

NEED FOR C

ROLE OF HYDROGEN AND FUEL CELLS IN MARITIME SECTOR

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16 June 2017

ABOUT HYGEAR

Clean tech company

- Gas processing and industrial gas system design

Strong financial performance and autonomously financed

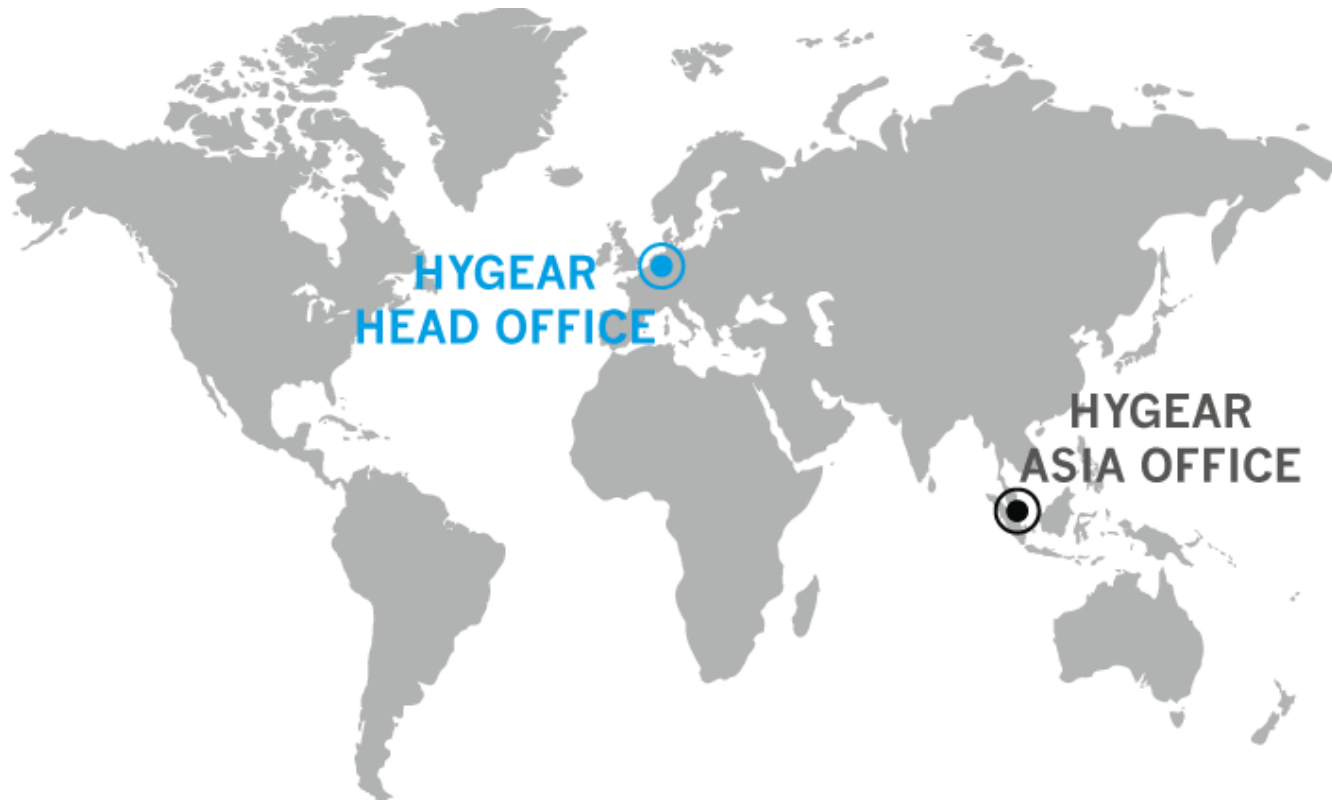
Focused company (65 people)

History

- 2002 Established
- 2006 HyGEN5 release
- 2009 Take-over fuel cell activities Plug Power Europe
- 2010 HyGEN50 release
- 2013 BioGas upgrading release
- 2016 O.GEN, N.GEN releases
- 2017 H₂ Filling site operational

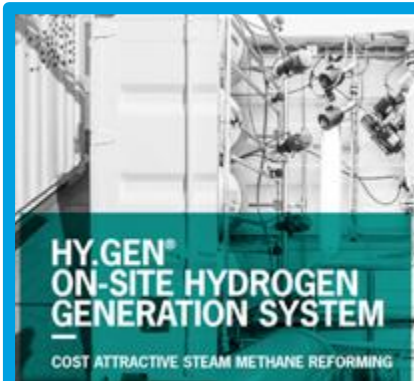


GLOBAL PRESENCE AND SUPPORT



Local offices in Europe & Asia, with partnerships for back-up supply and a complete portfolio of Industrial Gases

