



HYDROG(E)NICS

SHIFT POWER | ENERGIZE YOUR WORLD

“EXPERIENCES WITH POWER-TO-GAS TECHNOLOGIES
IN INTERNATIONAL PROJECTS”

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Electrochemical Conversion & Materials

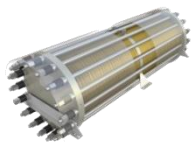
The Hague, June 29, 2018

Introduction video



<https://youtu.be/UJXhX4dLMtA>

Leading Hydrogen TECHNOLOGY PROVIDER



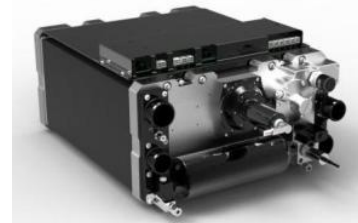
Onsite Generation | Electrolysers



Industrial Hydrogen



Hydrogen Fueling



Power Systems | Fuel Cell Modules



Stationary Power



Mobility Power

Hydrogenics, a 100% global hydrogen company

Hydrogenics Corporation



- **Headquarter**
- Mississauga, Ontario, Canada
- Since 1948
- +/- 70 employees
- Areas of expertise: Fuel cells, PEM electrolysis, Power-to-Gas
- Previously: The Electrolyser Company, Stuart Energy

Hydrogenics Europe



- Oevel, Belgium
- Since 1987
- +/- 70 employees
- Areas of expertise: pressurized alkaline electrolysis, hydrogen refueling stations, Power-to-Gas
- Previously: Vandenborre Hydrogen Systems

Hydrogenics GmbH



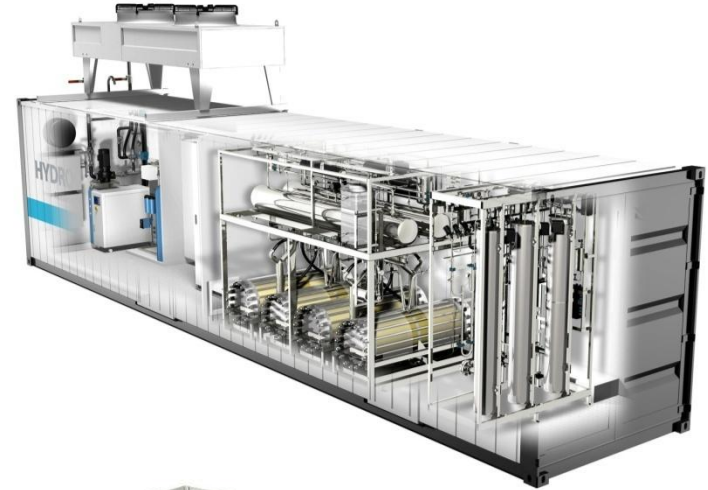
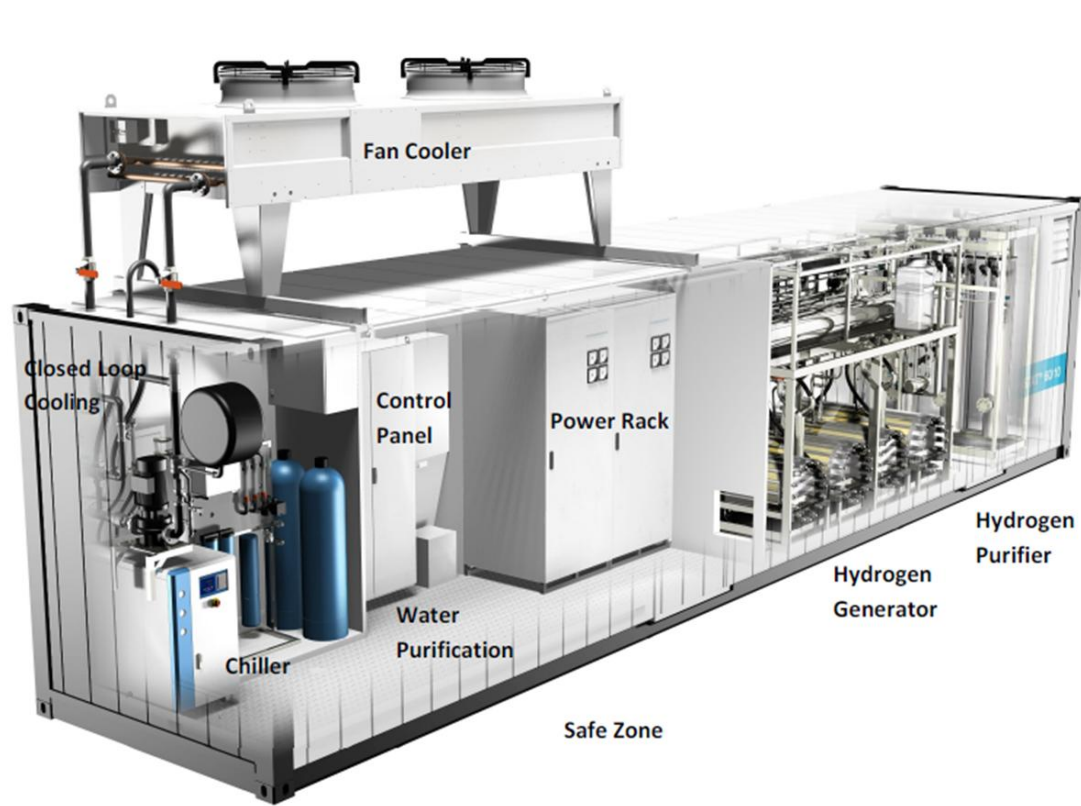
- Gladbeck, Germany
- Since 2002
- +/- 15 employees
- Areas of expertise: Fuel cells, mobility projects, Power-to-Gas

