



HYDROG(E)NICS

SHIFT POWER | ENERGIZE YOUR WORLD

“HyBALANCE : state-of-the-art PEM electrolysis paving the way to multi-MW renewable hydrogen systems”

HyBalance

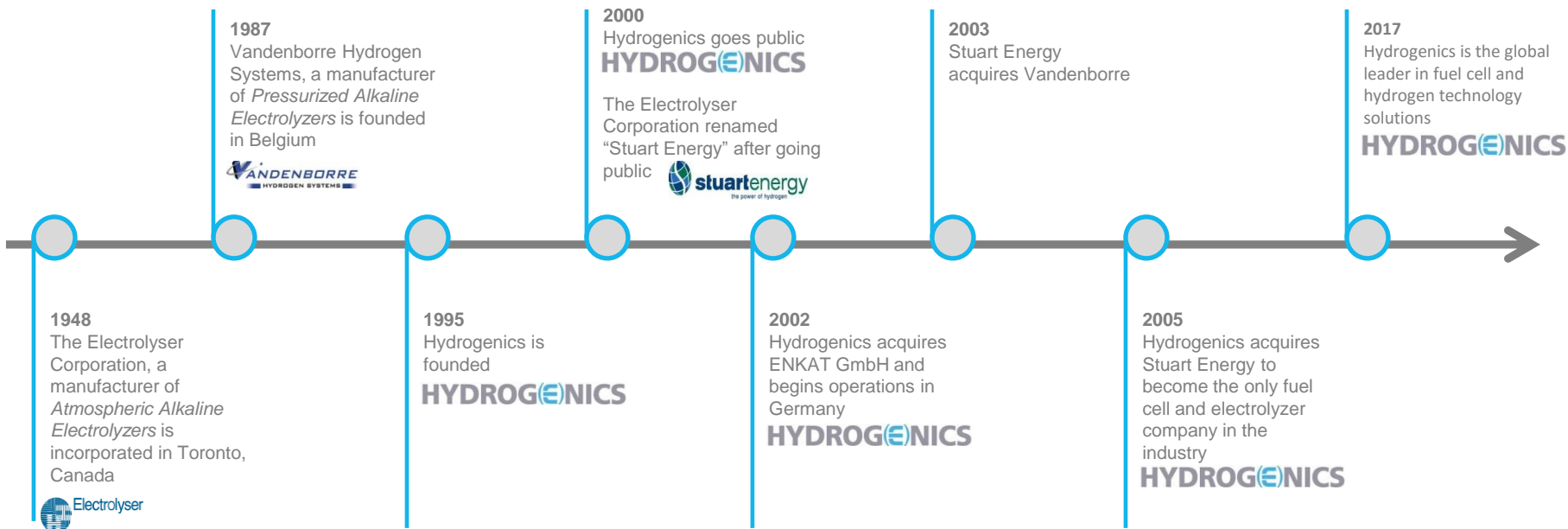
Filip SMEETS & Denis THOMAS
Hydrogenics Europe N.V.

Oevel, Belgium, 13 February 2017

Agenda

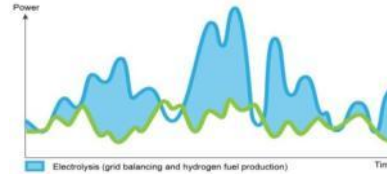
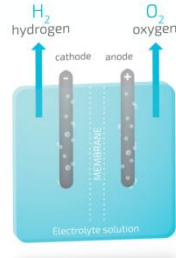
1. **Hydrogenics in brief**
2. Hybalance : 1.2 MW PEM electrolyser
3. What is next & necessary EU regulatory framework?
4. Conclusions

Our History: Over 60 Years of Experience



Electrolysers: Power \rightarrow Hydrogen

Fuel cells: Hydrogen \rightarrow Power (+ heat)



Electrolysis

- Industrial applications
- Hydrogen refueling stations
- Power-to-X (grid balancing)

WATER (H_2O) + POWER

Electrolysis



HYDROGEN (H_2) + OXYGEN (O_2)

(+ HEAT)