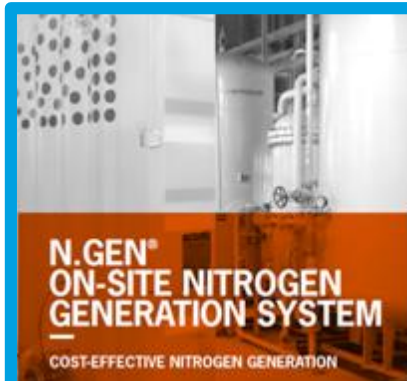
OUR TECHNOLOGY BACKBONE



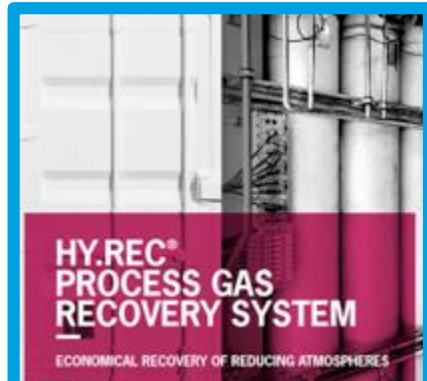
**STEAM
METHANE
REFORMING**



**LOW
PRESSURE
AIR
SEPARATION
BY VPSA**



**LOW
PRESSURE
AIR
SEPARATION
BY VPSA**



**IN-LINE
RECOVERY OF
SPENT GAS**



OUR DISTINCT ADVANTAGE



Combining advanced on-site generation with traditional supply

**COST
SAVINGS**



**RELIABLE
SUPPLY**



**INCREASED
SAFETY**



**REDUCED
EMISSIONS**



WORLD-WIDE SALES



SOME EXAMPLES

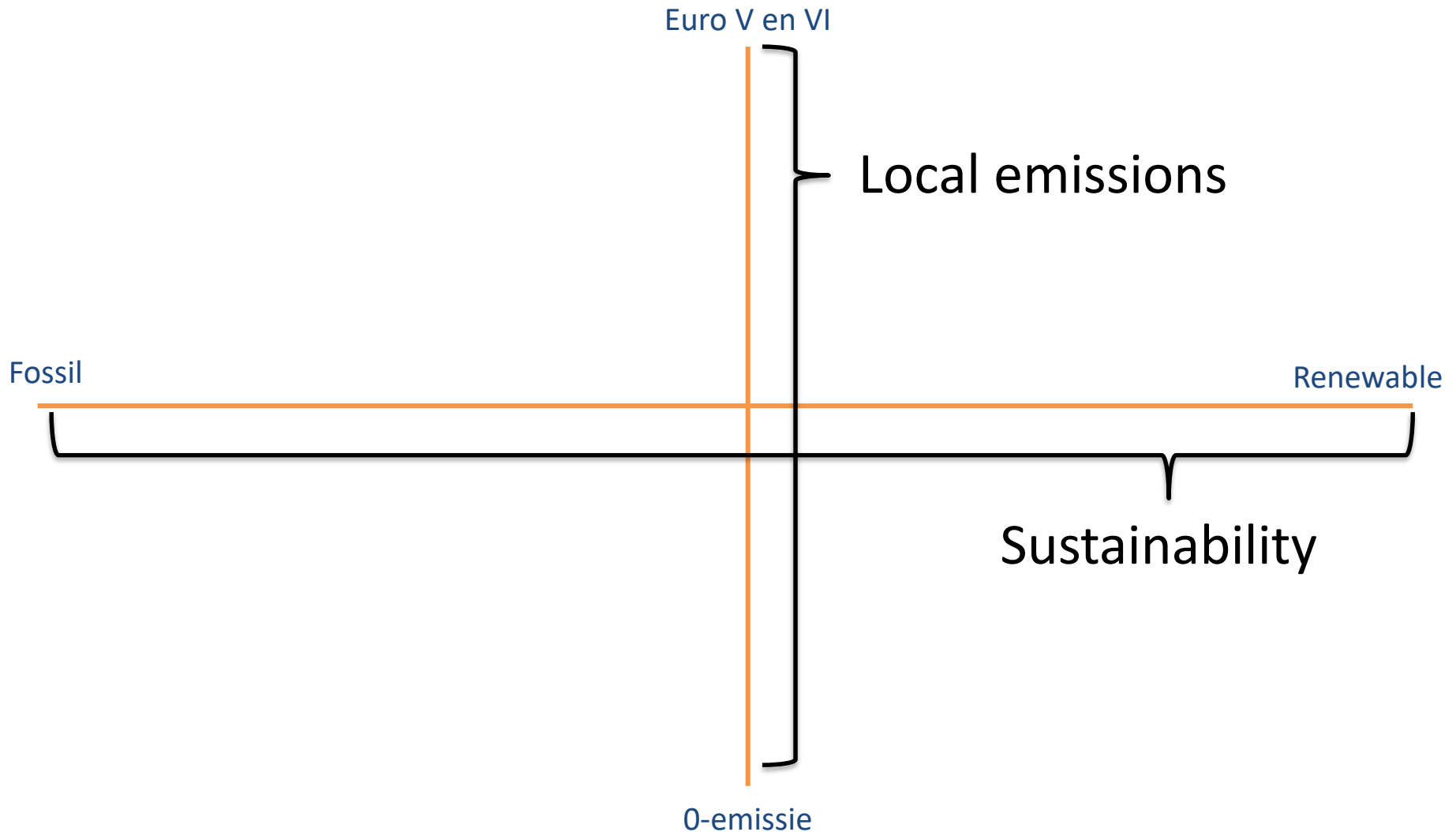


REFERENCE CUSTOMERS

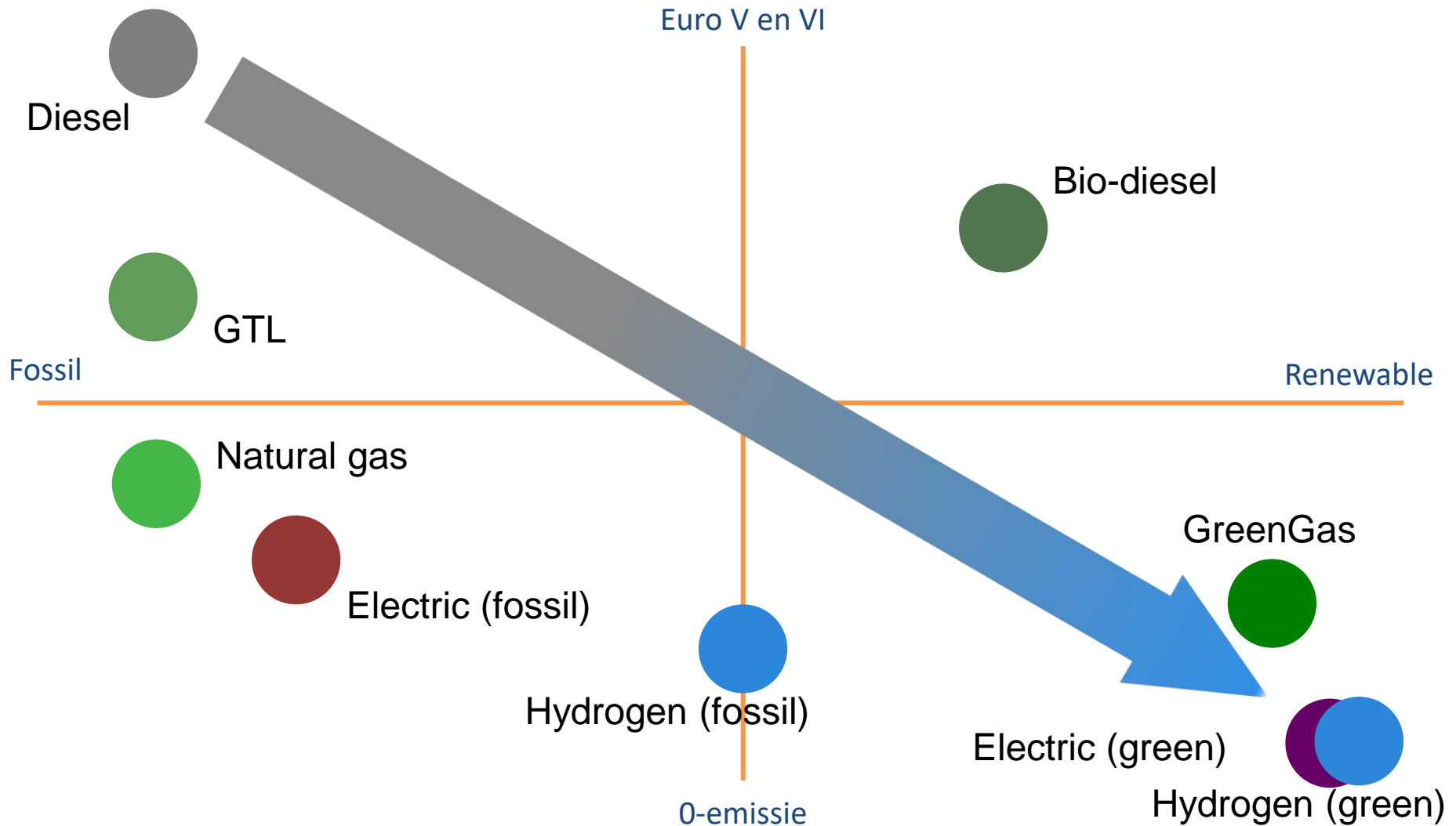


TRANSPORT FUELS OF THE FUTURE

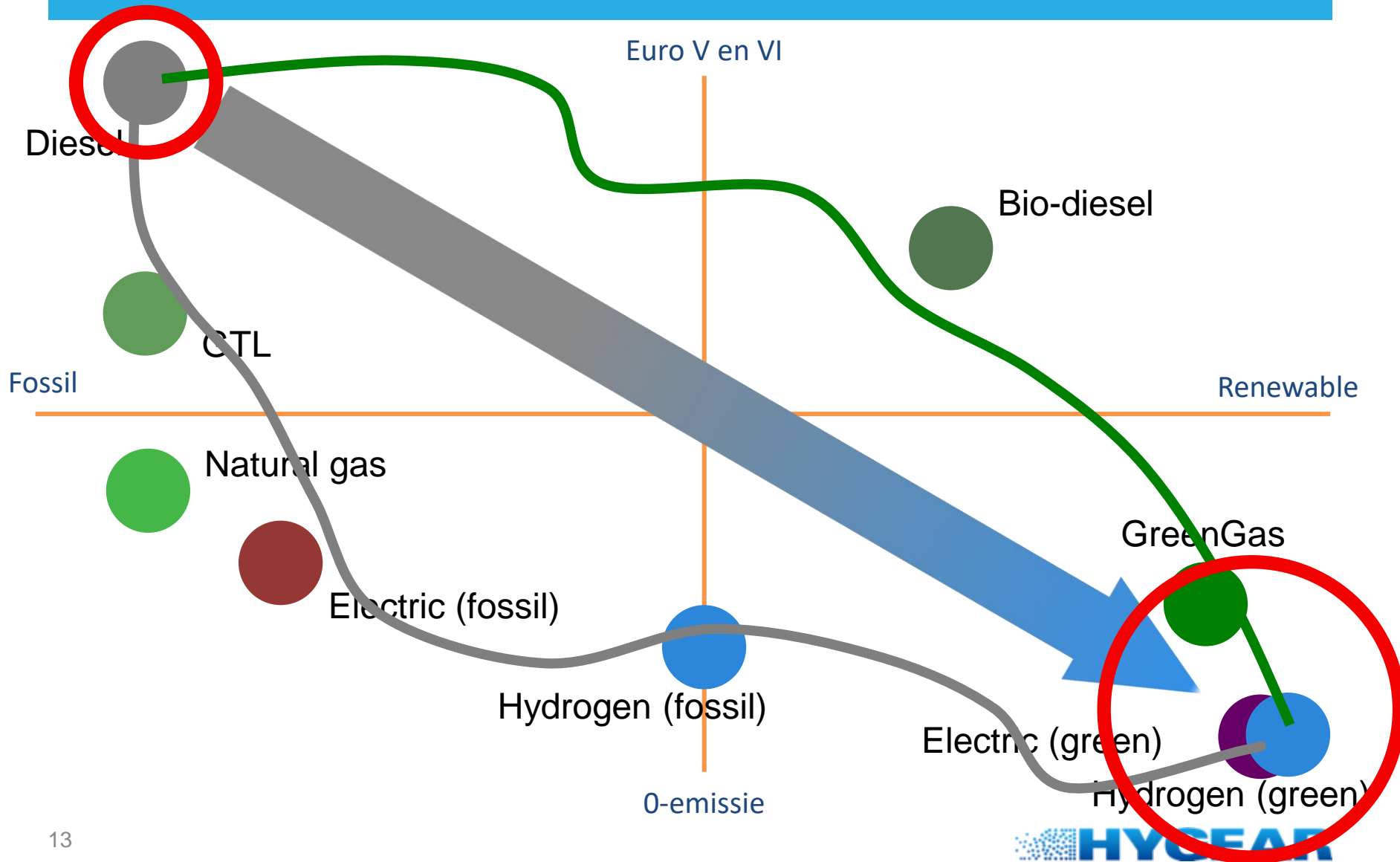
TRANSPORT WELL-TO-WHEEL DIRECTION



TRANSPORT WELL-TO-WHEEL DIRECTION



DIRECTION IS CLEAR: WHAT WILL BE ROUTE?



