HYDROGENICS

SHIFT POWER | ENERGIZE YOUR WORLD

HYDROGEN PRODUCTION FROM OFFSHORE WIND POWER

Thought Leaders Forum

MHI VESTAS OFFSHORE WIND

Denis THOMAS

Business Development - Renewable Hydrogen

Hydrogenics Europe N.V.

WindEurope Exhibition 2019

Bilbao (Spain), 2 April 2019

Hydrogen production from offshore wind power

AGENDA

1. **Intro: Hydrogenics, Hydrogen and Renewable Hydrogen**
2. Renewable hydrogen from floating offshore wind in Japan (JIDAI)
3. Renewable hydrogen from offshore wind in the Netherlands
4. Closing remarks

Hydrogenics in Brief

4 productions sites
Belgium, Canada, Germany and USA

180+
dedicated employees

$ 48M
2017 annual sales

Our raw materials
water & renewable power are
infinite!

2000+
fuel cell sites

1 single focus
hydrogen solutions

HYDROGENICS

Publicly
traded
NASDAQ (HYGS) and
TSX (HYG) since 2000

500+
Electrolysis plants
in operation

Global leader
in 2 main hydrogen technologies:
electrolysis and fuel cells

70+ years
of experience

1,500+
Electrolysis plants
sold since 1948

ON-SITE HYDROGEN GENERATION
Electrolyzers
Industrial Hydrogen supply

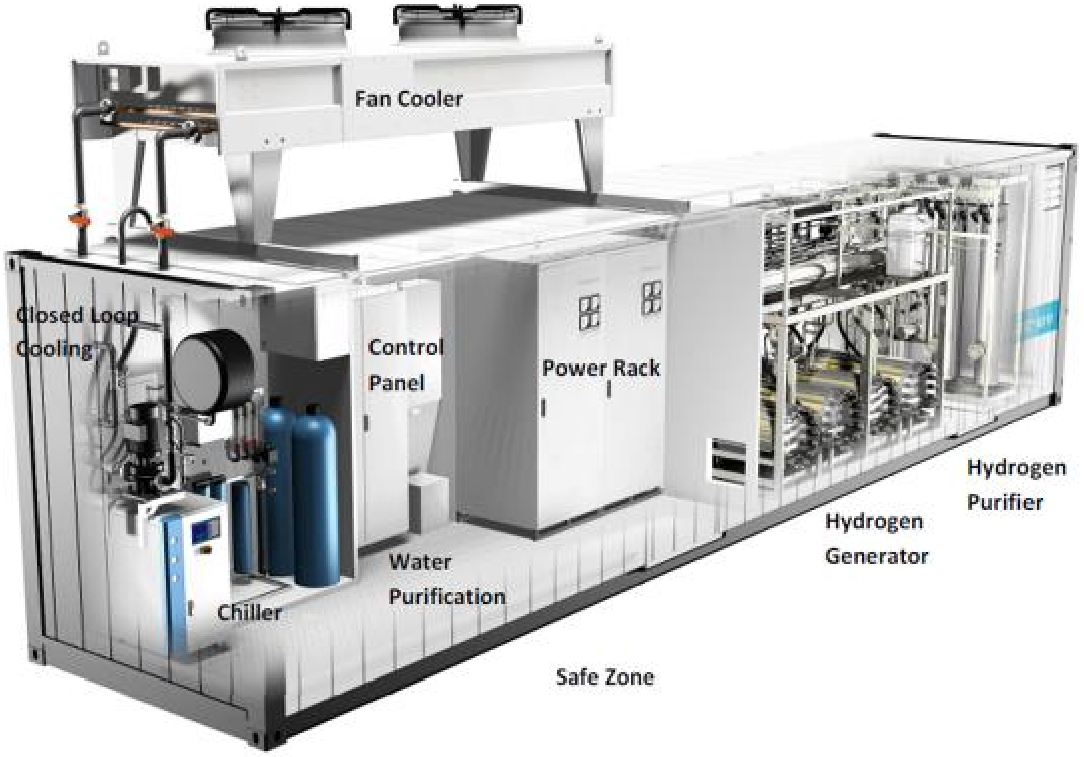
H_2O + electricity → H_2 + ½ O_2

POWER SYSTEMS
Fuel cells
Stand-by Power
Mobile Power Modules
MW Power Plants

H_2 + ½ O_2 → H_2O + electricity

RENEWABLE HYDROGEN
Energy Storage
Hydrogen Refueling Station
Power-to-X
Grid balancing services

HySTAT™ 60 - alkaline electrolyser



World hydrogen market

But most (96%) of the hydrogen produced today is not CO_2-free (from gas, oil, coal)

⇩

If produced from renewable power via electrolysis, hydrogen is fully renewable and CO_2-free.

⇩

Renewable hydrogen has the potential to decarbonize a large range of applications

