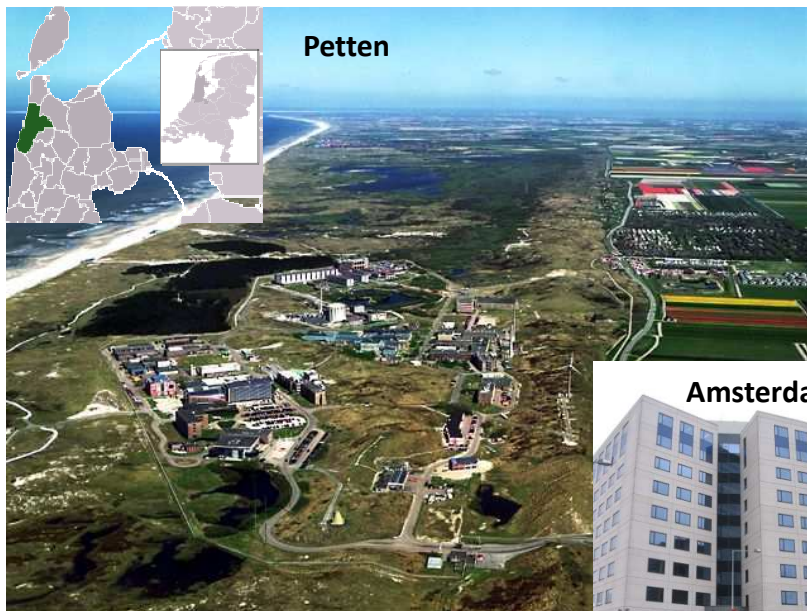


Latest Hydrogen Achievements and Trends in the Netherlands

Marcel Weeda, International Hydrogen Energy Development Forum 2012,
Fukuoka, February 1, 2012