Fuel cell

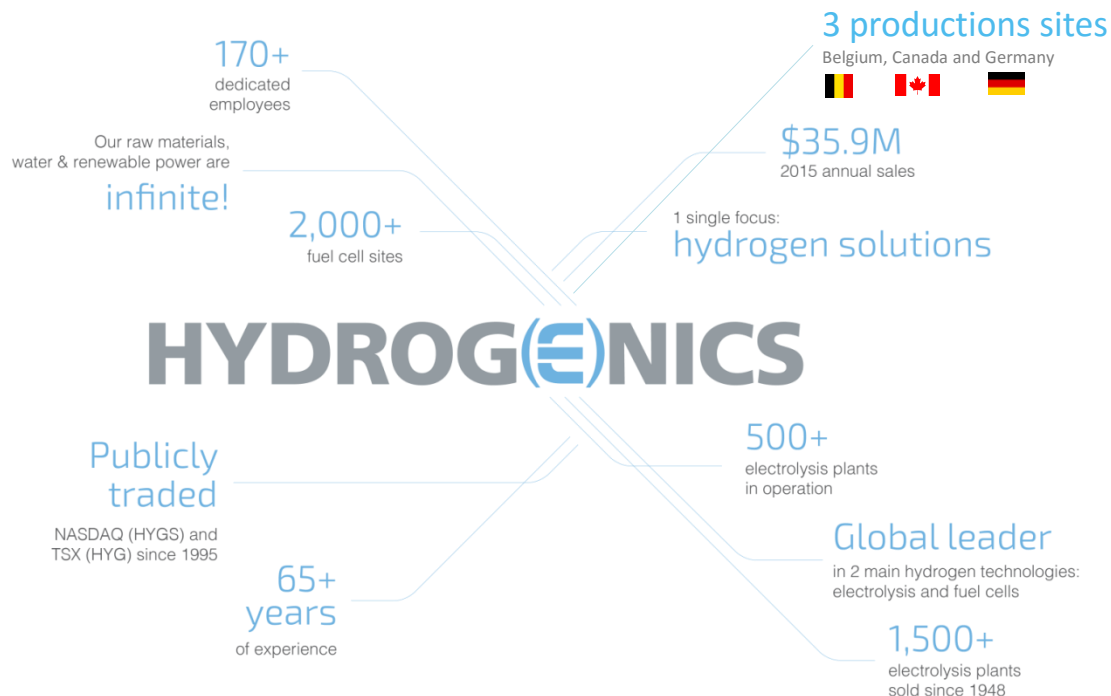
(+ HEAT)



Fuel cells

- Back-up power
- Stationary power
- Mobile power

Hydrogenics in Brief



ON-SITE HYDROGEN GENERATION

Electrolyzers

Industrial Hydrogen supply



POWER SYSTEMS

Fuel cells

Stand-by Power
Mobile Power Modules
MW Power Plants



RENEWABLE HYDROGEN

Energy Storage

Hydrogen Refueling Station
Power-to-X
Grid balancing services

Selection of 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



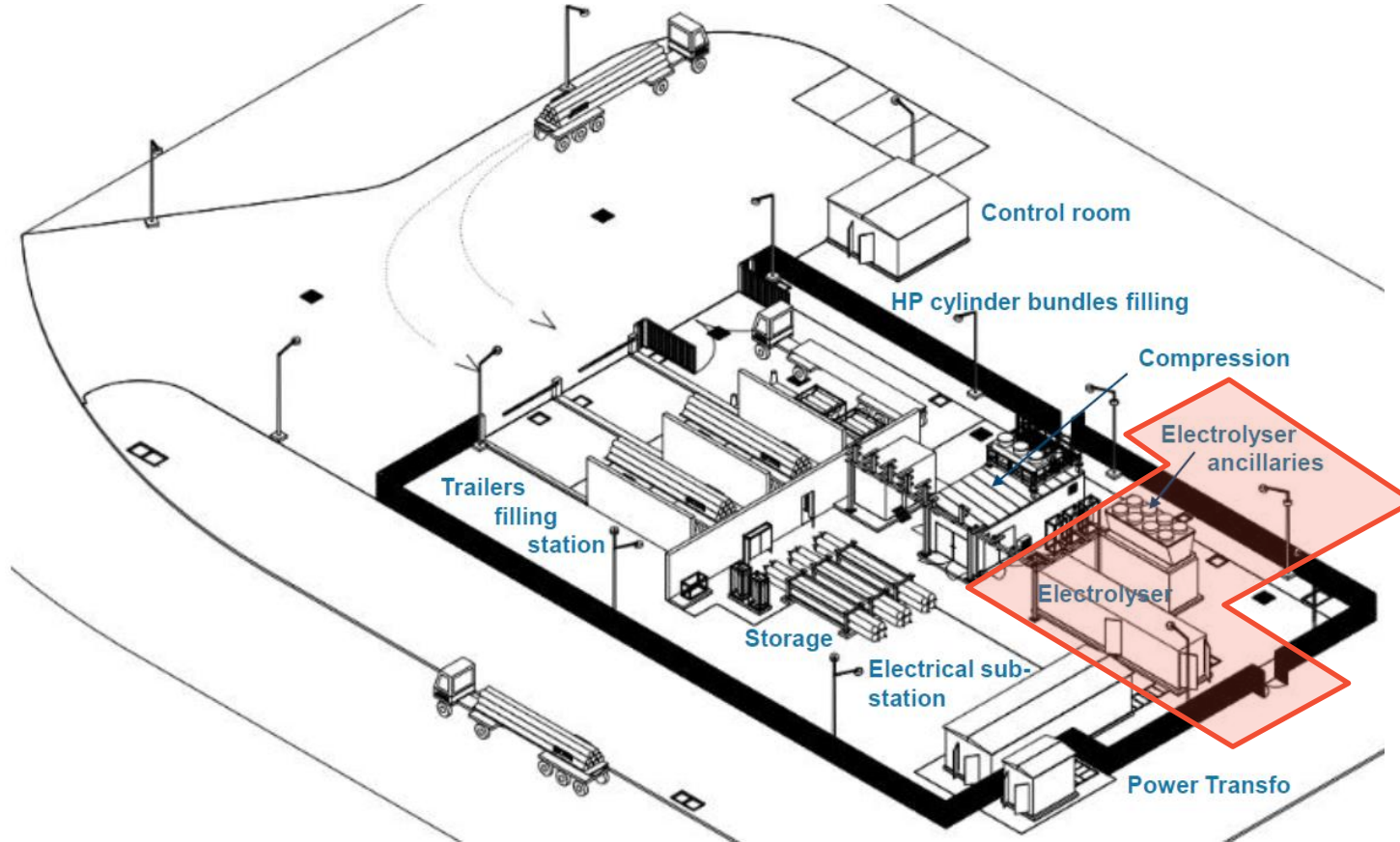
Fuel cell for mobility (H_2 airplane)
H2Fly, DLR, Germany