CHOOSE DIRECT PATH?

From diesel/oil to hydrogen:

- Shortest, but not fastest, cleanest or cheapest path
- Not a logical transition path
 - Requires vehicle, engine, legislative and infra changes
 - Upfront investments huge
 - Requires collaboration / cooperation

GreenGas

Diesel/oil

Green
Electricity

Hydrogen

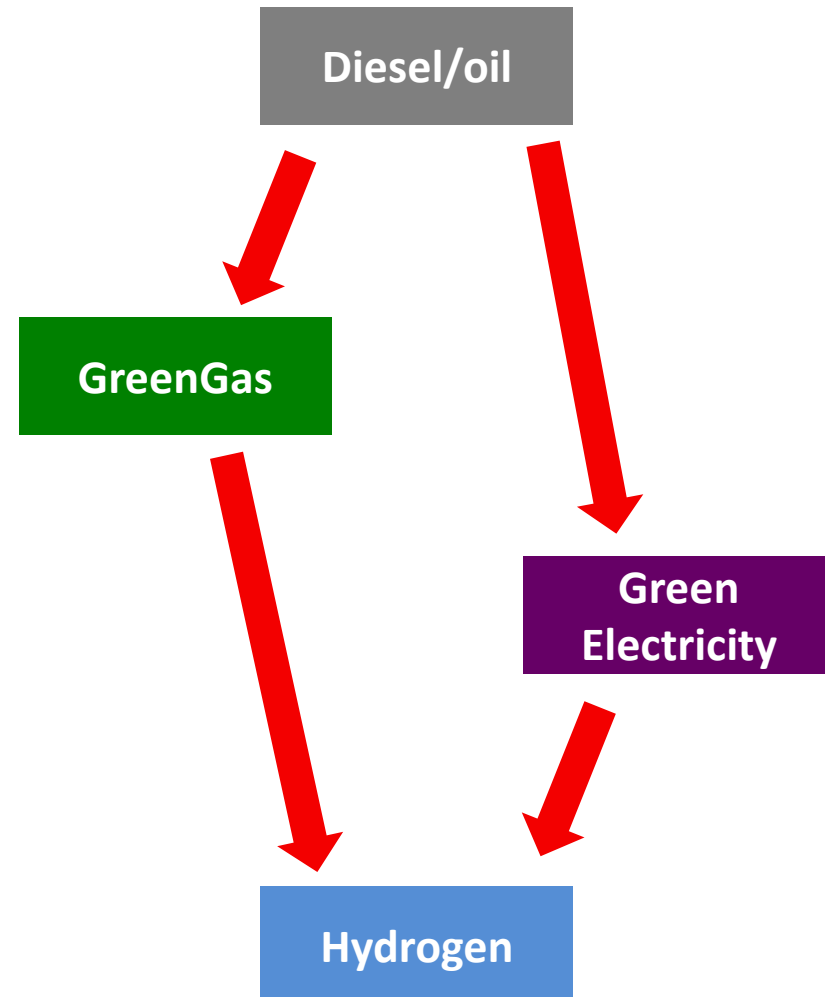
TRANSITION VIA GREEN ELECTRICITY AND —GREEN GAS

Via GreenGas:

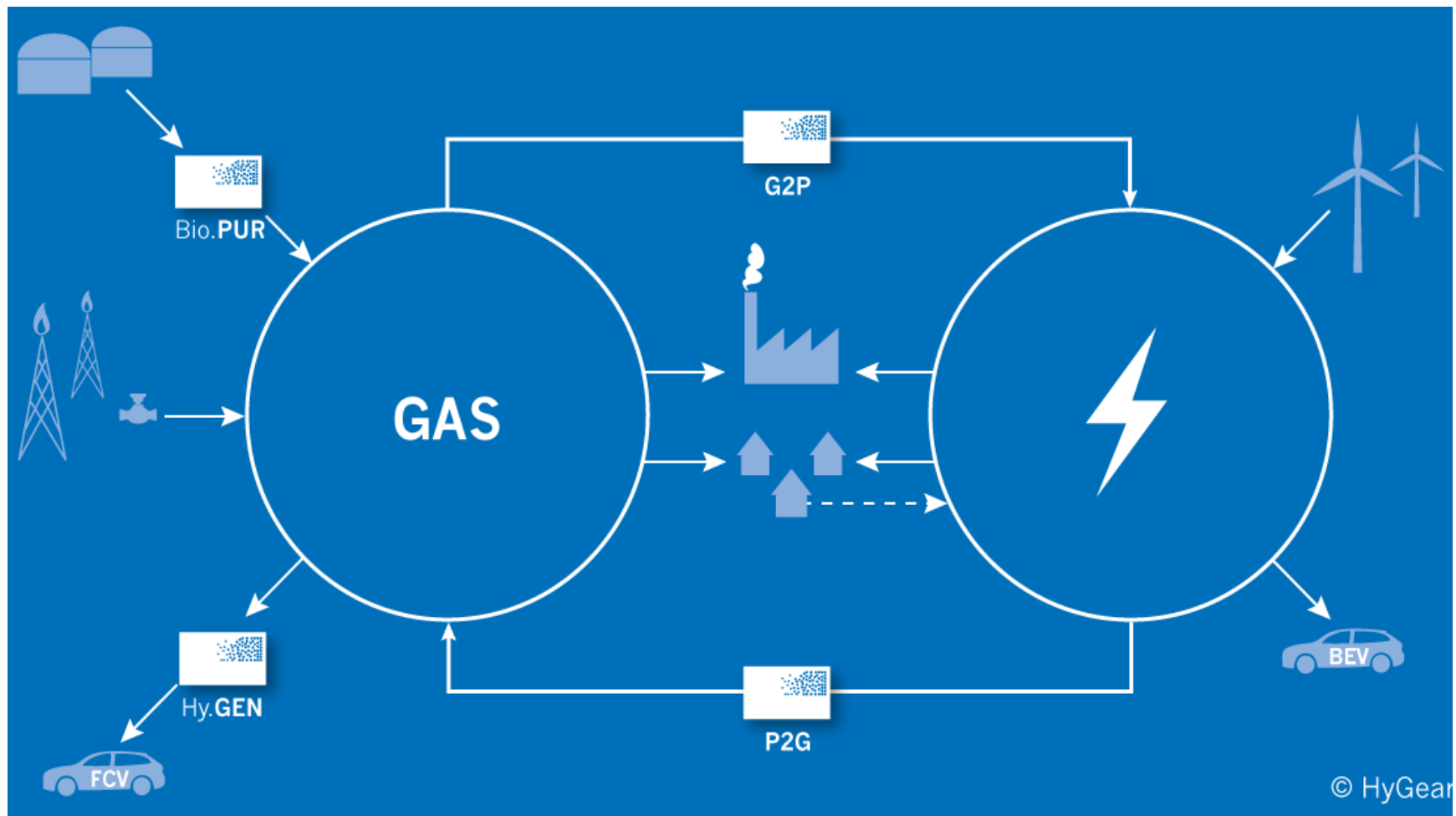
- Direct large environmental benefits
- Direct and broadly usable (CNG/LNG)
- TCO comparable to diesel
- Supports transition towards hydrogen by improving gas technology
- Connect biobased industry and hydrogen

Via Green Electricity:

- Urban use, Ferry use
- Limited usability
- TCO much higher than diesel
- Supports transition to hydrogen by improving electro-technology
- Connect electricity industry and hydrogen



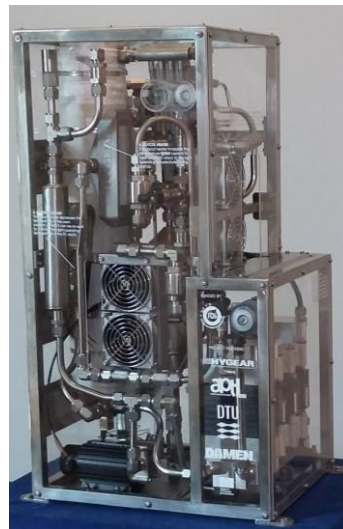
FUTURE ENERGY VISION HYGEAR



TECHNOLOGY DEVELOPMENTS

Gas 2 power – Fuel Cell Systems

- CHP system in collaboration with ATAG Heating
 - SOFC
 - PEM
- APU
 - SOFC
 - PBI



