)
  – Fuel Cells (in development)

• SME (60 persons) in Arnhem

• Core expertise
  – Development and integration of Small Chemical Systems
HGS Field Deployment Strategy

- Sell what’s proven, don’t gamble with customers!
- Main markets of Hydrogen Generators
  - Glass manufacturing
  - Metal treatment
  - Food
  - ‘New energy’

- Product range:
  - HGS-V (5Nm³/h H₂) introduced in 2006, 20 units operational
  - HGS-L (50Nm³/h H₂) introduced in 2009, 5 units operational
  - HGS-CCL (250Nm³/h H₂) prototyping market introduction 2013/2014

HyGear’s Hydrogen and Fuel Cell status
Fuel Cells

• HyGear is system integrator
  – In-house reforming technology
    • SR, ATR, CPO

  – Uses HyGear’s & Plug Power’s field experience
    • HyGear acquired Plug Power Europe in 2009

  – Development of
    • Natural gas fed μCHP (SOFC)
    • LPG fed power-pack (SOFC)
    • Propane fed APU (PBI-PEM)
    • Diesel fed Generator (PEM)
Electro-chemical Hydrogen Compression

**WORKING PRINCIPLE**

Potentiostatic hydrogen compression from 10 → 400 bar and hydrogen de-compression back from 400 → 10 bar

**Technical Advantages EHC:**

- Single stage compression
- High efficiency (isothermal)
- Silent, no moving parts
- Purification of H₂ gas supply

1 → >70MPa
≤2.4 kWh/kg - η ≥ 90%
Target Market Applications:
- Small-scale refueling stations (e.g. Forklifts)
- Medium retail refueling stations
- Large industrial applications

Plan 2012: Build pre-commercial series
- 1 Nm³/hr ‘building block’
- Pressure >400 Bar single stage
- Field testing prototype systems
HyMove: combining regional strengths

- Local, metropolitan and provincial governments
- Regional businesses
- University

FC-Hybrid Truck

FC-Hybrid Bus

Filling station

Wheel hub motors
Light House projects

- Amsterdam
  - Fuel Cell Boat
  - Hydrogen Busses

- Hydrogen region Flanders/Netherlands

- Mixing of hydrogen into natural gas grid

- THRIVE: rollout FCEV and filling infrastructure
Fuel Cell Boat

Boats previously used by the Dutch to conquer the world
GVG Amsterdam:
- 2 buses from 15 Aug. ’11
- Testing phase on the line
- In operation in October’11

RVK Cologne:
- 2 buses from 2 May ’11
- Testing phase completed
- Driving in service
**Specification Phileas H2 for GVB & RVK**

**Ballard HD6 fuel cell system:**
- Power 150 kW
- Voltage 440 - 800 V
- Weight 350 kg

**Dynetek hydrogen tanks:**
- 8 tanks of 205 l each = 1640 litres
- Weight of the hydrogen fuel 42 kg
- Pressure 350 bar

**Hoppecke Battery System:**
- NiMeH technology
- 252 cells Hoppecke SNH 116X
- Voltage 327 V
- P-nominal 23 kW / P-peak 110 kW

**Vossloh Kiepe Hybrid Traction**
- Performance 240 kW
- 450 - 800 V DC

**Maxwell Super Caps:**
- 6x module HTM 125
- Capacity 0.1 kWh / module
- Voltage 125 V / module
- Current 150A - 750A (peak)
Hydrogen Region Flanders – South NL

- Budget: 14.1 M€
- Concrete results consistent with industrial activities in the region (e.g. Hydrogenics, Solvay, and bus manufacturers Van Hool, VDL)

- 2 relocatable H₂ stations
- 5 small logistic vehicles
- 3 vessels
- Busses: call to be launched
- 1 MW PEM Power Plant
- Development 1 m² photo-electrolysis unit
Adding Hydrogen to Natural Gas Grid

- Admixing 5 – 20% H₂ in period 2007 – 2011
- Apartments equipped with conventional gas appliances
- Result: pipeline and appliances not a restricting factor (up to 20%)

M.J. Kippers et al., Pilot project on hydrogen injection in natural gas on island of Ameland in the Netherlands, IGRC, Seoul, 2011
THRIVE: Study of hydrogen roll-out scenarios

Towards a Hydrogen Refuelling Infrastructure for VEHicles

- Dynamic simulation consumer-driven, interdependent roll-out of a FCEV fleet and corresponding hydrogen refuelling infrastructure
- Cost analysis
- Analysis impact on GHG emissions

Focus:
- Hydrogen as fuel for passenger cars
- Commercialisation phase
- The Netherlands
Example THRIVE results: animation high scenario rollout 2015 - 2050

- Increasing number of \( \text{H}_2 \) refuelling units
- Increasing \( \text{H}_2 \) car penetration
Latest developments

• Power to gas / Gas to Electricity program
  - 2012-2016; indicative budget 10 M€
  - Role of gas in integration intermittent RES

• Ministry Infrastructure & Environment
  - New hydrogen initiative; government budget 5 M€
  - Plan “Driving on hydrogen in the Netherlands”; Spring 2012

• Stimulation electric driving
Plan “Driving on Hydrogen in the Netherlands”

- Starting points:
  - Create nuclei for rollout
  - Hydrogen corridors
  - International cooperation
  - In consultation with industry

- Ruhr area, NRW
- Antwerp
- Brussels
- France
- Cologne
- Frankfurt
- Stuttgart
Stimulation EV’s (also FCEV’s)

- No specific purchase tax on cars to 2018
- No road tax (at least to 2015)
- No addition to taxable income for lease/company car (at least to 2015)
- Part of investment in EV’s (36% in 2011) can be deducted from taxable profit of companies
- Specific subsidies by provinces and municipalities on vehicles and/or charging stations
- No excise duty on hydrogen
THANK YOU!

World’s first draft beer powered by a hydrogen fuel cell at the Dutch Pavilion WHEC 2010

Marcel Weeda
weeda@ecn.nl
+31 224 56 4495