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Hydogenics' scope in HyBalance

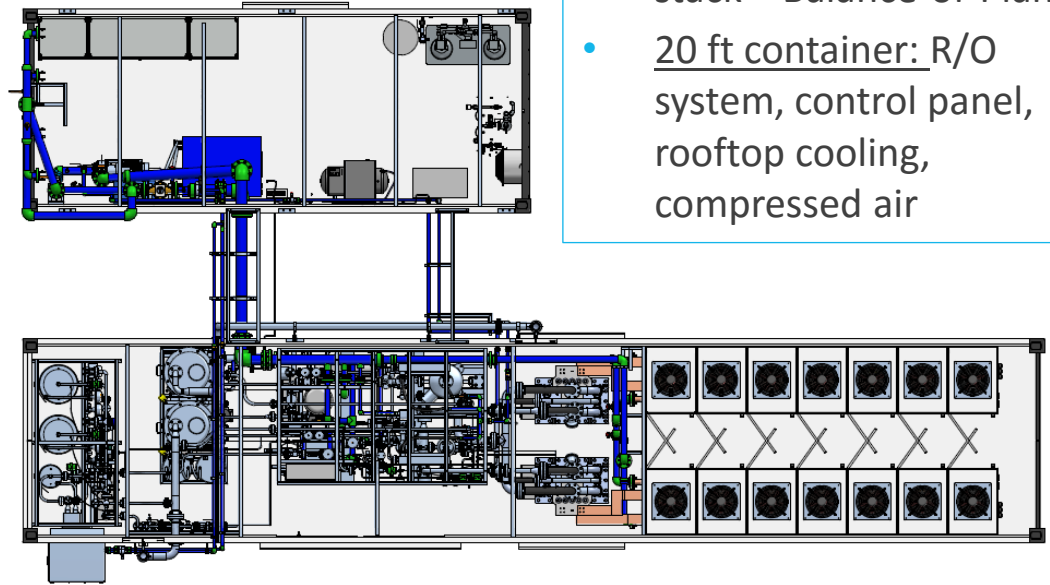
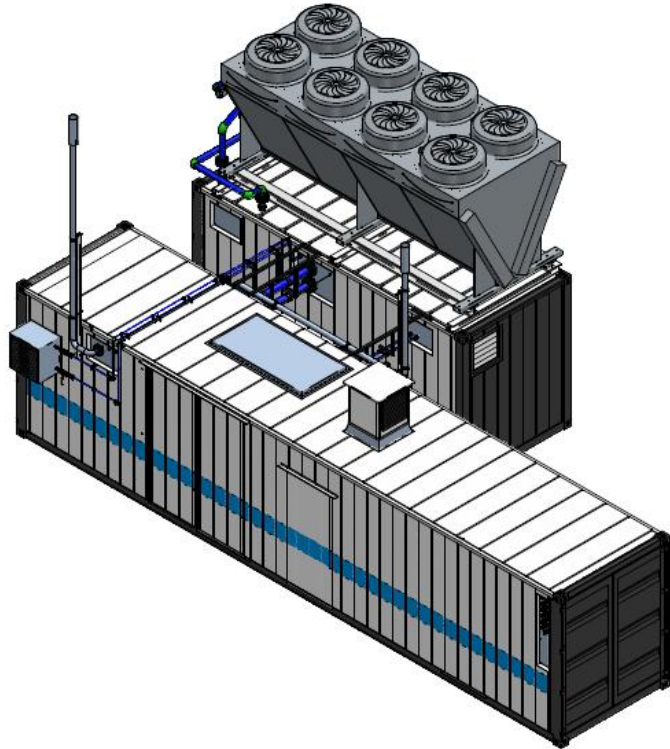
1.2 MW PEM electrolyser