Data source: The Hydrogen Economy, M. Ball 2009 & Esprit Associates 2014

Extensive experience in industry

Saint Gobain, Colombia


Elemash, Russia

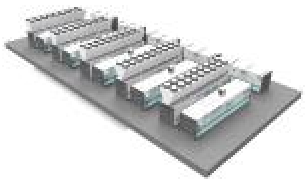

Bushan, India


Camao, Brazil


Nyagan, Russia

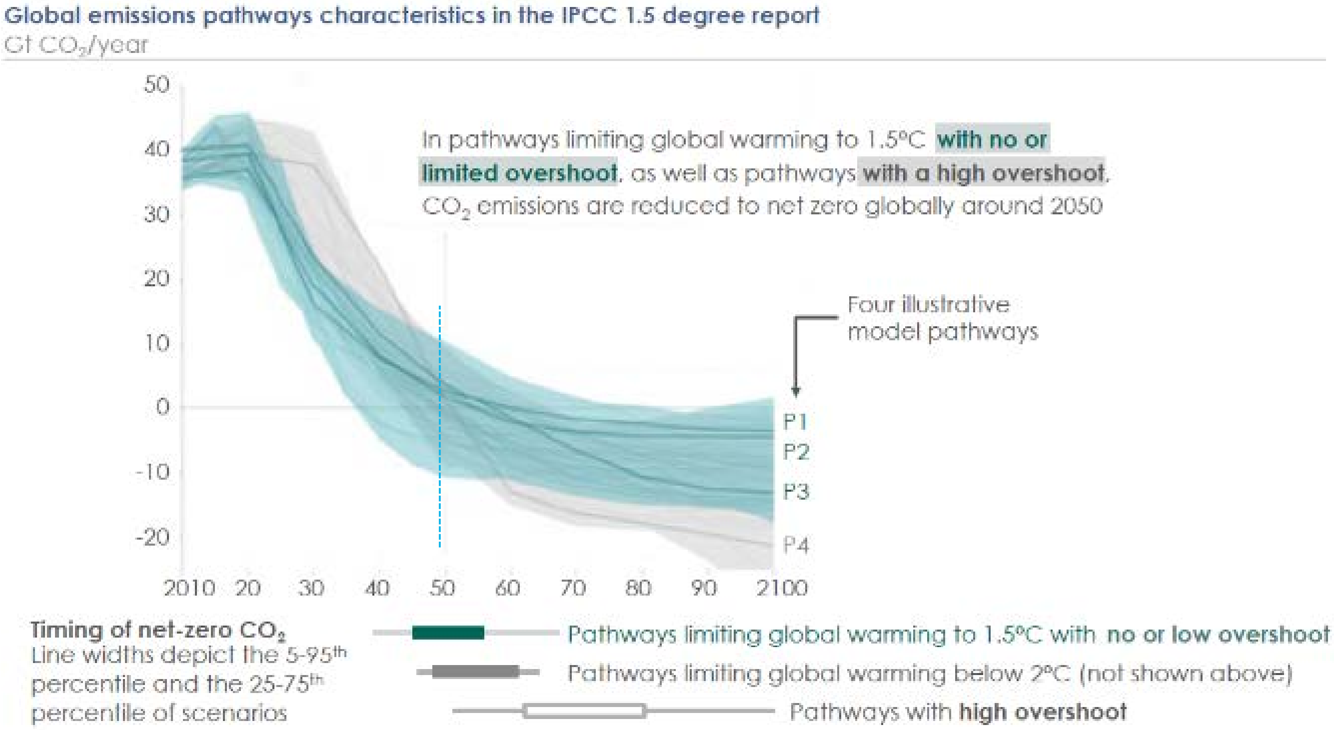

Kirovgrad, Russia

Alkaline & PEM electrolysis | Product’s line

	Alkaline			PEM (Proton Exchange Membrane)		
						
	HySTAT®-15-10	**HySTAT®-60-10**	**HySTAT®-100-10**	**HyLYZER® -300-30**	**HyLYZER® -1.000-30**	**HyLYZER® -5.000-30**
Output pressure	10 barg (27 barg optional)			30 barg		
Number of cell stacks	1	4	6	1	2	10
Nominal Hydrogen Flow	15 Nm³/h	60 Nm³/h	100 Nm³/h	300 Nm³/h	1.000 Nm³/h	5.000 Nm³/h
Nominal input power	80 kW	300 kW	500 kW	1.5 MW	5 MW	25 MW
AC power consumption (utilities included, at nominal capacity)	5.0-5.4 kWh/Nm³			5.0-5.4 kWh/Nm³ (lower possible)		
Hydrogen flow range	40-100%	10-100%	5-100%	1-100%		
Hydrogen purity	99.998% O2 < 2 ppm, N2 < 12 ppm (higher purities optional)			99.998% O2 < 2 ppm, N2 < 12 ppm (higher purities optional)		
Tap water consumption	<1.4 liters / Nm³ H2			<1.4 liters / Nm³ H2		
Footprint (in containers)	1 x 20 ft	1 x 40 ft	1 x 40 ft	1 x 40 ft	2 x 40 ft	10 x 40 ft
Footprint utilities (optional)	Incl.	Incl.	Incl.	1 x 20 ft	1 x 20 ft	5 x 20 ft


Nations Unies
Conférence sur les Changements Climatiques 2015
COP21/CMP11
Paris, France
SECRETAIRE EXECUTIVE CCNUCC
PRESIDENT
SECRETAIRE