Energy research Centre of the Netherlands

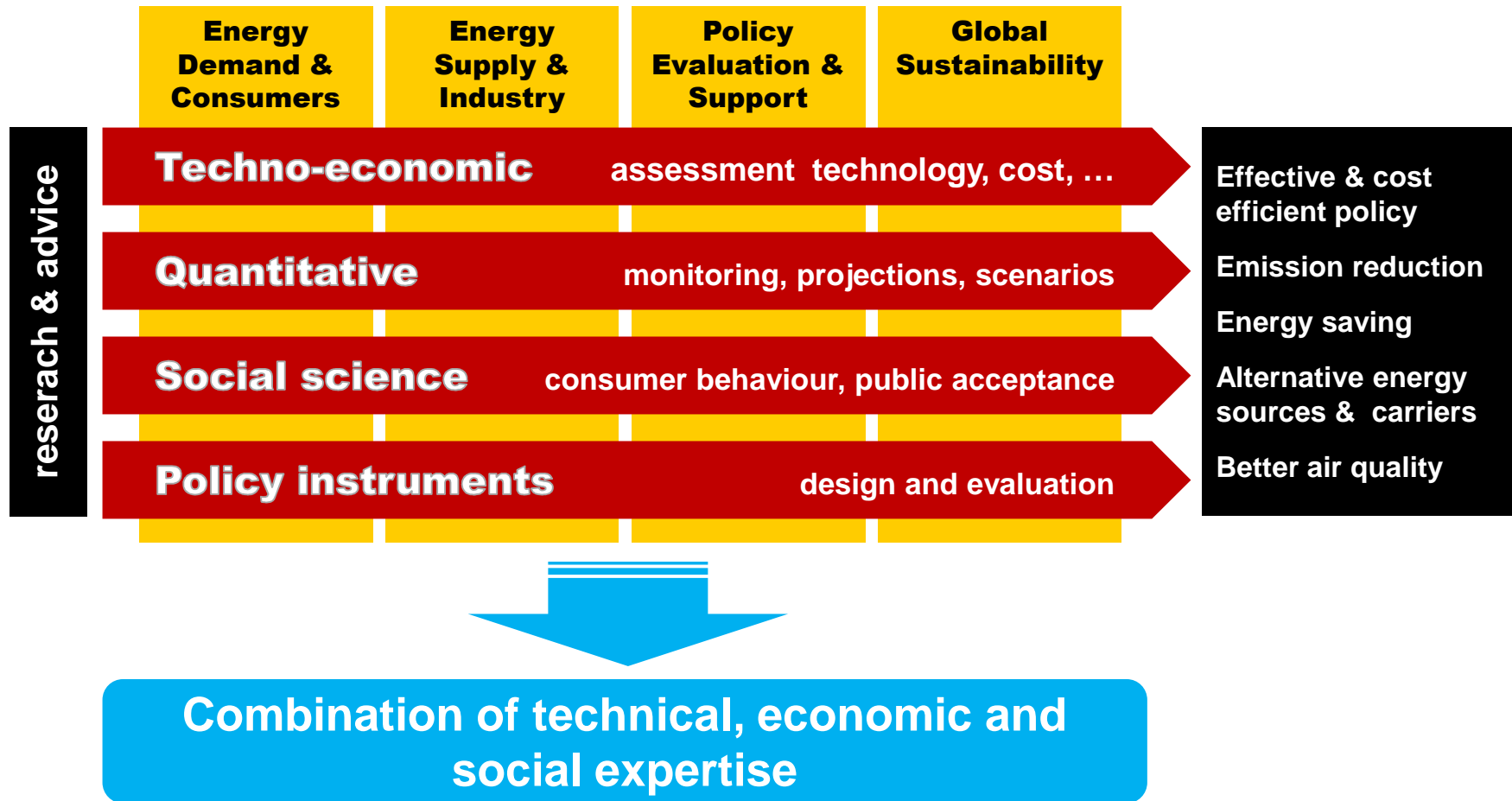


ECN's mission:

With and for the market ECN develops knowledge and technology that enable a transition to a sustainable energy system

- 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

Research at ECN Policy Studies:



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 H₂ and FC in the Netherlands
- Overview Hydrogen and Fuel Cell activities
- Arnhem H₂ and FC technology cluster
- Light House projects in the Netherlands
- Latest Developments in the Netherlands

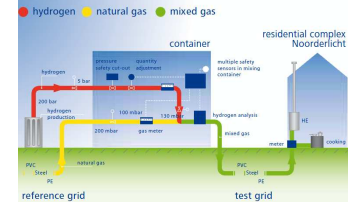
Drivers for Hydrogen and Fuel Cells

- 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



Arnhem:
Hydrogen & Fuel Cell
technology cluster



Nedstack
PEM FUEL CELLS



Hydrogen & Fuel Cell technology cluster

- Nedstack



- HyGear



- HyET



Nedstack overview

Partnering for reliable,
sustainable, affordable
green energy solutions



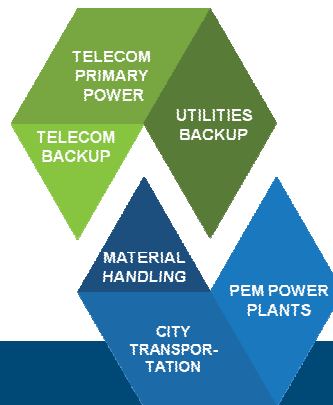
Founded in 1998

- 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

We are dedicated to
designing and producing
the best value for money
PEM fuel cell stacks in
the market.