Hydrogenics' scope in HyBalance

1.2 MW PEM electrolyser

- 40 ft container: power racks (rectifiers), dual cell stack + Balance-of-Plant
- 20 ft container: R/O system, control panel, rooftop cooling, compressed air



1.2 MW PEM electrolyser

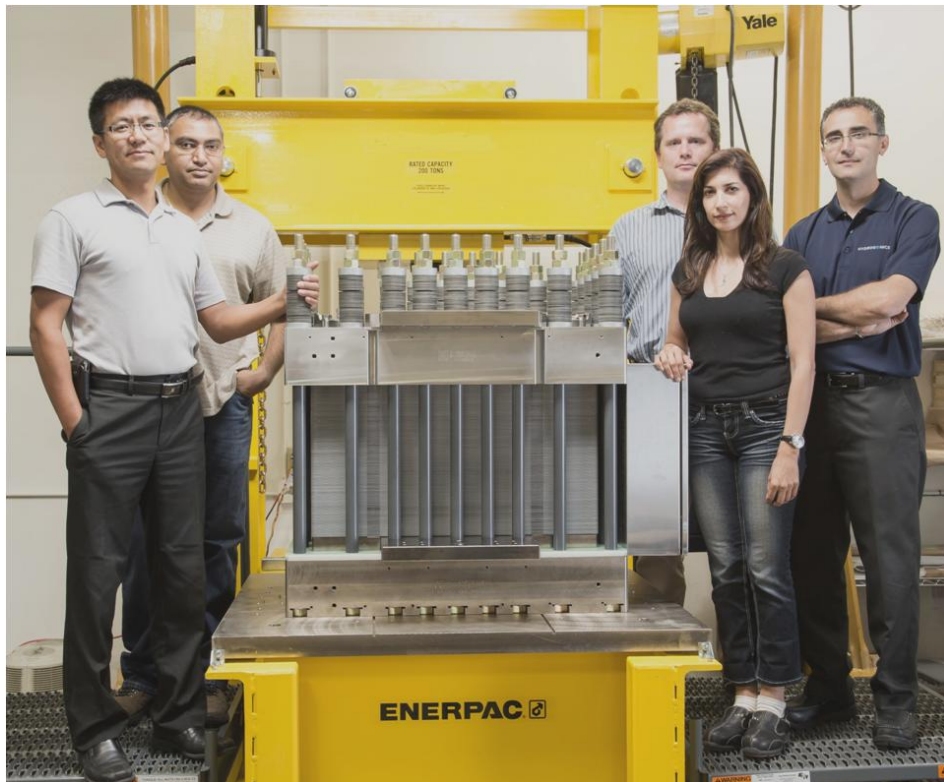
Technical specifications

- **Dual** high efficiency PEM cell stack designed for enhanced grid balancing
- Ideal for dynamic operation (connection with renewables)
 - PEM : 1-100% of operation range - no porosity in membrane
 - Response time in power soak: down to seconds
 - Fast response due to small footprint (warm-up + inertization)
- System efficiency: **5.3 kWh/Nm³** at nominal power (~58 kWh/kg)
- Lifetime: stack is designed for **>50.000 hours** of operation



1.2 MW PEM electrolyser

Why Proton Exchange Membrane (PEM)?