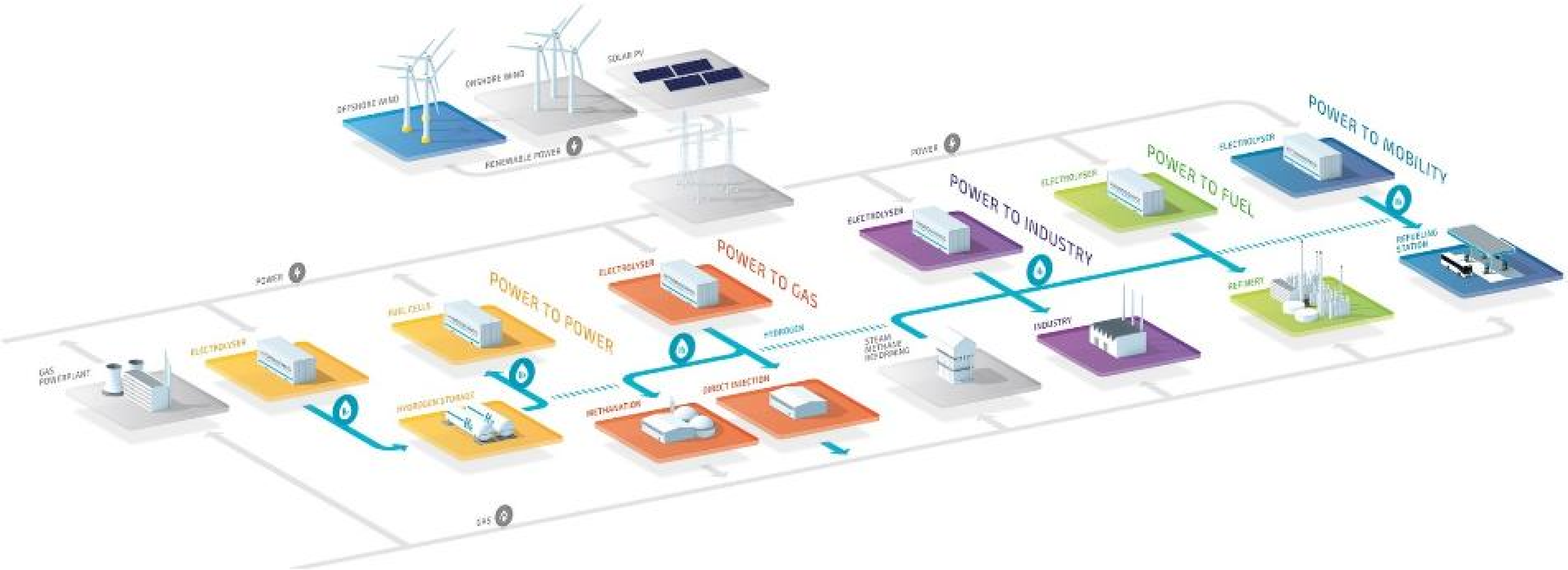
CO2 emissions are reduced to net-zero globally by around 2050 in global emissions pathways for 1.5◦C from IPCC



Source: IPCC (2018), *Global Warming of 1.5°C*

www.energy-transitions.org

Renewable Hydrogen



Selection of our key references

Electrolysis

700 bar Hydrogen Refueling Station
Aberdeen, Scotland (UK)

1,5 MW PEM P2G (direct injection), Hamburg, Germany

1 MW alkaline P2G (methanation)
BIOCAT, Copenhagen, Denmark

Fuel cells

1 MW stationary Fuel cell (H_2 repowering)
Kolon, South-Korea

Fuel cell for mobility (H_2 trains)
Alstom Coradia iLint , Germany

Fuel cell for mobility (H_2 buses), China

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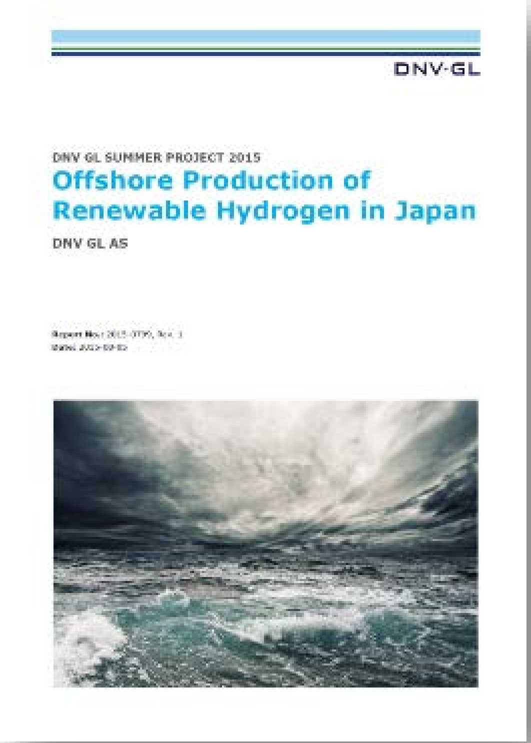
Renewable hydrogen from floating offshore wind in Japan (JIDAI)

- Source: Offshore Production of Renewable Hydrogen in Japan, DNV GL Summer Project 2015, Norway

- Objective: To develop a concept for offshore production of hydrogen powered by floating wind turbines, with Japan as a case study

- https://www.dnvgl.com/news/a-new-era-for-hydrogen-energy-unveiled-by-summer-students-at-dnv-gl-33379