➔ **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

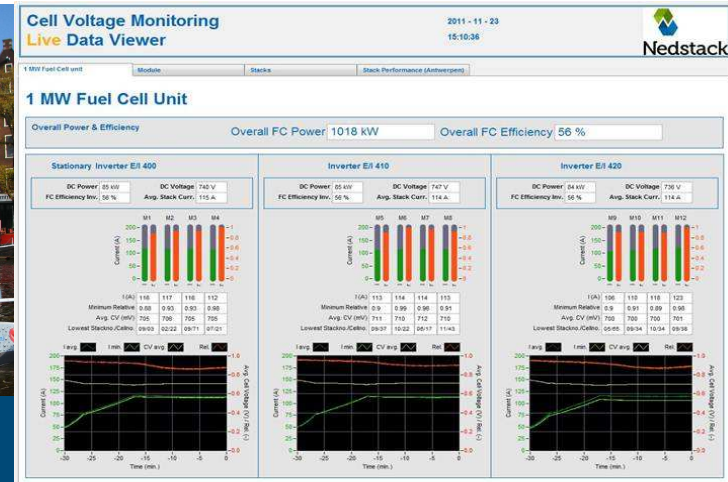


70kW demonstration power plant running >25,000 hrs since August 2007



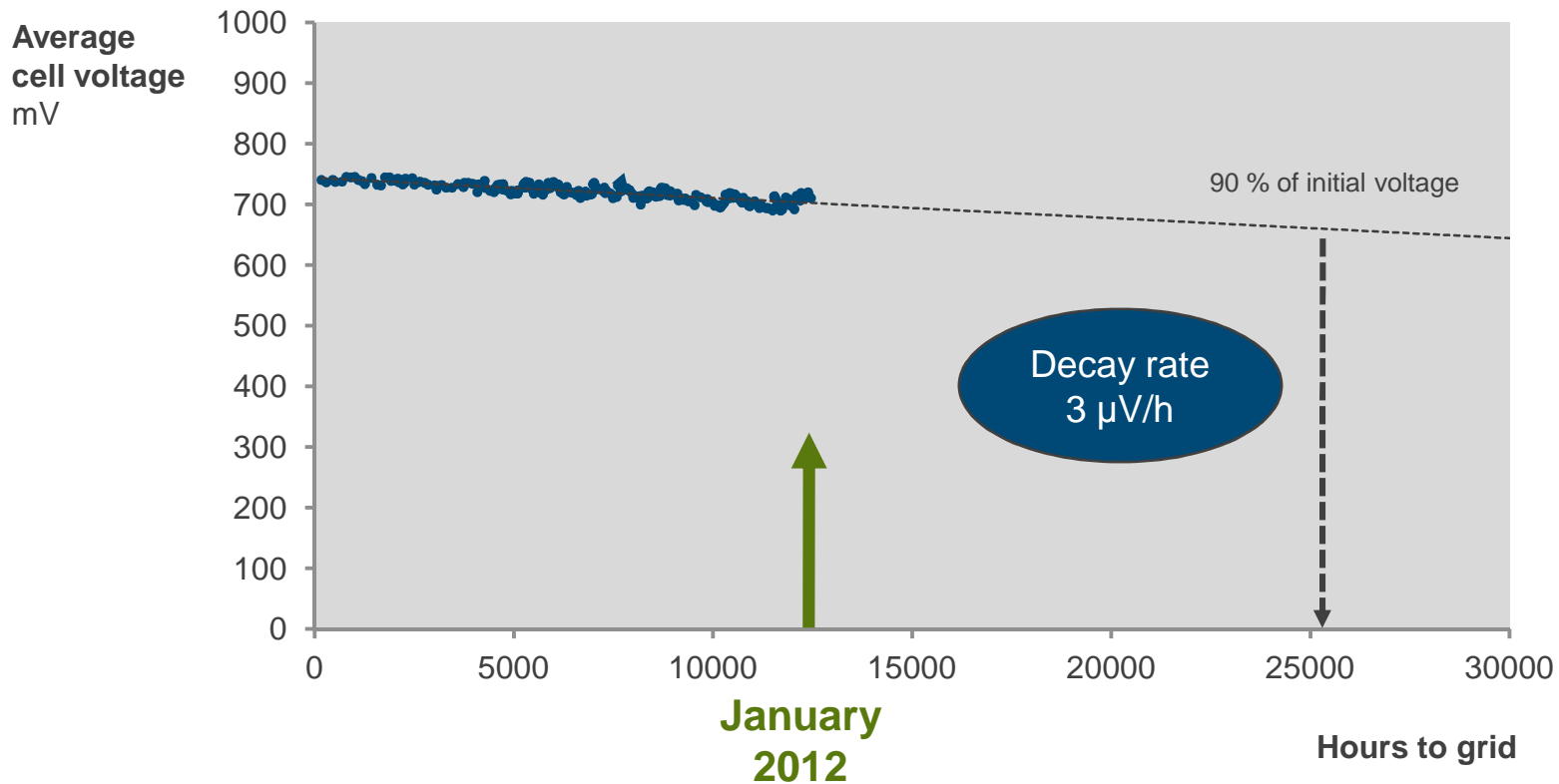
1MW plant at Solvay chlorine plant

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

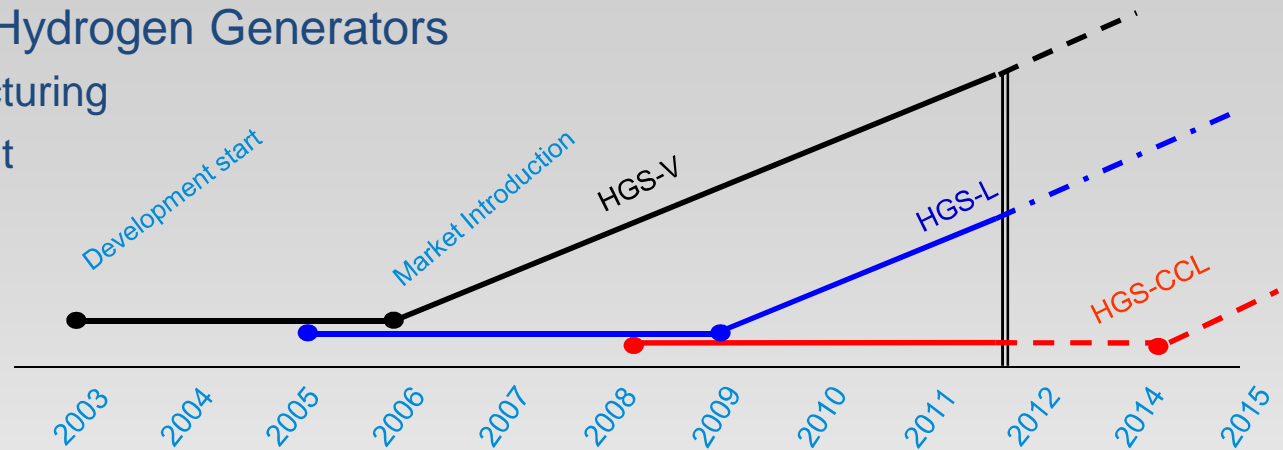


- A Product and Services provider
 - Hydrogen Generators