1

MW Scale Electrolyzer Stack

1.5MW industry benchmark

2

Reduction of Plant Capital Costs

Achieved target system cost

3

Stack Efficiency Improvements

Leading industry performance

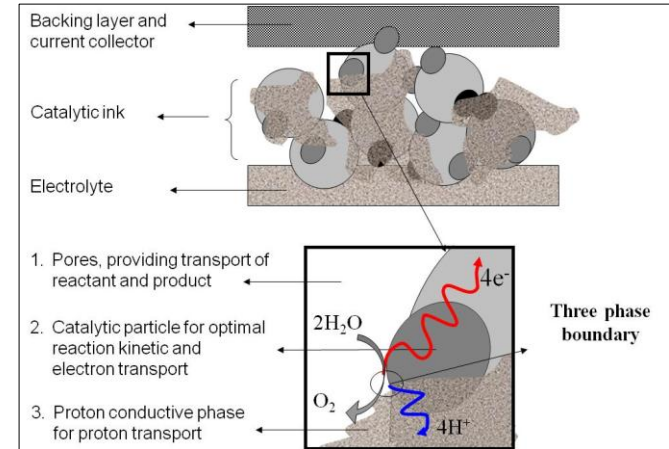
4

Fast Response and Dynamic Operation

Key IPR established

1.2 MW PEM electrolyser

Membrane-Electrode-Assembly (MEA) technology



- High purity
- >30 bar operational pressure
- 150 μm thick
- 2.3 A/cm²



1.2 MW PEM electrolyser

Hybalance electrolyser advancements

- **Environmental**
 - Minimal water to drain, minimal noise, minimal footprint
- **Design for fast response**
 - Power measurement, heated BOP, fast control loops
- **Design for high efficiency**
 - Frequency controlled utilities, dual stack
- **Design for grid support**
 - Low harmonic – high power factor – key IP AC/DC technology

HyBalance

A project which fits perfectly in our development roadmap

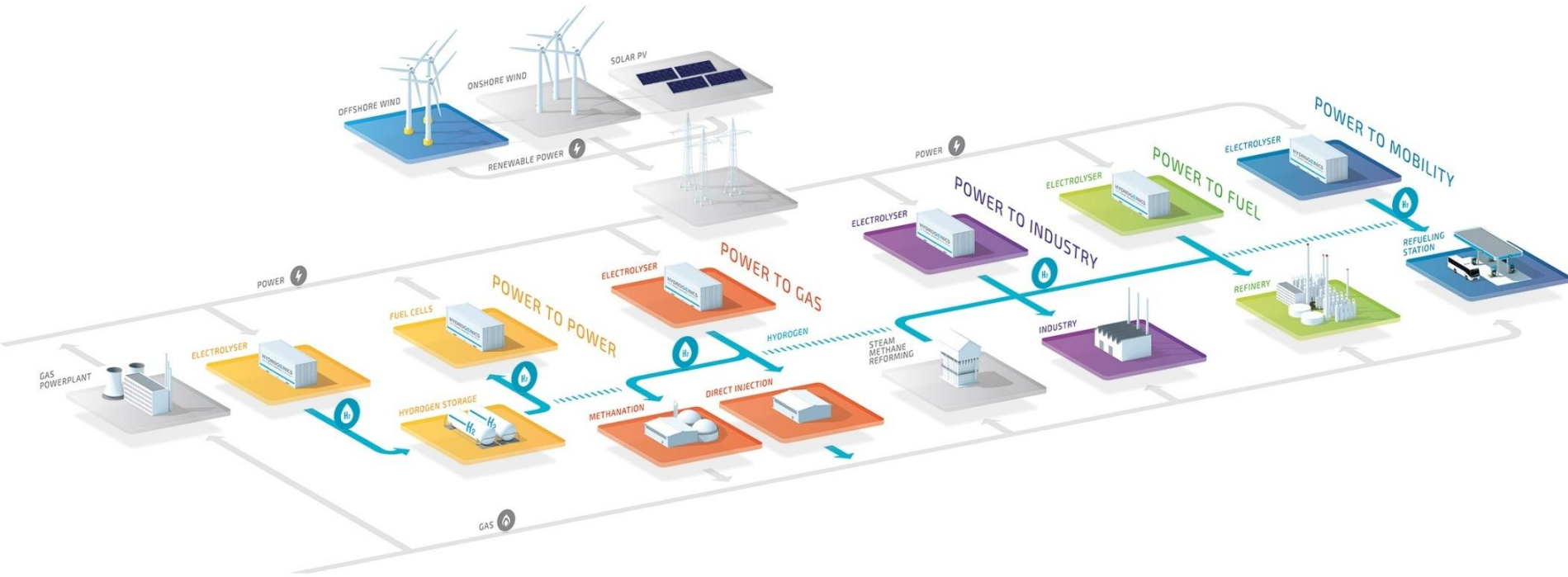
- Main trends:
 - From kW to MW
 - From alkaline to PEM
 - More stacks / BOP & More MW/ BOP (Balance-of-Plant)
 - Cost decreases with scale !