TECHNOLOGY DEVELOPMENTS

Power to X

SOE electrolyser systems

- In collaboration with SOLIDpower, Sunfire



Power to Liquid / gas

- Fischer Tropsch / Sabatier
- Based on flare gas
- Based on solar power
- Based on electricity



MARITIME PROJECTS

pure  FCH-JU, GA 303457)

- APU for recreational yachts, 500We
- 2013 – 2016

DAMEN



HySEAS (Dutch project)

- On board power for coasters, 200-300kWe
- 2010 – 2014

DAMEN



(FP7, GA 605190)

- Ultralow emission shipping
- 2013 - 2017



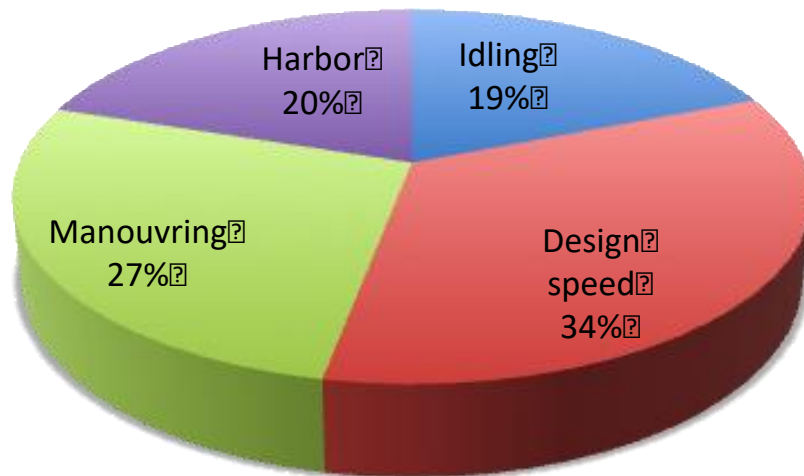
SECTORS MOST SUITED FOR FC

Ferries (8% of WW shipping CO₂)

- 150kW (inland) – 50MW (Ocean)
- Specific power patterns
- Well suited for hybrid use

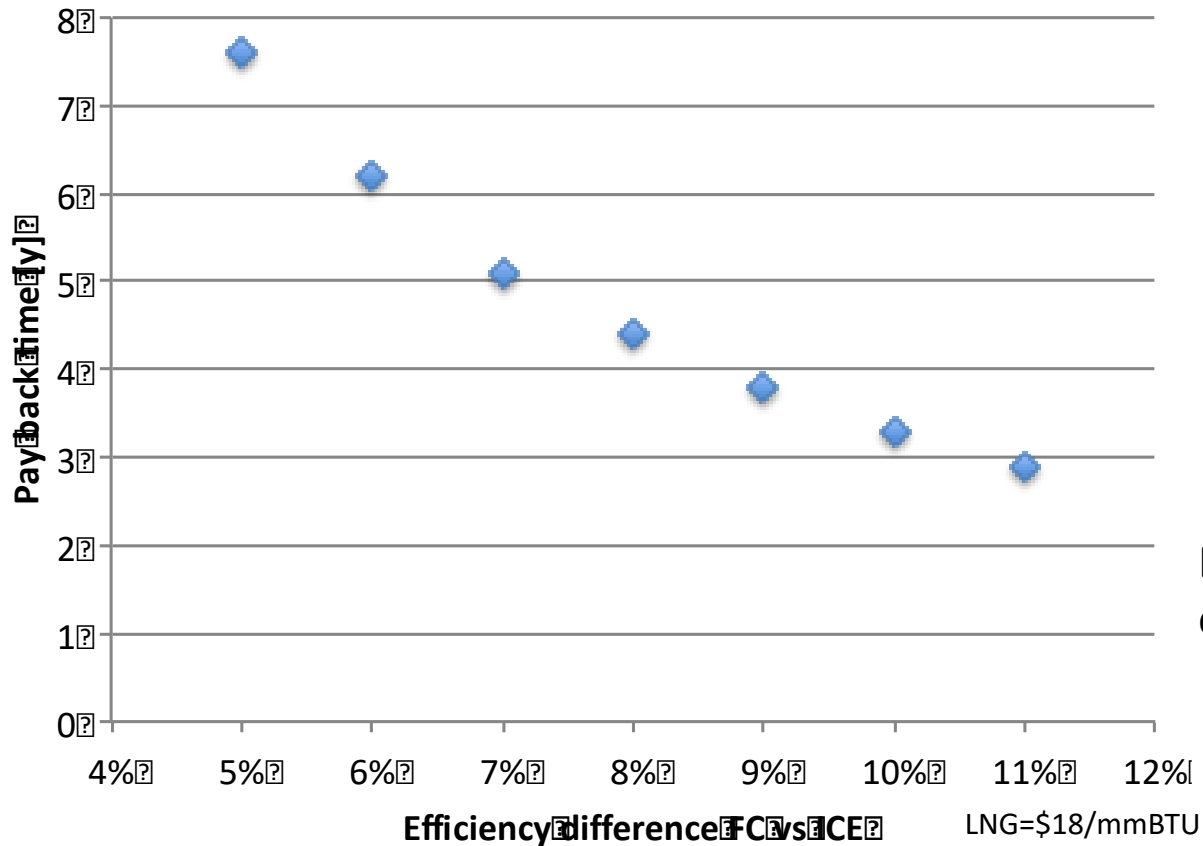
Replace diesel engines

- Part load of diesel reduces efficiency, increases maintenance



ENGINE EFFICIENCIES

Difference of (average) efficiency difference is highly important

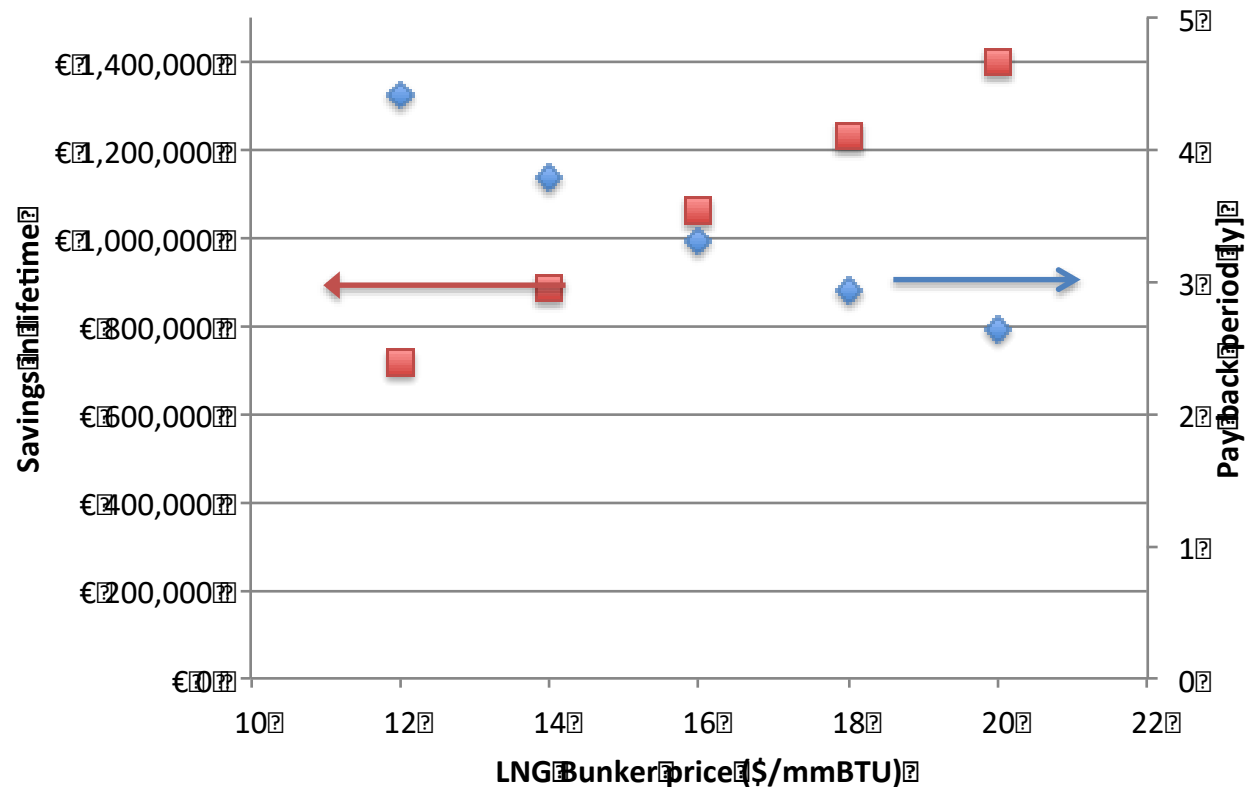


Note: $\eta_{\text{Diesel}} = 45-54.4\%$
e.g. MAN S80ME-C7

INFLUENCE OF FUEL PRICE

(Simple) payback time directly related to OPEX cost savings

- 250kW example PEM system (LNG feed).
- Assumption 10% efficiency increase



MARITIME TRENDS – GOOD FOR FUEL CELLS

Emissions reductions legislation become more stringent

- NO_x, Particles, Sulfur

Electric power train more common

- FC fits well

OPEX costs of ship largely function of fuel costs

- Fuel use x Fuel price
- Fuel efficiency very important

All major ship yards and Shipping companies see fuel cells as the standard in the future