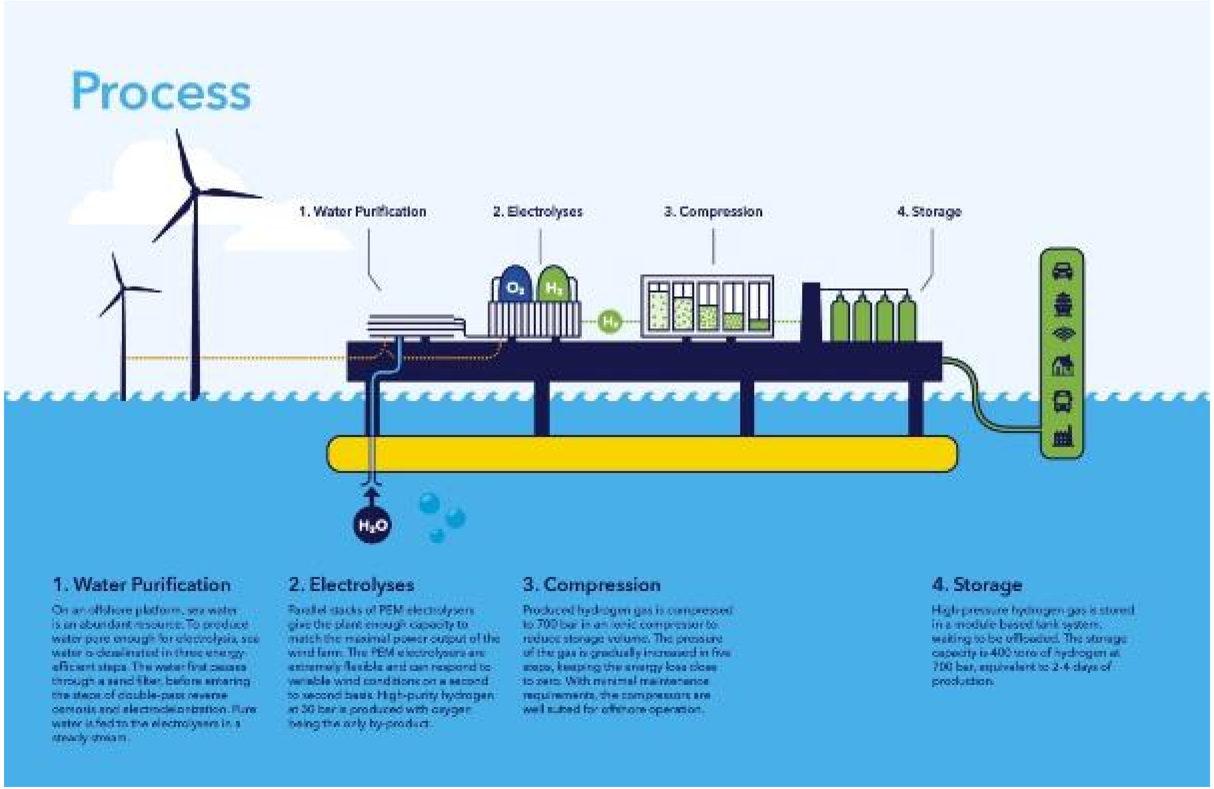

DNV·GL

DNV GL SUMMER PROJECT 2015

Offshore Production of Renewable Hydrogen in Japan

DNV GL AS

Renewable hydrogen from floating offshore wind in Japan (JIDAI)



Renewable hydrogen from floating offshore wind in Japan (JIDAI)

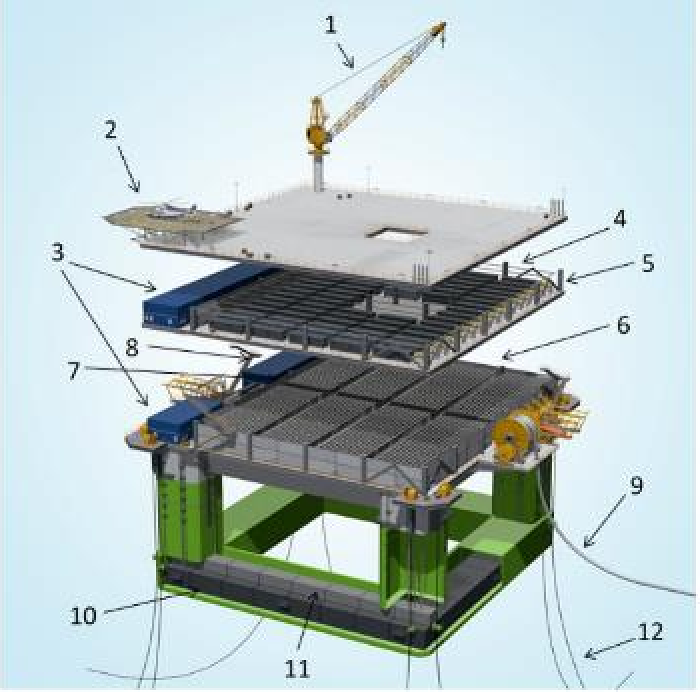
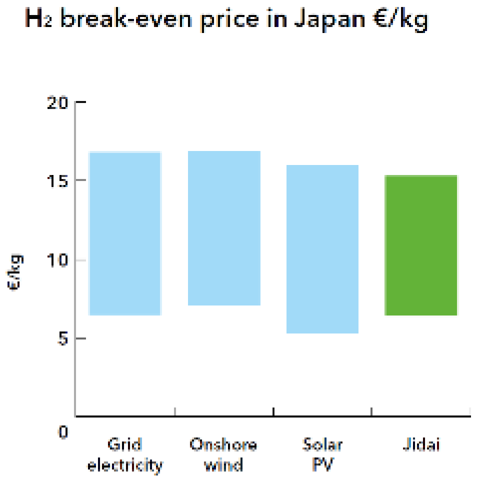


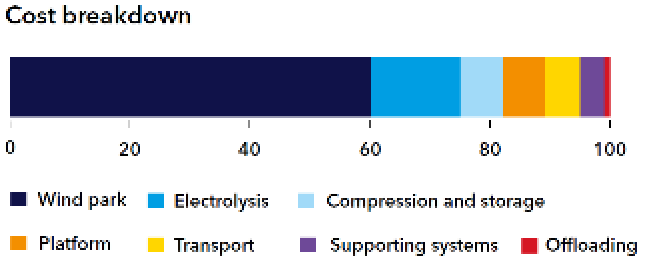
Figure 11. Exploded view of the semi-submersible. The platform contains (1) Crane, (2) Helipad, (3) Living quarters, (4) PEM electrolysers, (5) Compressors, (6) Storage tanks, (7) Reverse osmosis and electrodeionization units, (8) Power substation and control room, (9) Cable to wind farm, (10) Sea water storage, (11) Purified water storage, (12) Mooring lines

Figure 15. Hydrogen offloading. The hydrogen is transferred from the storage area with a hose (1). Through a buoy offloading system (2) it enters a hydrogen carrier vessel (3) for transportation to shore.