- In total: +170 employees
- Incorporated in 2000 [NASDAQ: HYGS; TSX: HYG]
- More than 3,000 products deployed in 100 countries worldwide
- Total revenues (2017): 48.1 Mio \$
- Over 65 years of electrolysis leadership

● Production facility

○ Sales office

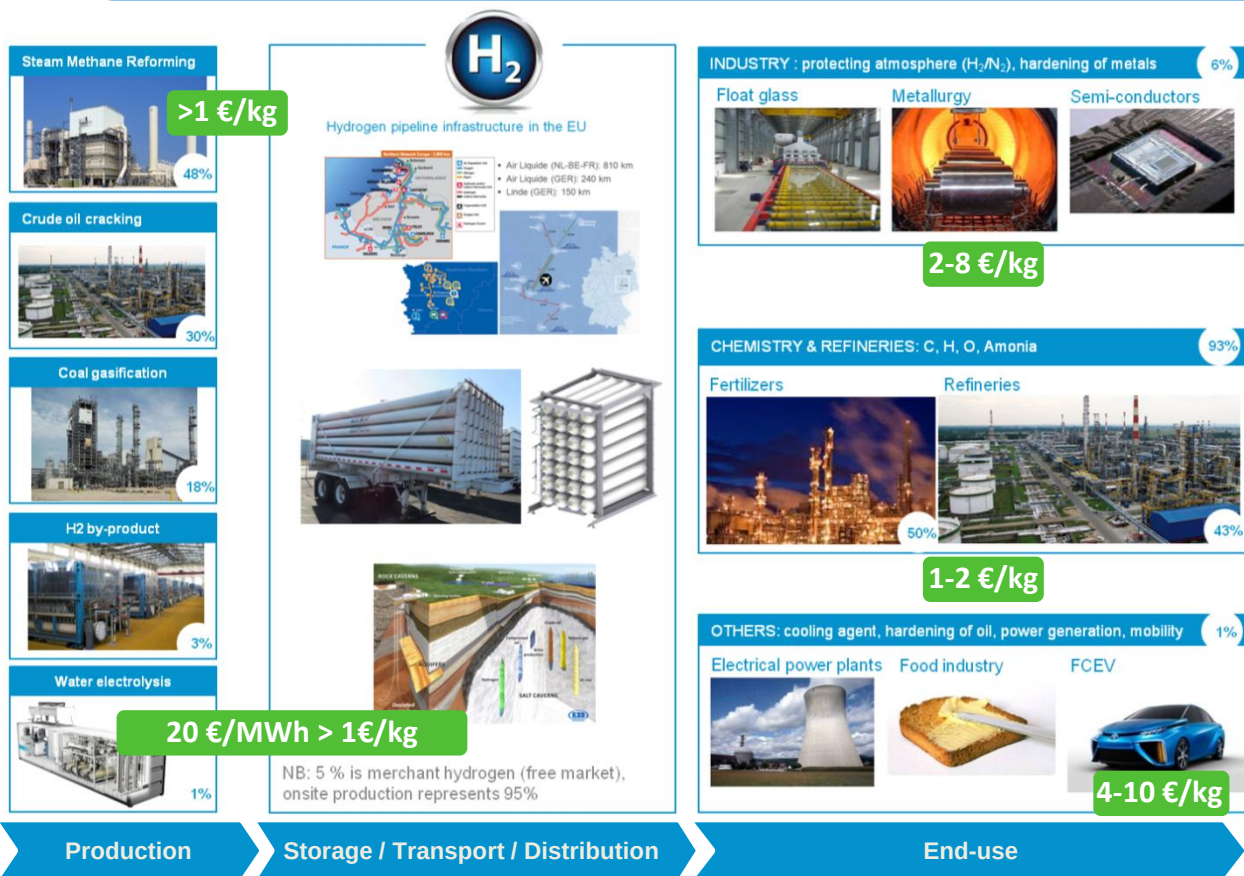
HySTAT™ 60 - alkaline electrolyser



Extensive experience with alkaline technology



World hydrogen market



But most (96%) of the hydrogen produced today is not CO₂-free (from gas, oil, coal)



If produced from renewable power via electrolysis, hydrogen is fully renewable and CO₂-free.



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

HyLYZER® - PEM : key milestones @ Hydrogenics

+15 MW



Test large stack



Field test 1.5 MW electrolyser



2.5/3 MW cell stack



1999

2004

2012

2014

2015

2017

2018

...