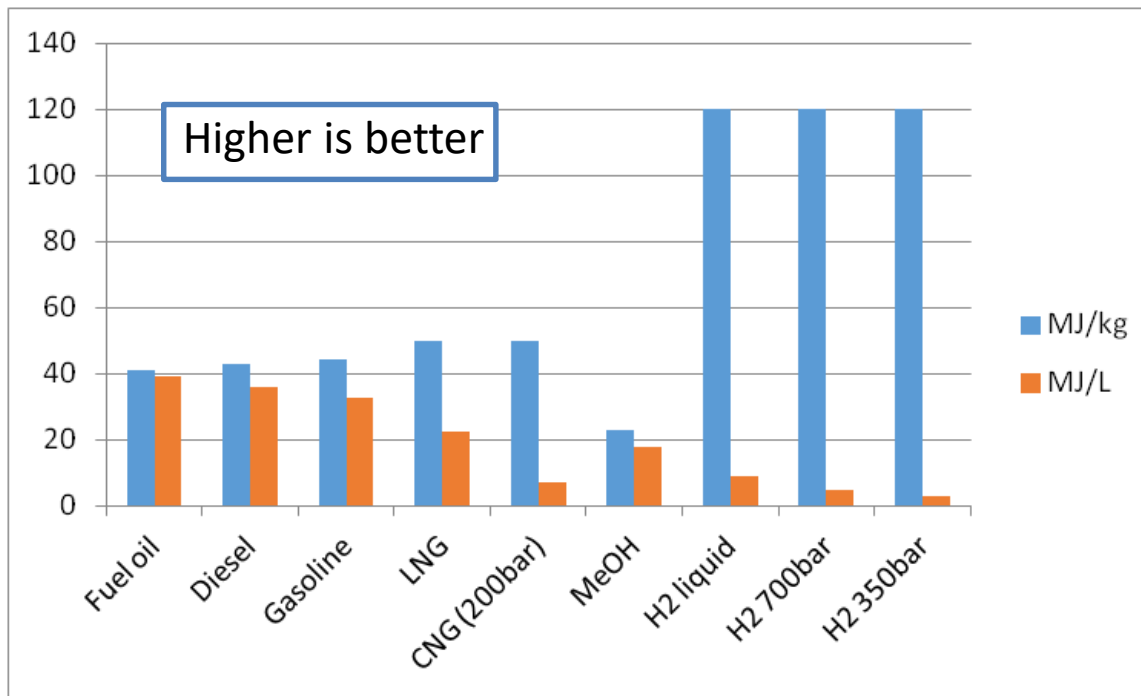
BUT Maritime sector very conservative

- Start demonstration today to have technology implemented in next 10-15 years ☺

MARITIME FUEL DEMANDS

FUEL NEEDS (MARITIME)

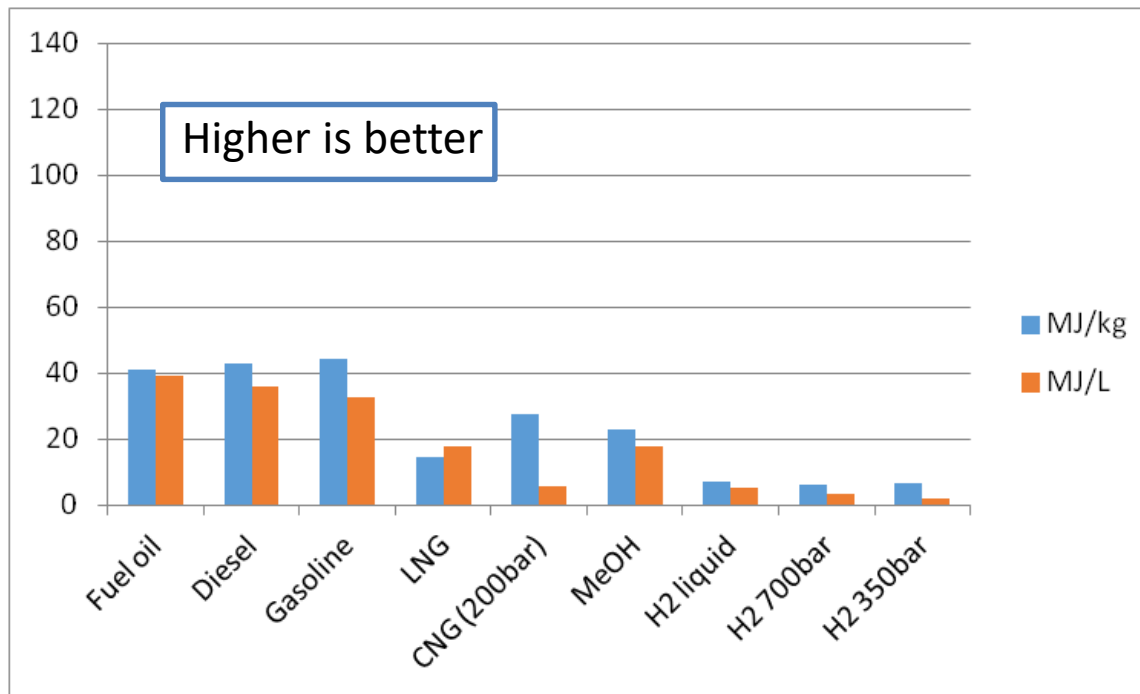
Size and weight are important



Comparison of fuels

FUEL NEEDS (MARITIME)