Renewable hydrogen from floating offshore wind in Japan (JIDAI)
Case study - main results

- Case study of a **500MW wind park and floating hydrogen production** unit 30 km off the south coast of Hokkaido, **Japan 2030**.
- Main cost drivers : wind park, electrolysis units, and the transportation of hydrogen to shore.
- Both the wind park and the electrolysis units are expected to have substantial cost reductions, and are the main prerequisites for financial viability of the project.
- The results shows that this concept is competitive with other emission free hydrogen sources with a **break-even price of 7.59 €/kg hydrogen**.





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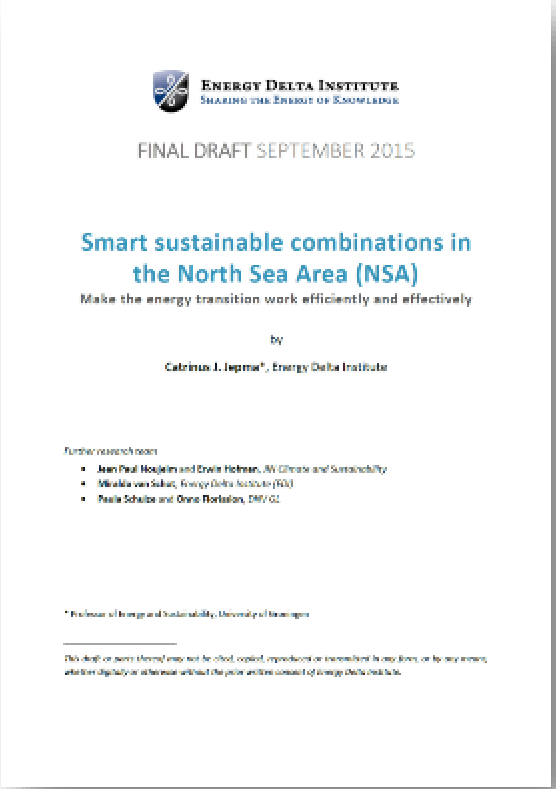
Smart sustainable combinations in the North Sea Area (NSA)

- Source: Energy Delta Institute et al. (2015), Smart sustainable combinations in the North Sea Area (NSA) http://www.europeanpowertogas.com/fm/download/99

- 2 main drivers in all North Sea countries :
  - Gradual decommissioning of +/- 600 oil and gas installations,
  - Massive investment in offshore wind activity

- Objective: Reconversion of old platform for production of renewable hydrogen


ENERGY DELTA INSTITUTE
SHARING THE ENERGY OF KNOWLEDGE

FINAL DRAFT SEPTEMBER 2015

Smart sustainable combinations in the North Sea Area (NSA)

Make the energy transition work efficiently and effectively

by

Catrinus J. Jepma*, Energy Delta Institute

Smart sustainable combinations in the North Sea Area (NSA)
2 platforms have been considered

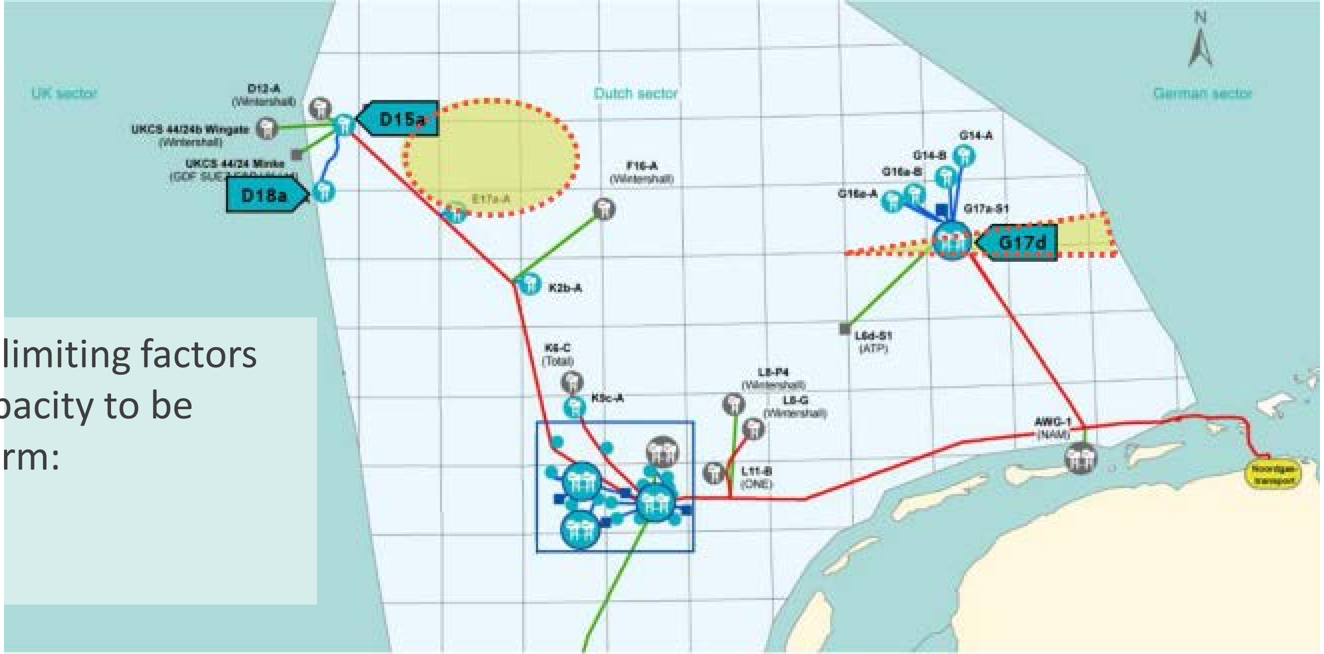
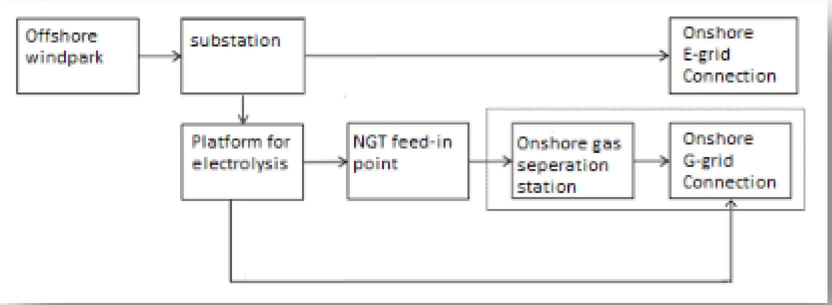