Small scale PEM electrolyser



1,5 MW cell stack



Dual cell stack design



Multi MW design

New benchmark in PEM electrolysis HyLYZER®-600

3 MW cell stack from Hydrogenics for multi-MW projects

1

MW Scale Electrolyzer Stack

3.0 MW industry benchmark

2

Reduction of Plant Capital Costs

Achieved target system cost

3

Stack Efficiency Improvements

Leading industry performance



Power Input: 3.0 MW
Hydrogen Output: 620 Nm³/h
Design Pressure: 40 bar

Power Input: 1.5 MW
Hydrogen Output: 310 Nm³/h
Design Pressure: 40 bar

4

Fast Response and Dynamic Operation

Key IPR established

5

Very compact

Lowest footprint on the market

6

Reduced Maintenance

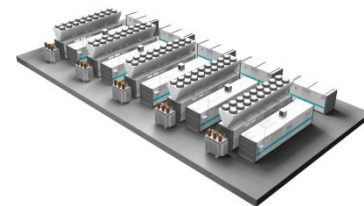
Limited and optimised

Alkaline & PEM electrolysis | Product's line

Alkaline

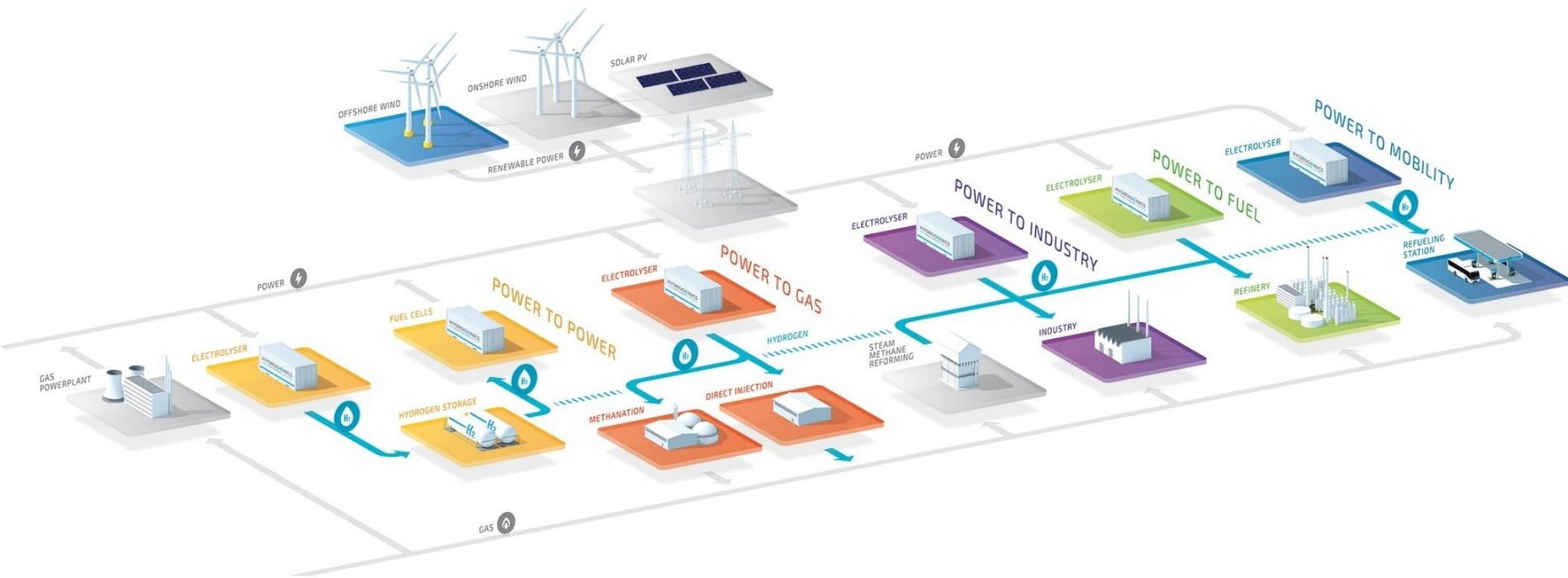


PEM (Proton Exchange Membrane)