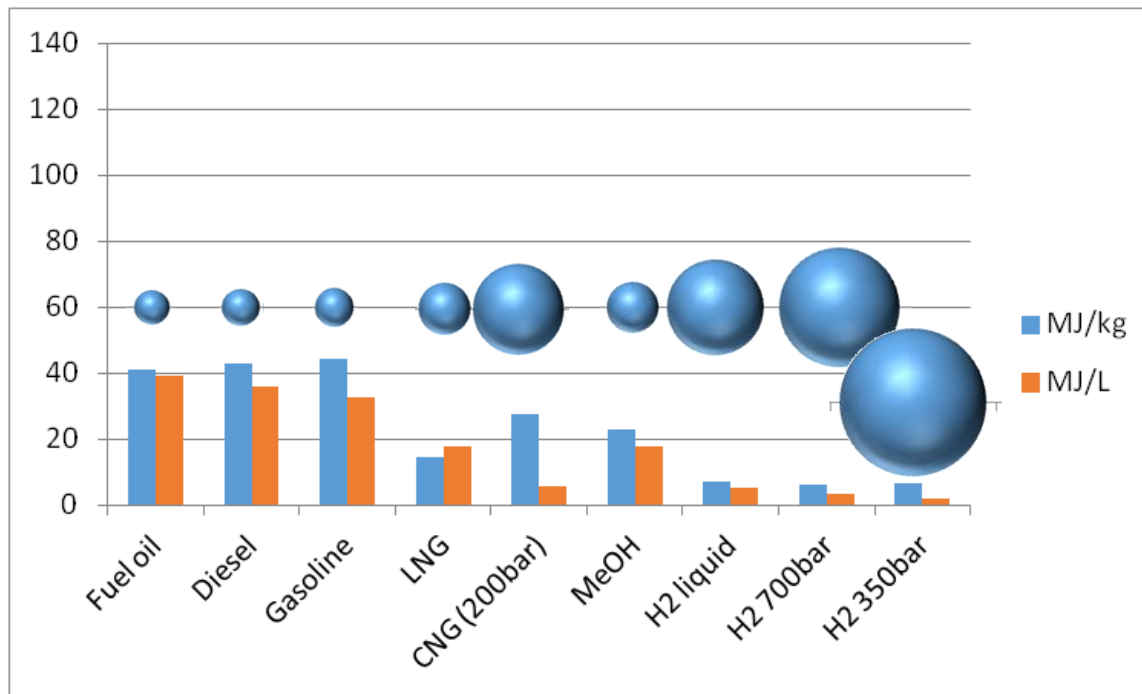
Size and weight are important



Comparison of fuels with tank

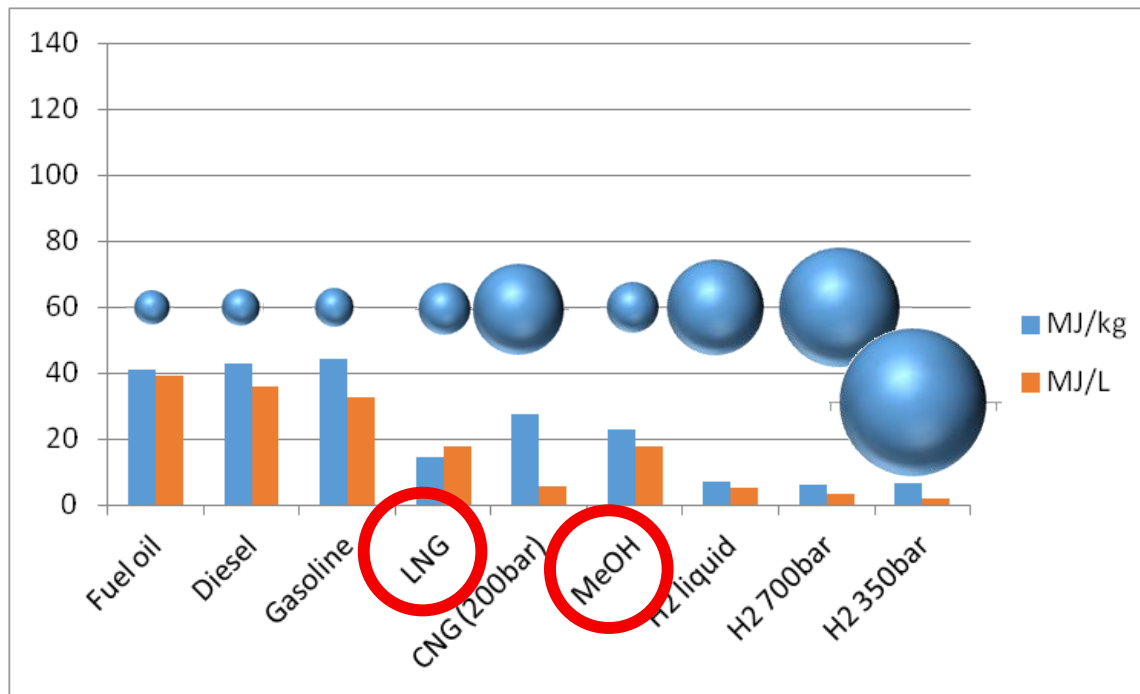
FUEL NEEDS (MARITIME)

Compare tank sizes



FUEL NEEDS (MARITIME)

Compare tank sizes



So, large power storage requires carbon containing fuels

SUMMARY

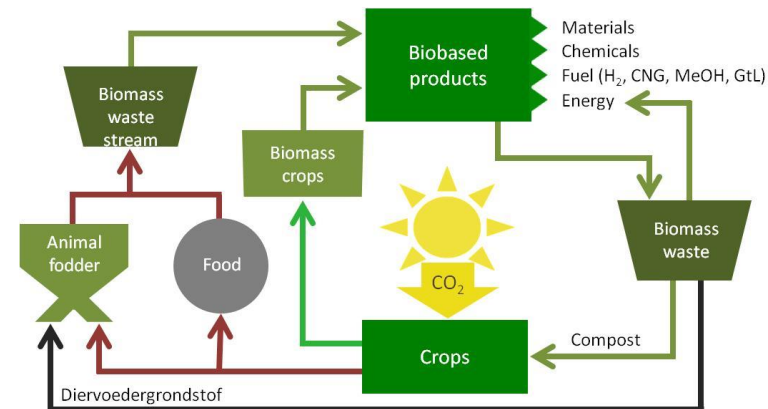
The future of transport fuel is hydrogen (based)

We expect that transition goes via

- Electricity – coupling with power industry and
- GreenGas – coupling with biobased industry

For maritime sector

- Fuel cell serves a need for low emissions, sustainable power train
- Efficiency very important
- High power density fuel required
 - carbon based fuel stays important



THANK YOU!

www.hygear.com

HyGear head office

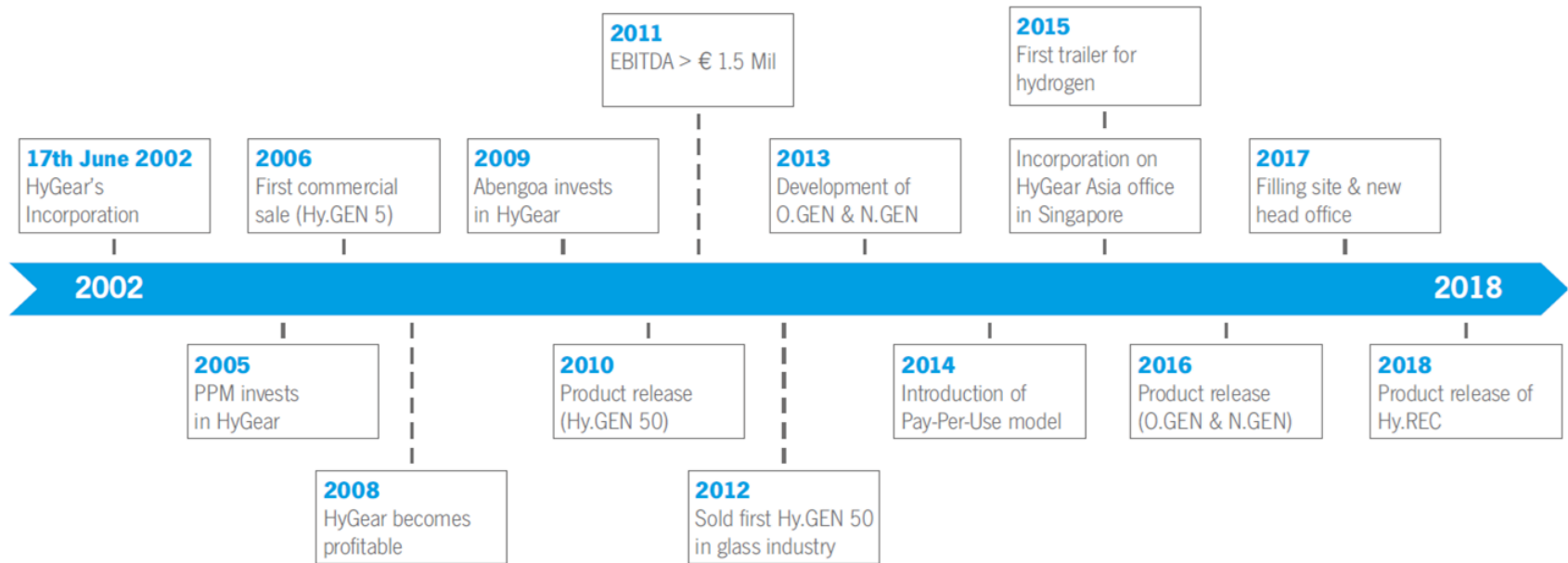
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HISTORY HYGEAR