 - BioGas upgrading
 - Gas to Liquid systems (in development)
 - Fuel Cells (in development)
- SME (60 persons) in Arnhem
- Core expertise
 - Development and integration of Small Chemical Systems



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 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

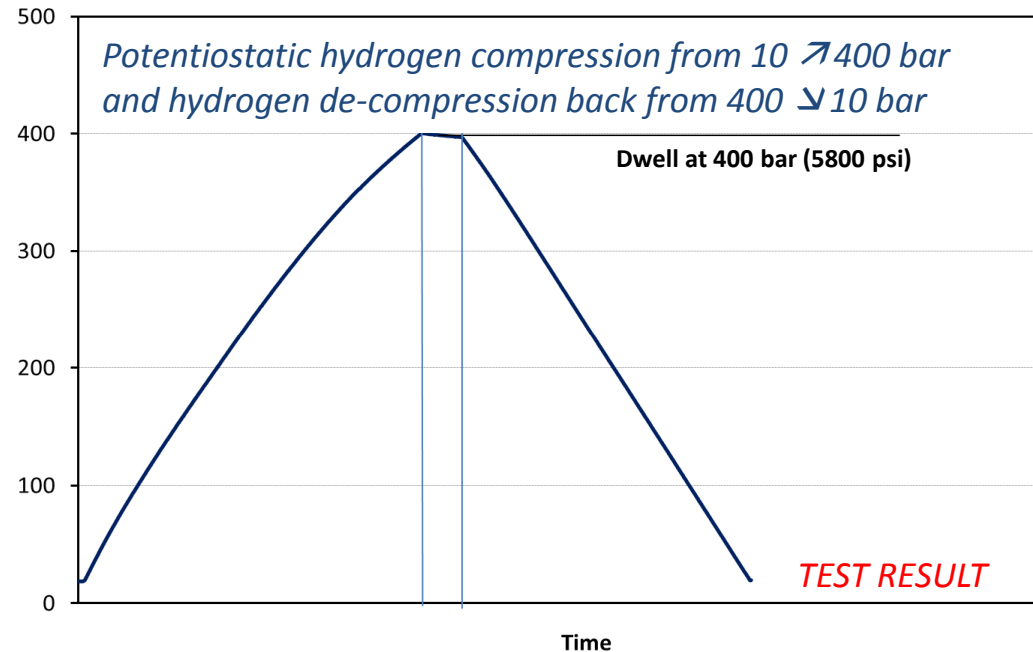
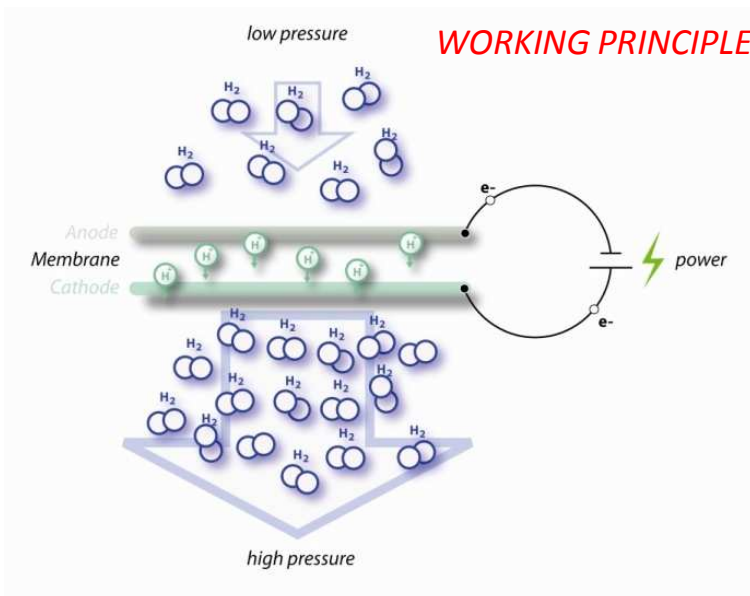