Figure 1. Locations of North Sea platforms and relevant infrastructure; source: Noordgastransport (2013), adapted by EDI

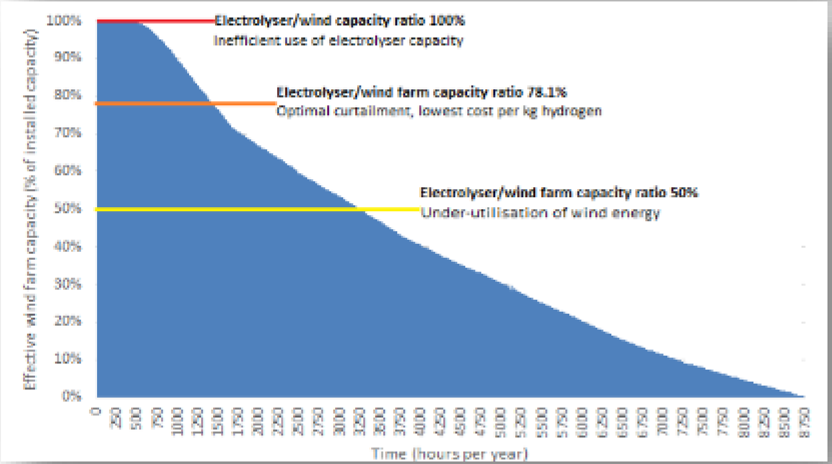
- Space and weight are limiting factors for the electrolysis capacity to be installed on the platform:
  - G17d: 250 MW
  - D18a: 60 MW

Smart sustainable combinations in the North Sea Area (NSA)

- 2 cases have been analysed :
  - Hydrogen only (G scenario)
  - Electricity + Hydrogen (G+E scenario)

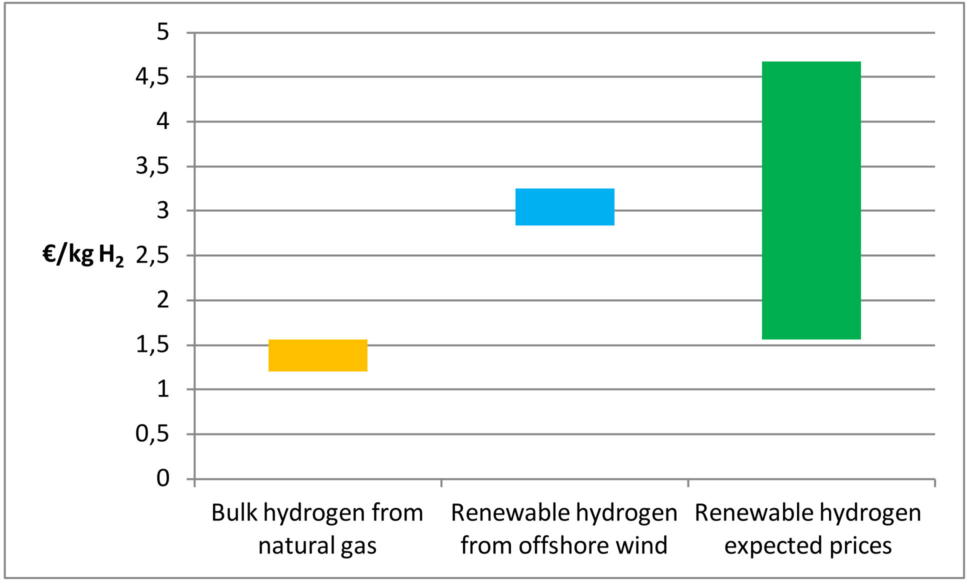


- Optimum size of the electrolyzer: +/- 78% of the offshore wind installed capacity