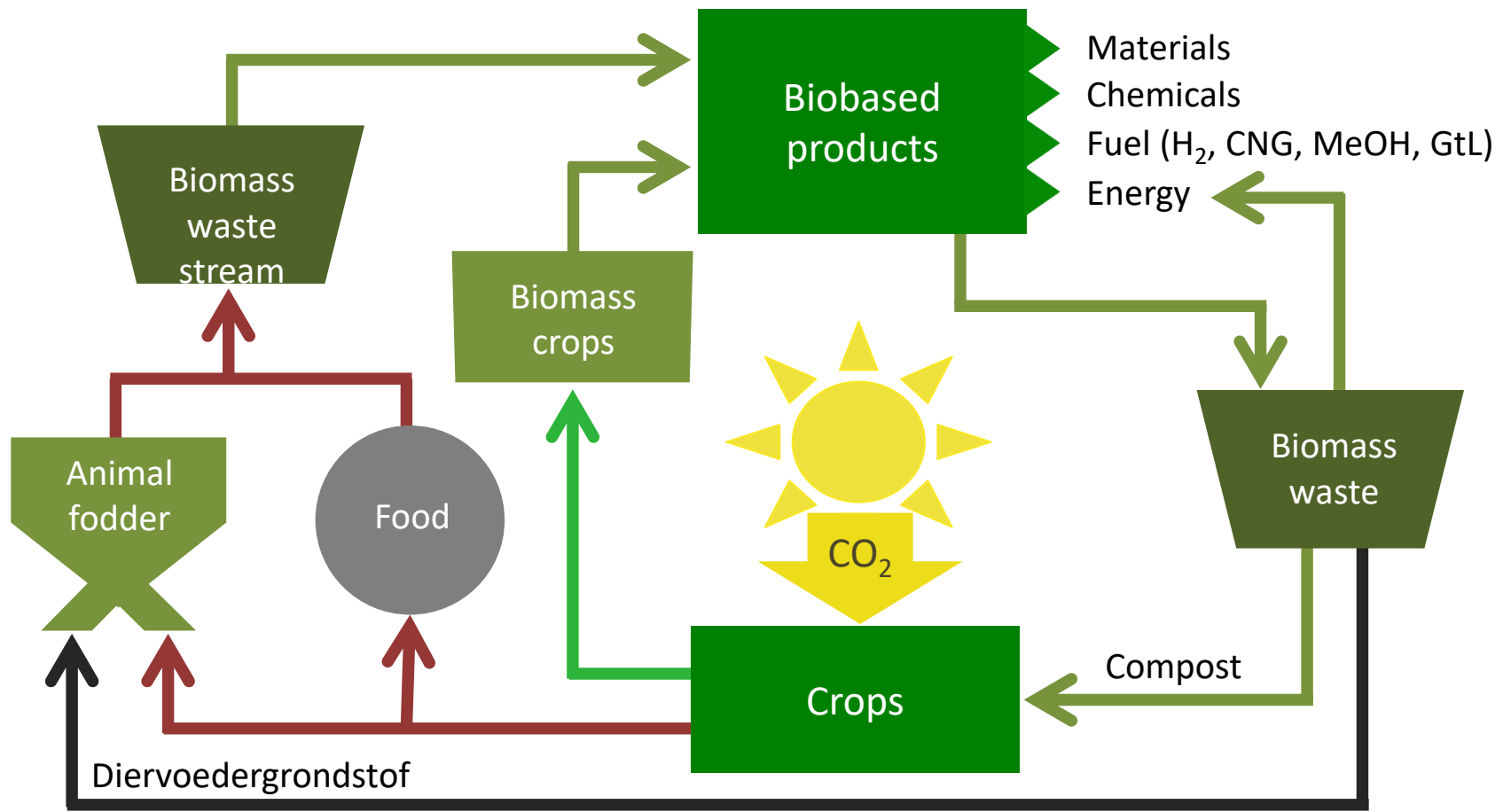
2002 Incorporation

2009 Take-over fuel cell activities Plug Power Europe

2014 Pay-per use model

2017 Filling site operational

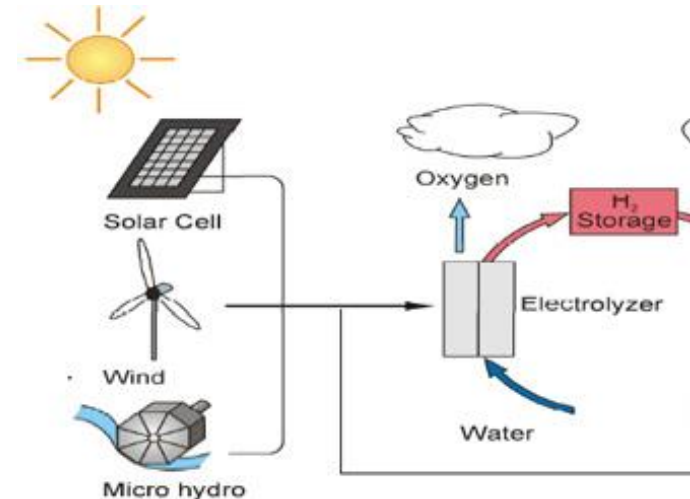
COUPLE WITH BIOBASED INDUSTRY



GREEN HYDROGEN - TODAY

Electrolysis of green electricity

- High power consumption
- €9-11 / kg H₂

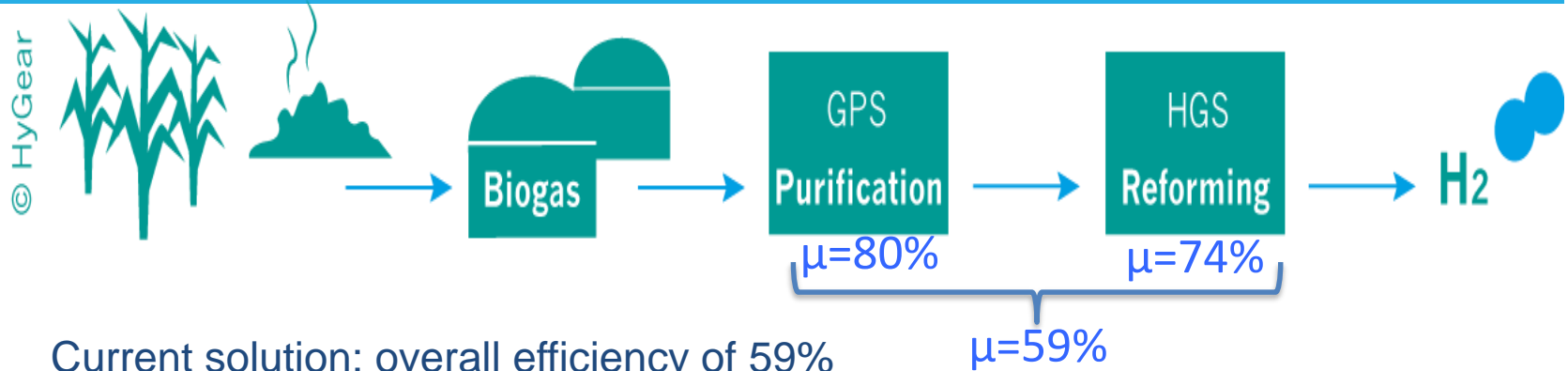


Convert BioMethane into H₂

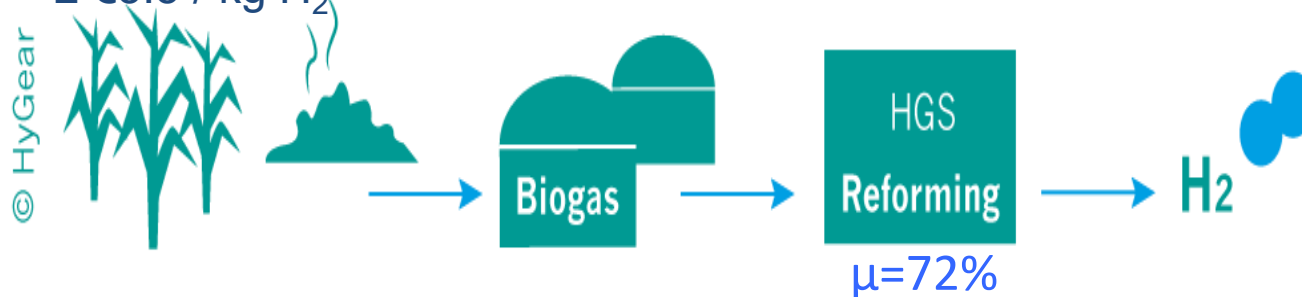
- Medium costs: €5.5 / kg H₂



GREEN HYDROGEN -TOMORROW



± €5.5 / kg H₂



Dry reforming overall efficiency of 72%



± €4 / kg H₂

GREEN HYDROGEN BUSINESS

No commercial market pull for sustainable hydrogen

Green Hydrogen demand originate from pilot projects

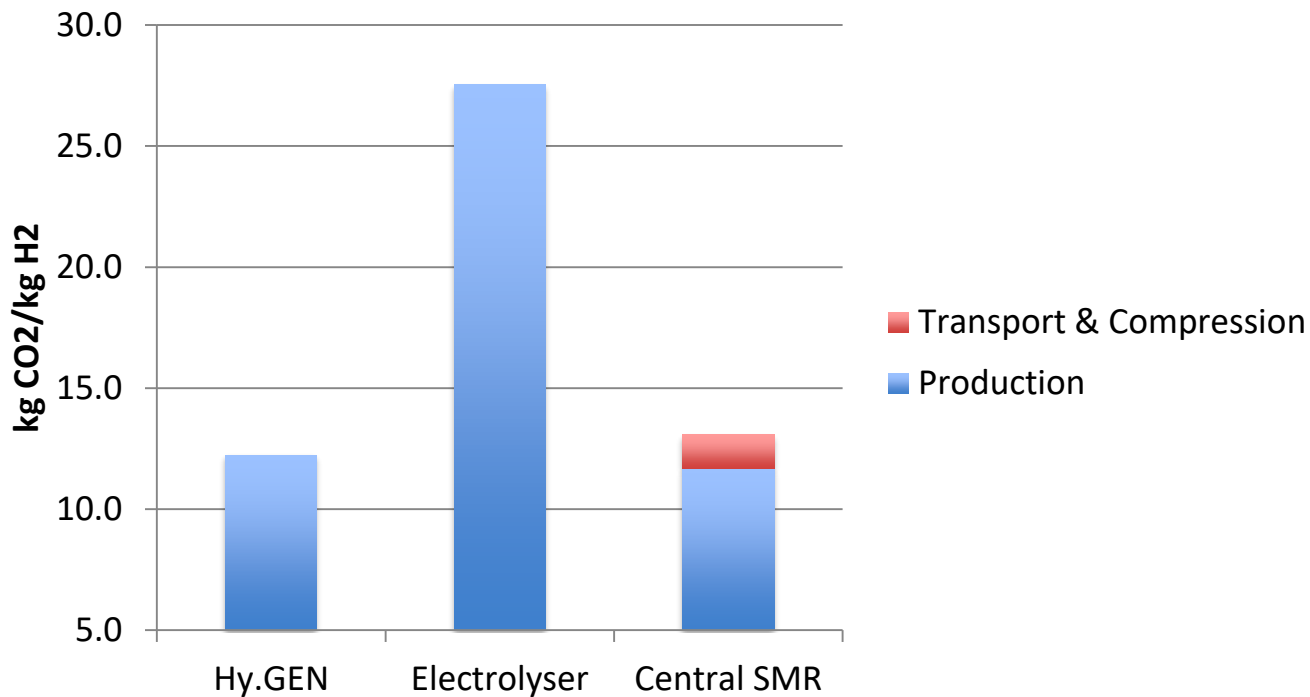