Commissing year	Project	Tech	Power	# stacks	BOP	# stacks / BOP	MW / BOP
2013	Falkenhagen	Alkaline	2 MW	24	6	4	0.33 MW
2016	BioCat	Alkaline	1 MW	12	2	6	0.5 MW
2015	Don Quichotte	PEM	150 kW	1	1	1	0.15 MW
2015	WindGas Reitbrook	PEM	1.5 MW	1	1	1	1.5 MW
2017	HyBalance	PEM	1.2 MW	2	1	2	1.2 MW
2018	???	PEM	10 MW	8	1	8	10 MW

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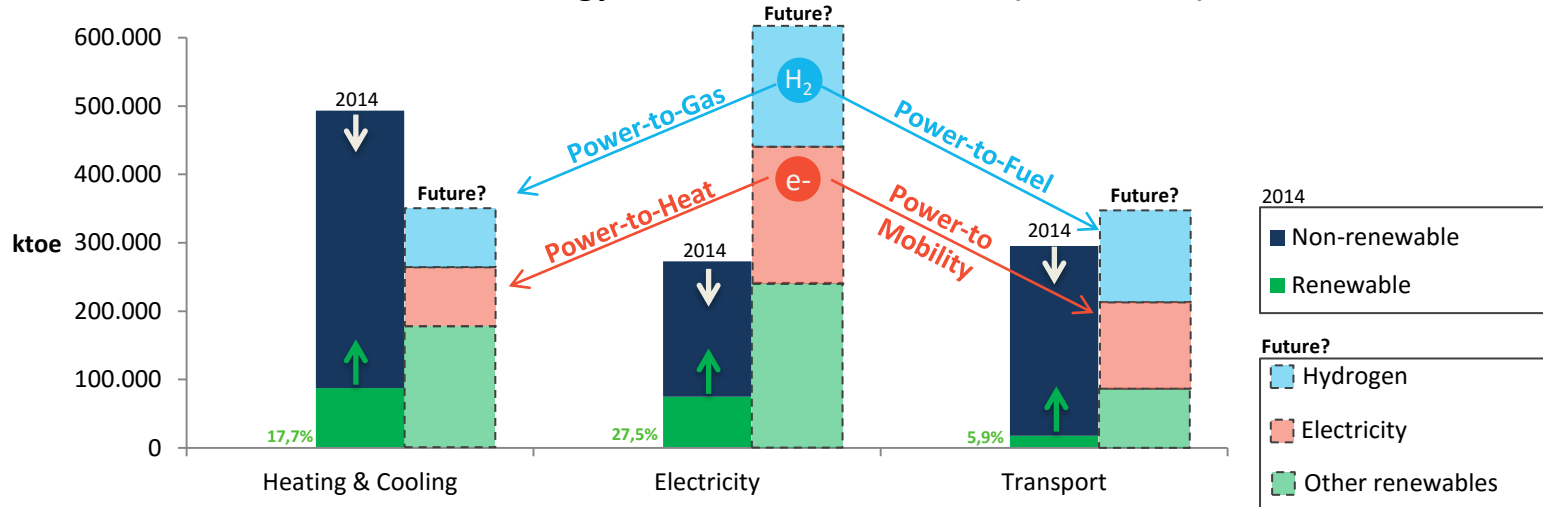
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Renewable Hydrogen: various valorization pathways

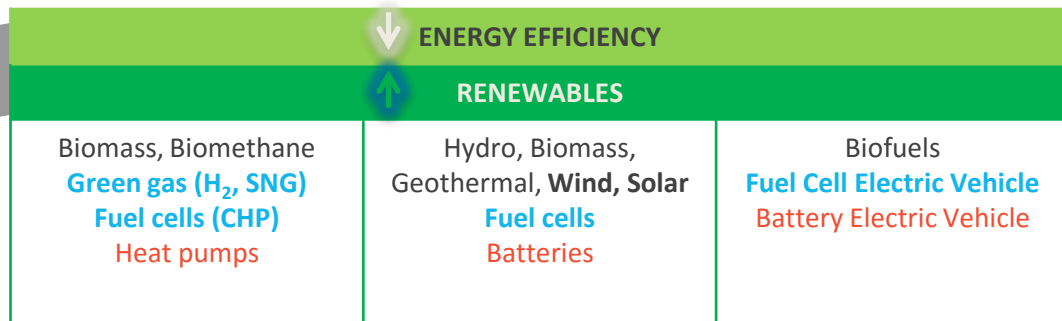


The role of energy vectors (electricity and hydrogen) in the decarbonisation of the EU energy system

Overall share of energy from renewable sources (EU28, 2014)

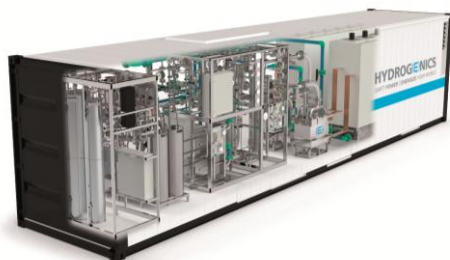


Decarbonisation options



How to unlock the potential of renewable hydrogen

- Find sites with suitable conditions “connecting all the dots”
 - Integrate the renewable power production in the economics and promote $\text{RES} \rightarrow \text{H}_2$ as a way to lock-in and future-proof transportation fleet fuel prices
 - Create market conditions for renewable hydrogen in regulation
 - Reducing the cost of the hydrogen technology by going very large scale.
- NB: Only the industry can provide a sufficient market to absorb large quantities of hydrogen