Smart sustainable combinations in the North Sea Area (NSA)
Main results

- Economical results



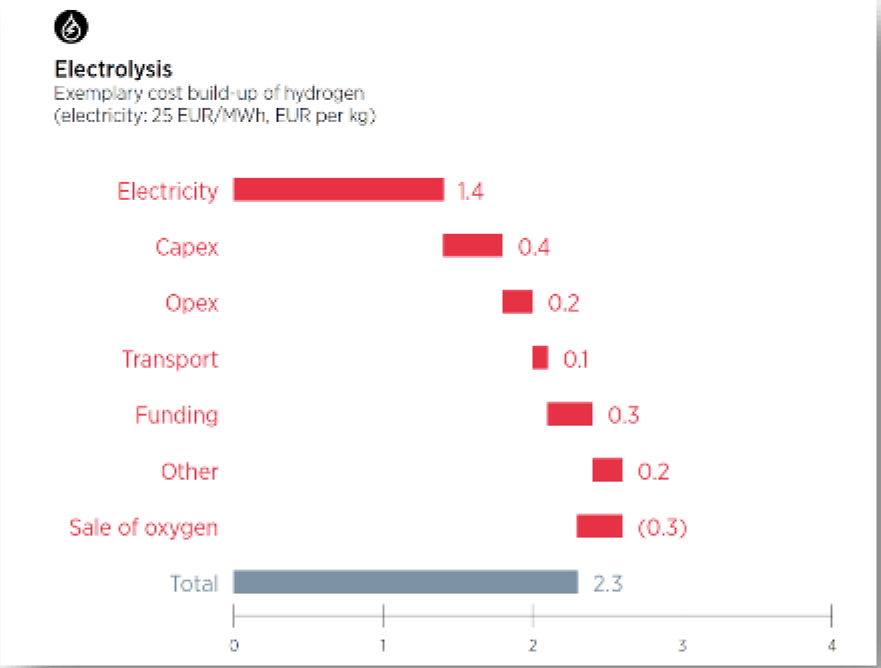
- Optimal hydrogen transport modes from the platform to shore:
  - long distance: to admix the hydrogen to the natural gas flow and separate it once on shore,
  - short distance and high volumes: to invest in a dedicated grid for hydrogen.

The Green Hydrogen Economy in the Northern Netherlands

- Source: www.noordelijkeinnovationboard.nl, 2017
- Netherlands: Carbon free economy by 2050 in the Netherlands
- **The Northern Netherlands is uniquely positioned** to develop a green hydrogen economy because of
  - large-scale offshore wind),
  - strong interconnections with Norway, Denmark and Germany,
  - large-scale chemical cluster,
  - existing gas infrastructure, which can be retrofitted easily and cheaply to transport green hydrogen.

The Green Hydrogen Economy in the Northern Netherlands

- Rabobank has prepared an initial financial model to assess the financial viability for the construction and operation of a 1 GW electrolysis plant.
- For electrolysis, the main cost driver is: electricity !



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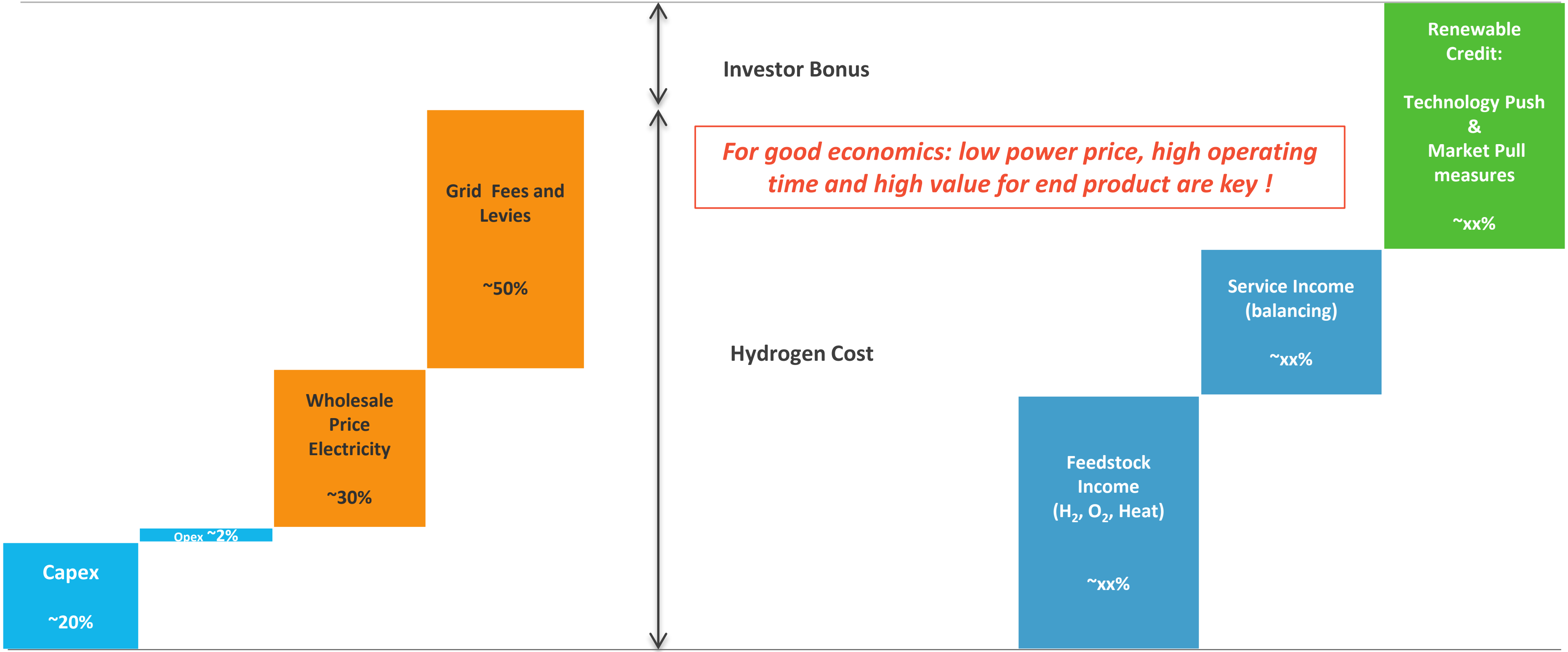
Business Case Drivers

For more information on the economics, consult the Power-to-Gas Roadmap for Flanders: www.power-to-gas.be/roadmap-study