	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 Nm ³ /h	60 Nm ³ /h	100 Nm ³ /h	300 Nm ³ /h	1.000 Nm ³ /h	5.000 Nm ³ /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/Nm ³			5.0-5.4 kWh/Nm ³		
Hydrogen flow range	40-100%	10-100%	5-100%	1-100%		
Hydrogen purity	99.998% O ₂ < 2 ppm, N ₂ < 12 ppm (higher purities optional)			99.998% O ₂ < 2 ppm, N ₂ < 12 ppm (higher purities optional)		
Tap water consumption	<1.7 liters / Nm ³ H ₂			<1.4 liters / Nm ³ H ₂		
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

Renewable Hydrogen



BioCat, Avedøre, Denmark (2016)

Biological methanation and SNG injection in distribution gas grid



BioCatProject
POWER-TO-GAS VIA BIOLOGICAL CATALYSIS

www.biocat-project.com

1 MW
Alkaline
Reduced
footprint



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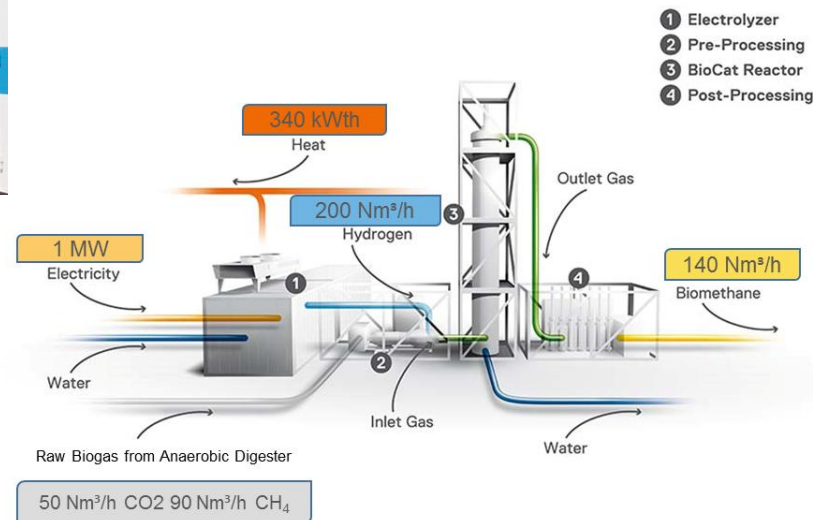