- Development of
 - Natural gas fed μ CHP (SOFC)
 - LPG fed power-pack (SOFC)
 - Propane fed APU (PBI-PEM)
 - Diesel fed Generator (PEM)





Electro-chemical Hydrogen Compression



Technical Advantages EHC:

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

1 \rightarrow >70MPa
 ≤ 2.4 kWh/kg - $\eta \geq 90\%$



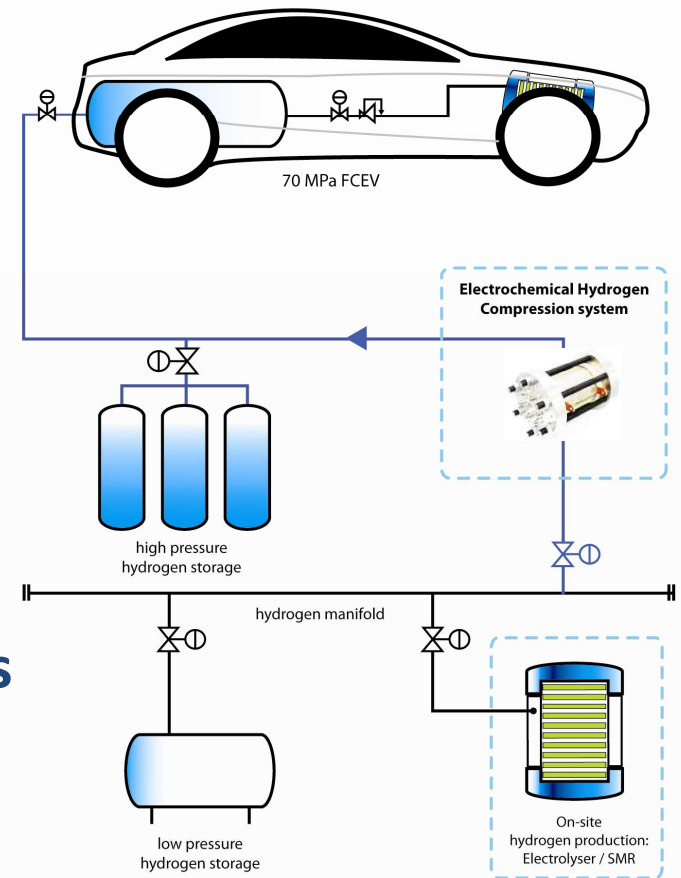
Target Market Applications:

- Small-scale refueling stations (e.g. Forklifts)
- Medium retail refueling stations
- Large industrial applications



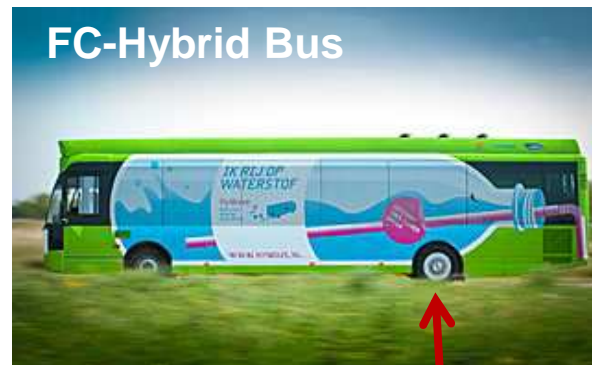
Plan 2012: Build pre-commercial series

- 1 Nm³/hr 'building block'
- Pressure >400 Bar single stage
- Field testing prototype systems

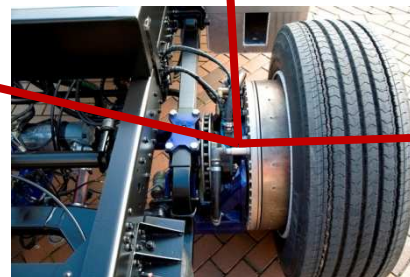


HyMove: combining regional strenghts

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



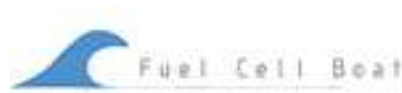
Wheel hub motors



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



GVB 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





First 18 m Fuel Cell vehicle in the world!