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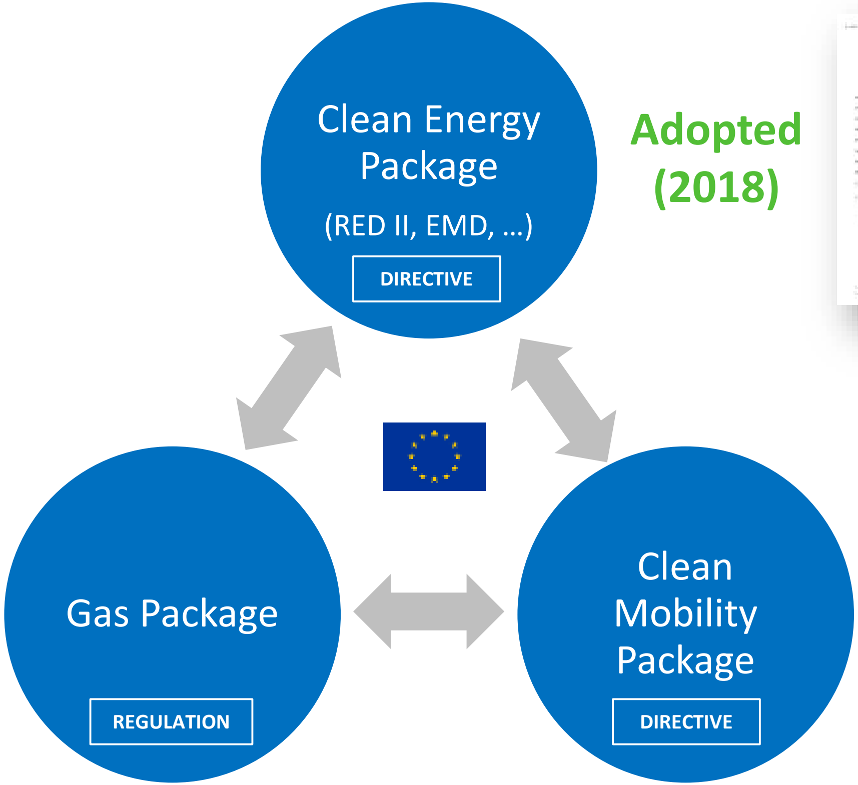
Main pieces of EU legislation affecting the development of hydrogen markets in Europe (2021-2030)



Adopted (2018)

in preparation

in discussion (advanced stage)

Conclusions

From niche

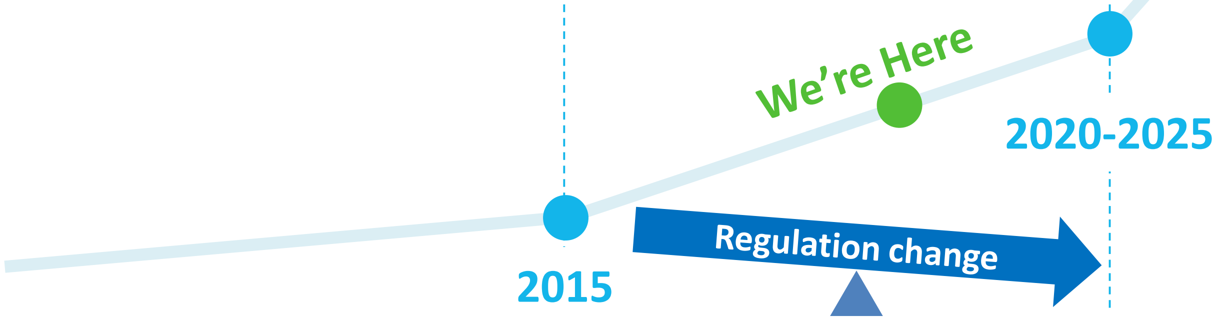
First products and demo projects
kW market
Workshop mode
Immature supply chain
Only small Industrial market is commercial
“Hydrogen is a hype“

Upscaling

Product evolution (alkaline, PEM)
MW market
Project manufacturing
Supply chain development
1st commercial energy applications
“Why not Hydrogen ?“

To mainstream

Product standardization
GW market
Product manufacturing
Optimized and competitive supply chain
Full commercial market deployment
“We always believed in hydrogen”



Thank you for your attention

We're Ready.

Denis THOMAS
M: +32 479 909 129
dthomas@hydrogenics.com
www.hydrogenics.com

WindEurope CONFERENCE & EXHIBITION 2019 2-4 APRIL BILBAO

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Hydrogen | Basic math

Hydrogen physics

- 1 kg ↔ 11,1 Nm^3 ↔ 33,3 kWh (LHV) and 39,4 kWh (HHV)
- High mass energy density (1 kg H_2 = 3,77 l gasoline)
- Low volumetric density (1 Nm^3 H_2 = 0,34 l gasoline)

Hydrogen production from water electrolysis (~5 kWh/Nm^3 H_2)

- **Power:** 1 MW electrolyser ↔ 200 Nm^3/h H_2 ↔ ± 18 kg/h H_2
- **Energy:** +/- 55 kWh of electricity → 1 kg H_2 ↔ 11.1 Nm^3 ↔ ± 10 liters demineralized water

Power production from a hydrogen PEM fuel cell from hydrogen (+/- 50% efficiency)

- **Energy:** 1 kg H_2 → 16 kWh

Cars and buses

FCEV	H_2 tank	H_2 consumption	Driving range	Annual driving distance	Annual H_2 consumption
Car (passenger)	5 kg	1 kg/100 km	500 km	15.000 km	150 kg
Bus (12 m)	35 kg	8 kg/100 km	350 km	60.000 km	5 tons

Thought Leaders forum

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Wind EUROPE

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