1.2 MW



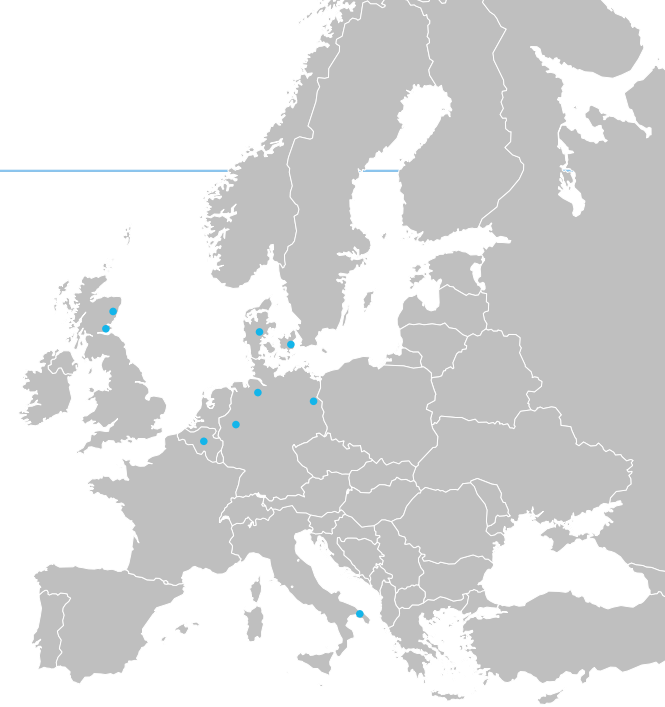
40 MW



Renewable hydrogen

Selection of recent demonstration projects

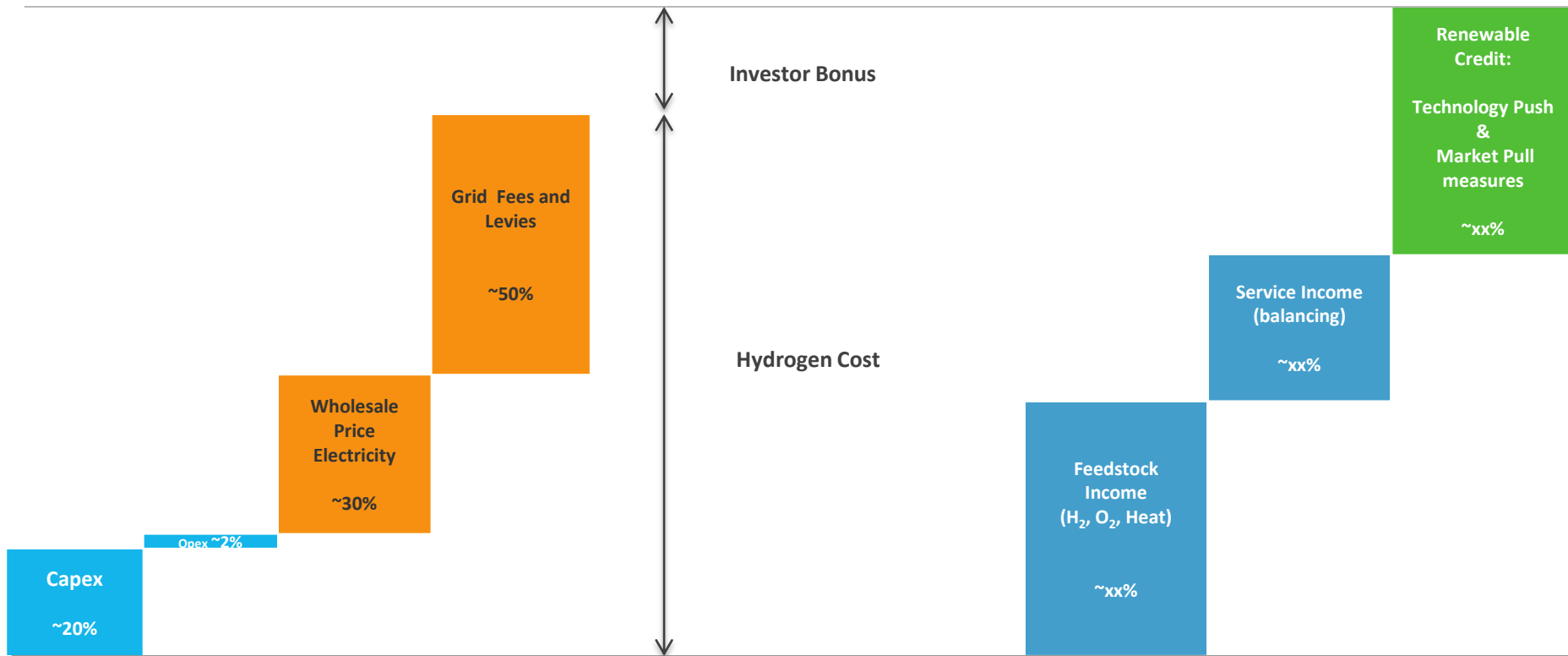
Country	Project	Size	Year	Electrolyser technology	Power	Gas	Industry	Mobility	Fuel
Thailand	EGAT	1.2 MW + 500 kW FC	2017	PEM	•				
Canada	Embridge P2G	2 MW	2017	PEM		•			
Germany	MefCO2	1 MW	2017	PEM					•
Denmark	HyBalance	1.2 MW	2017	PEM			•	•	
UK	Levenmouth	370 kW + 100 kW FC	2016	Alkaline + PEM	•			•	
Denmark	BioCat	1 MW	2016	Alkaline		•			
Italy	Ingrid	1 MW	2016	Alkaline	•	•	•		
UK	Aberdeen	1 MW	2016	Alkaline				•	
Germany	WindGas Reitbrook	1.5 MW	2015	PEM		•			
Canada	Raglan Nickel mine	350 kW + 200 kW FC	2015	Alkaline	•				
Belgium	DonQuichote	150 kW	2015	Alkaline + PEM	•			•	
Germany	WindGas Falkenhagen	2 MW	2014	Alkaline		•			