Specification Phileas H2 for GVB & RVK



Ballard HD6 fuel cell system:

Power 150 kW
Voltage 440 - 800 V
Weight 350 kg



Hoppecke Battery System:

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



Dynetek hydrogen tanks:

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



Vossloh Kiepe Hybrid Traction

Performance 240 kW
450 - 800 V DC

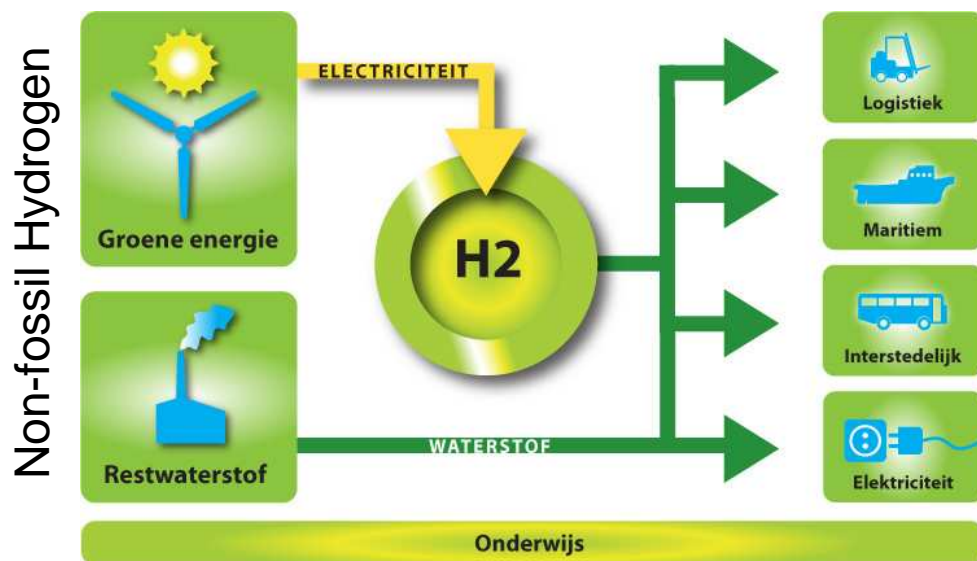


Maxwell Super Caps:

6x module HTM 125
Capacity 0,1 kWh / module
Voltage 125 V / module
Current 150A - 750A (peak)

Hydrogen Region Flanders – South NL

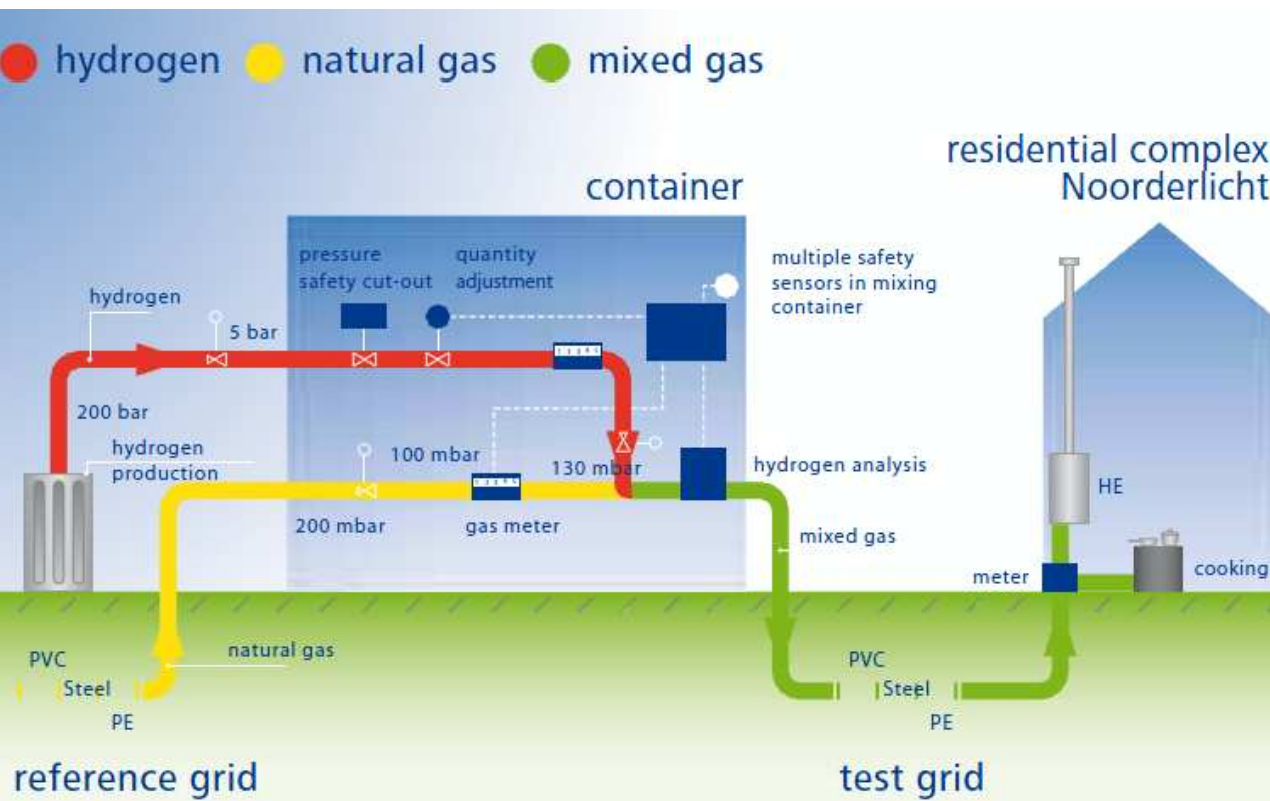
- Duration: 1/6/2009 – 31/5/2013
- Budget: 14.1 M€
- Concrete results consistent with industrial activities in the region (e.g. Hydrogenics, Solvay, and bus manufacturers Van Hool, VDL)