- Policy driven
- Limited run time of projects

Project based demand results

- Optimize economics per project
- Fastest and lowest risk solution is biogas upgrading before reforming or electrolyser
 - Keep current warranties

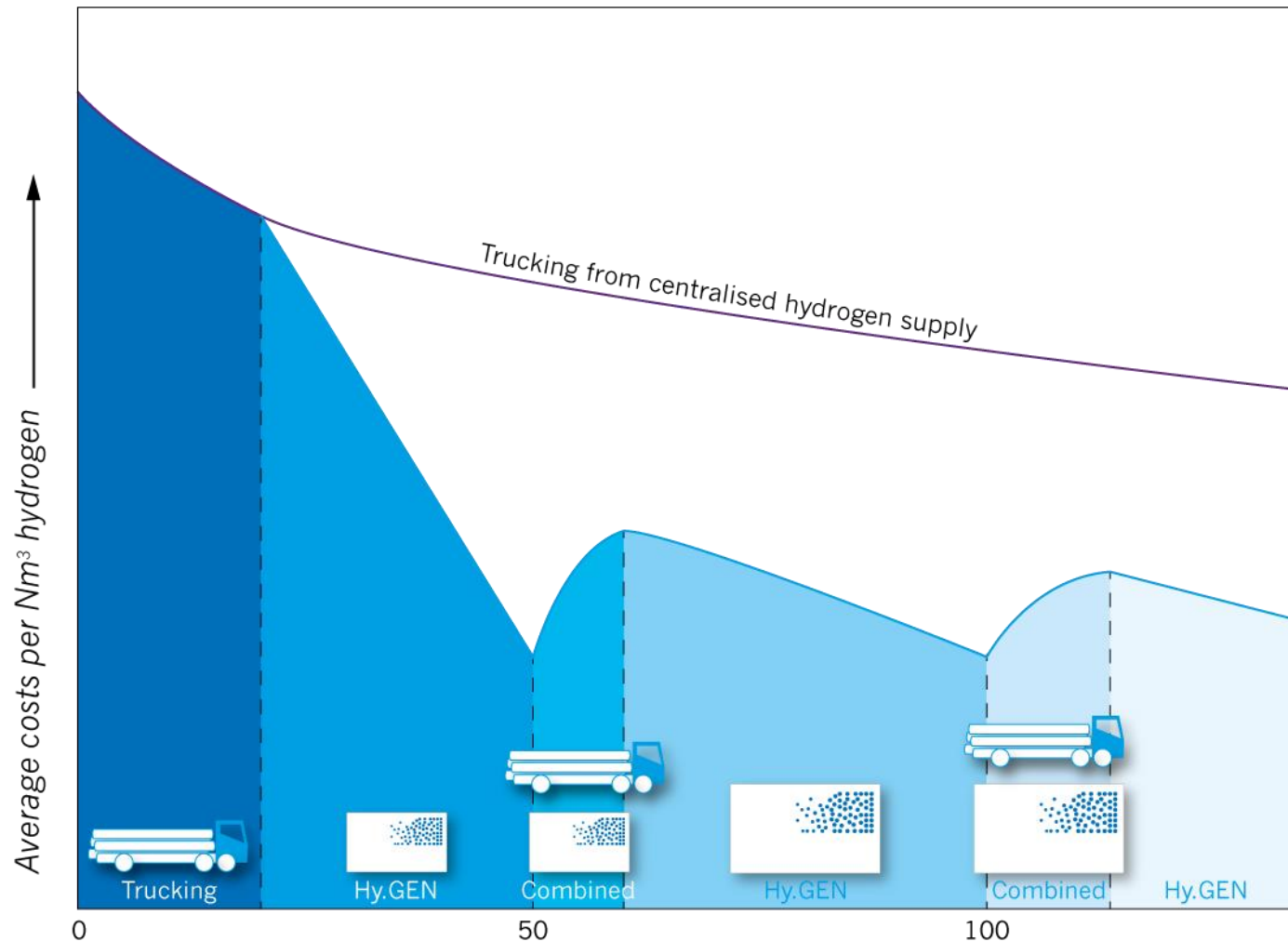
LOWER EMISSIONS

Hy.GEN[®] reduces emission with 1kg CO₂ per kg H₂



Hy.GEN & Central SMR natural gas feed
Electrolyser feed average EU power mix

COST ADVANTAGE ON-SITE PRODUCTION



SECURITY OF SUPPLY

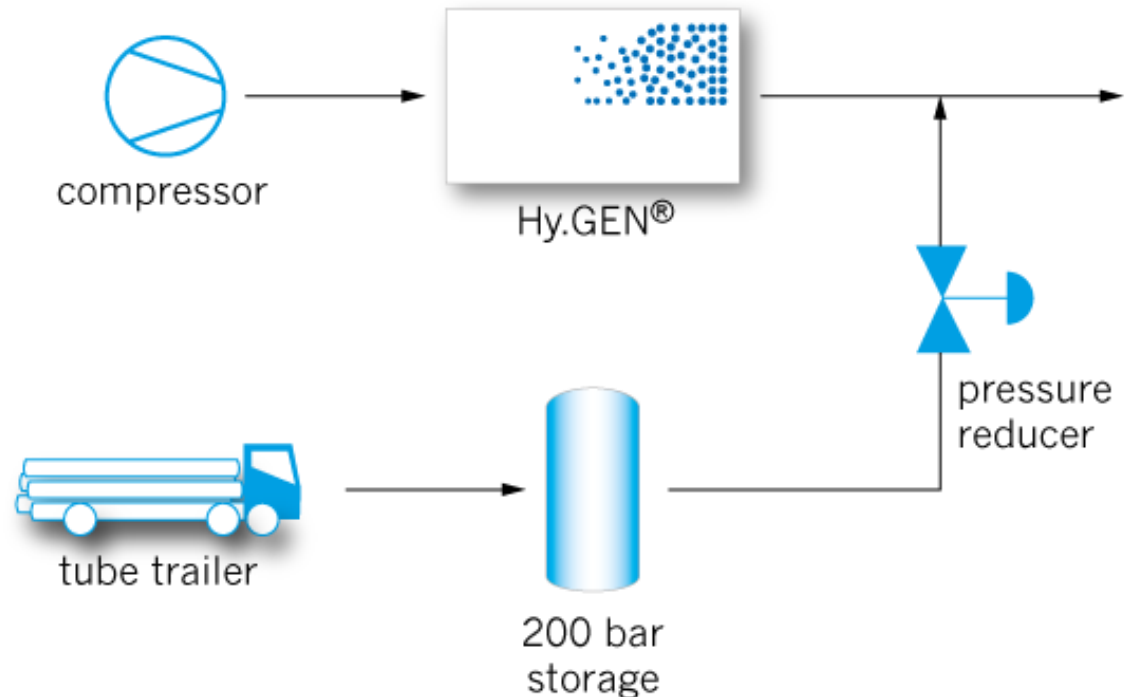
Hydrogen delivery 100%

Hy.GEN[®]

- Maintenance 7 days/year

On-site back-up

Trailer back-up



INCREASED SAFETY



RISK CONTOURS

Reduced safety distances compared with tube trailer

Tube trailer

H₂ refuelling station

HyGEN

HyGEN