Main conclusions from these projects:

1. Hydrogen **technologies work fine** and deliver according to expectations.
2. There is still room for further technical improvement but **no technology breakthrough is expected**.
3. There is a important potential for further **cost reduction**: going from project manufacturing to product manufacturing
4. Energy **regulatory framework is no suited** for these applications and **business operation** of these projects **remains very challenging**

Business case drivers & The need to recognise the added value of renewable hydrogen



Necessary EU regulatory framework

- Clean Energy Package published by the EU Commission (2020-2030)
- Recast Renewable Energy Directive will be the key directive for hydrogen !
- What do we need:
 - Certification mechanism for renewable hydrogen (the 'green button')
 - Added value for final consumer to use renewable hydrogen
 - Large scale applications : industry, fertilizer / fuel production
 - Reduce cost (through mass market/production): project → product manufacturing
 - Level playing field remunerating grid flexibility
 - Political support !

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Alkaline & PEM electrolysis | Product's line

Alkaline



HySTAT®-15-10/30 HySTAT®-60-10 HySTAT®-100-10

Output pressure	10 barg – 27 barg		
Number of cell stacks	1	4	6
Nominal hydrogen flow	15 Nm³/h	60 Nm³/h	100 Nm³/h
Nominal input power	80 kW	300 kW	500 kW
AC power consumption (utilities included, at nominal capacity)	5.0-5.4 kWh/Nm³		
Hydrogen flow range	40-100%	10-100%	5-100%
Hydrogen purity	99.998% O ₂ < 2 ppm, N ₂ < 12 ppm (higher purities optional)		
Tap water consumption	<1.7 liters / Nm³ H ₂		
Footprint	20 ft container	40 ft container	40 ft container

PEM (Proton Exchange Membrane)



HyLYZER® -100-30 HyLYZER® -400-30 HyLYZER® -3,000-30

Output pressure	30 barg		
Number of cell stacks	1	2	10
Nominal hydrogen flow	100 Nm³/h	400 Nm³/h	3,000 Nm³/h
Nominal input power	500 kW	2 MW	15 MW
AC power consumption (utilities included, at nominal capacity)	5.0-5.4 kWh/Nm³		
Hydrogen flow range	1-100%		
Hydrogen purity	99.998% O ₂ < 2 ppm, N ₂ < 12 ppm (higher purities optional)		
Tap water consumption	<1.4 liters / Nm³ H ₂		
Footprint	40 ft container	40 ft + 20 ft container	600 m² (indoor)

Final words

- Special thanks to FCH-JU, ForskEL (Energinet.dk), Air Liquide and all project partners
- Hydrogenics is leader in clean hydrogen technologies and ready for massive market deployment
- State of the art PEM electrolyser technology developed for HyBalance will help us to build the multi-MW systems needed for the energy transition
- Appropriate regulatory framework and political support are required !

www.hybalance.eu

Thank you for your attention



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