- 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%)

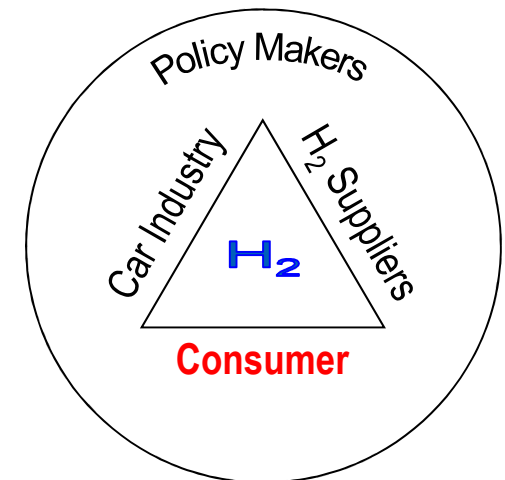


M.J. Kippers *et al.*, Pilot project on hydrogen injection in natural gas on island of Ameland in the Netherlands, IGRC, Seoul, 2011

THRIVE: Study of hydrogen roll-out scenarios

Towards a Hydrogen Refuelling Infrastructure for VEHICLES

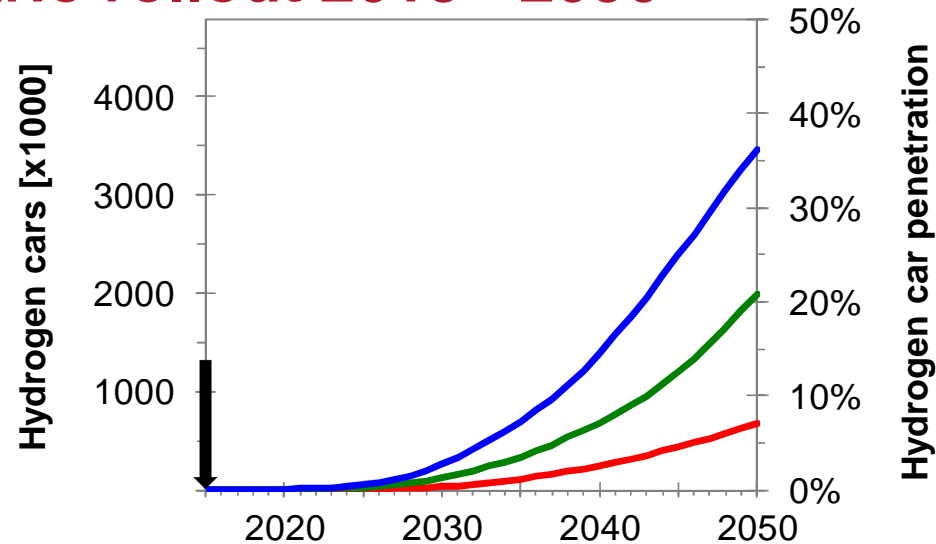
- Dynamic simulation consumer-driven, interdependent roll-out of a FCEV fleet and corresponding hydrogen refuelling infrastructure
- Cost analysis
- Analysis impact on GHG emissions
- Focus:
 - Hydrogen as fuel for passenger cars
 - Commercialisation phase
 - The Netherlands