INSERO
BUSINESS SERVICES



NEAS ENERGY

HYDROGENICS
SHIFT POWER | ENERGIZE YOUR WORLD



HyBalance, Hobro, Denmark (construction in 2017)

Industrial hydrogen and delivery to hydrogen refueling stations

1.2 MW
PEM
Dual stack

OBJECTIVES

- Validate the highly dynamic PEM electrolysis technology in a real industrial environment and provide grid balancing services on the Danish power market
- Validate innovative hydrogen delivery processes for fueling stations at high pressure

SOLUTION

- 1x HyLYZER®-230-30 (PEM, dual cell stack design) with all peripherals to produce 230 Nm³/h H₂ (power: 1,2 MW)

PARTNERS:

- This project receives financial support FCH-JU (GA No 671384) and ForskEL program, administered by Energinet.dk.



- More information: www.hybalance.eu



MEFCO₂, Niederaußem (Germany)

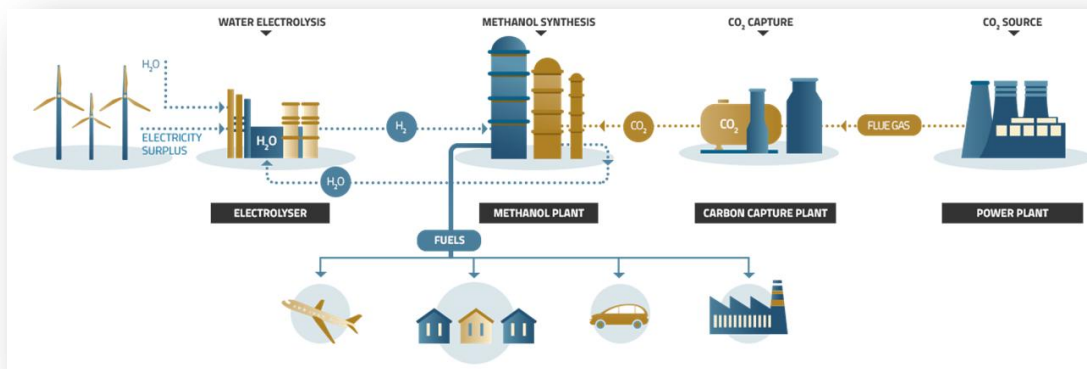
Power-to-Methanol

OBJECTIVES

- Produce **green methanol** as energy vector from captured CO₂ and hydrogen produced using surplus renewable energy.
- Existing post-combustion pilot CO₂ plant at coal power plant of RWE
- Flexible operation (RES driven)

SOLUTION

- 1x HyLYZER®-200-30 (PEM, single cell stack design) with all peripherals to produce 200 Nm³/h H₂ (power: 1 MW)



PARTNERS:



- This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement (No 637016).

- More information: www.mefco2.eu

Renewable hydrogen

Selection of recent demonstration projects



Country	Project	Size	Year	Electrolyser technology	Power	Gas	Industry	Mobility	Fuel
Norway	Haeolus	2 MW + 100 kW FC	2018	PEM	•				
Germany	MefCO2	1 MW	2018	PEM					•
Germany	WindGas Brunsbüttel	2.4 MW	2017	PEM		•			
Thailand	EGAT	1 MW + 300 kW FC	2017	PEM	•				
Canada	Embridge P2G	2.4 MW + 100 kW FC	2017	PEM		•			
Denmark	HyBalance	1.2 MW	2017	PEM			•	•	
Denmark	BioCat	1 MW	2016	Alkaline		•			
Italy	Ingrid	1 MW + 100 kW FC	2016	Alkaline	•	•	•		
UK	Aberdeen	1 MW	2016	Alkaline				•	
Germany	WindGas Reitbrook	1.5 MW	2015	PEM		•			
Belgium	DonQuichote	150 kW + 100 kW FC	2015	Alkaline + PEM	•			•	
Germany	WindGas Falkenhagen	2 MW	2014	Alkaline		•			