Example THRIVE results: animation high scenario rollout 2015 - 2050



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Scenario	Low	Medium	High
	—	—	—

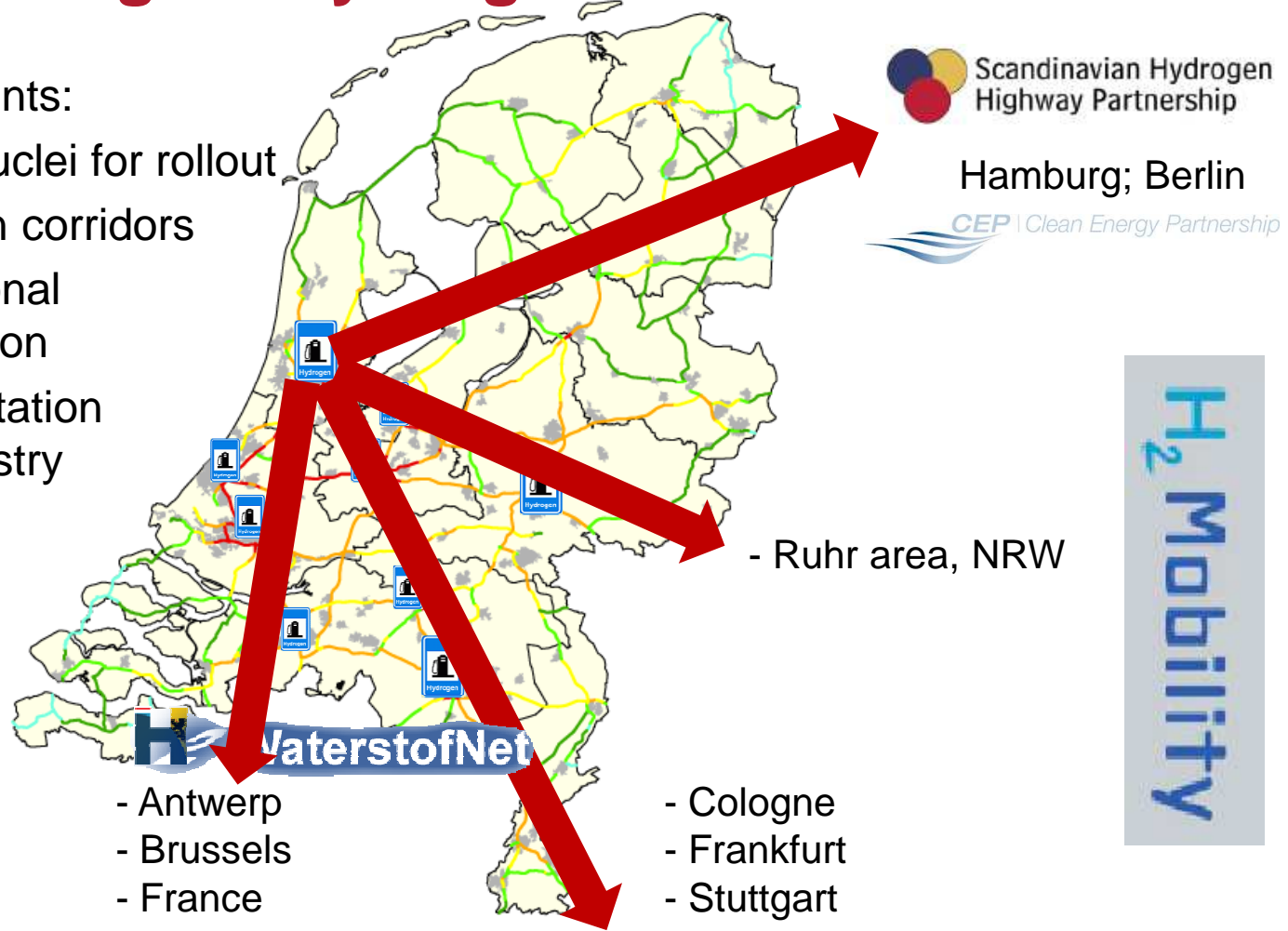
	→		Increasing number of H ₂ refuelling units
	→		Increasing H ₂ car penetration

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



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