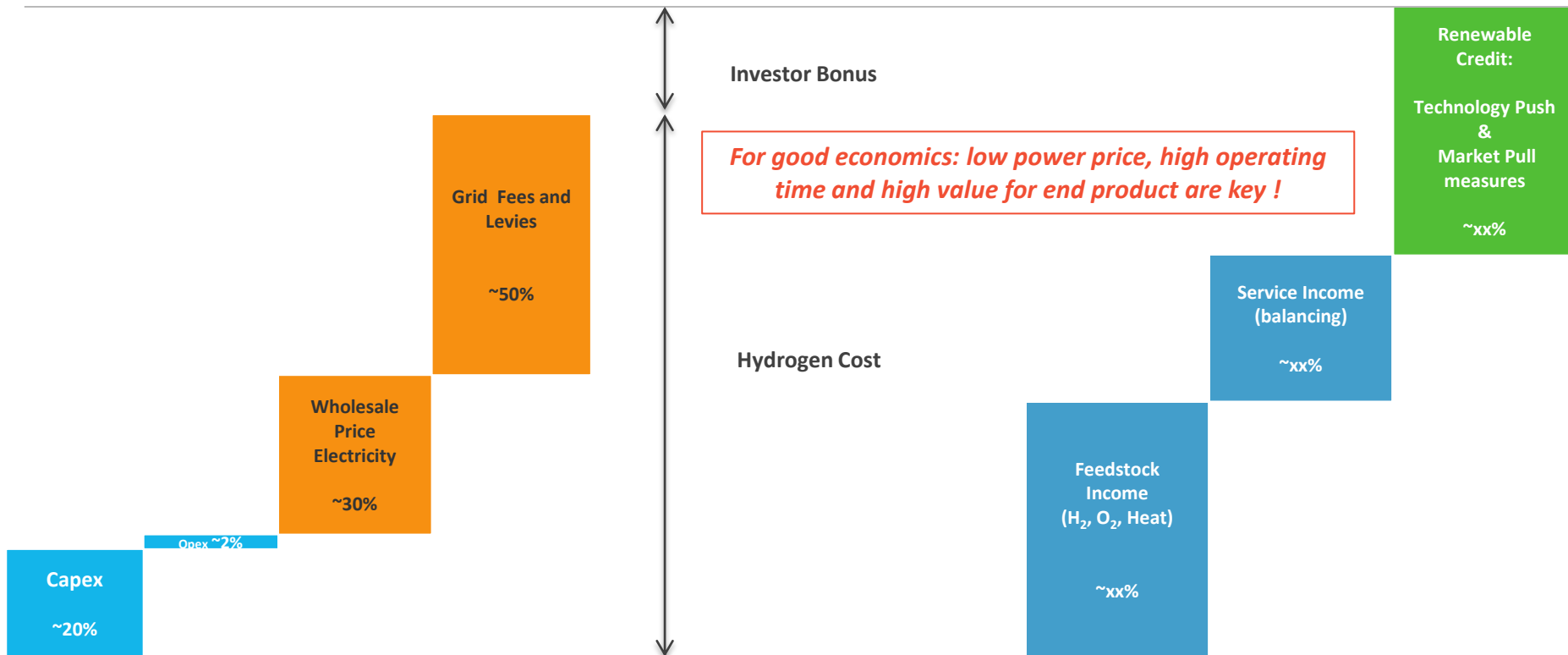


Main conclusions from these projects:

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

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



Concluding messages

- Hydrogen and Fuel Cell (FCH) **technologies are mature and ready**
- **Massive cost reduction is expected** for FCH technologies : from project to product manufacturing & product up scaling
- Massive **CO₂ reduction potential in power, gas, transport and industry**
- For a large deployment of FCH technologies, **a favorable regulatory framework is needed** (EU and national) containing (at least)
 1. Green hydrogen certification mechanism
 2. Premium value for end product / application
 3. Access to renewable electricity at low cost
 4. Grid connection to deliver balancing services

Thank you for your attention



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