NOVEMBER 2022 - BENELUX INFRASTRUCTURE FORUM

Green hydrogen/ammonia value chain

Green Giraffe

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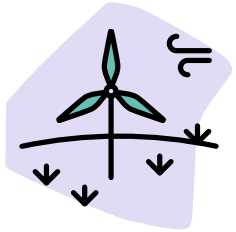
Green Giraffe

We focus on the energy transition, working with people, technologies and markets that we believe in

>EUR 32 bn funding raised
12 yrs of specialised advisory

120+ professionals globally
9 offices in 9 countries on 5 different continents



>250 transactions or projects
>180 GW total capacity

A specialised financial advisory firm launched in 2010

- Proven track record in renewable and energy transition technologies
- Operating from Boston, Cape Town, Hamburg, Madrid, London, Paris, Singapore, Sydney and Utrecht
- Multi-disciplinary skillset, including project & corporate finance, M&A, tendering, contracting, and legal expertise

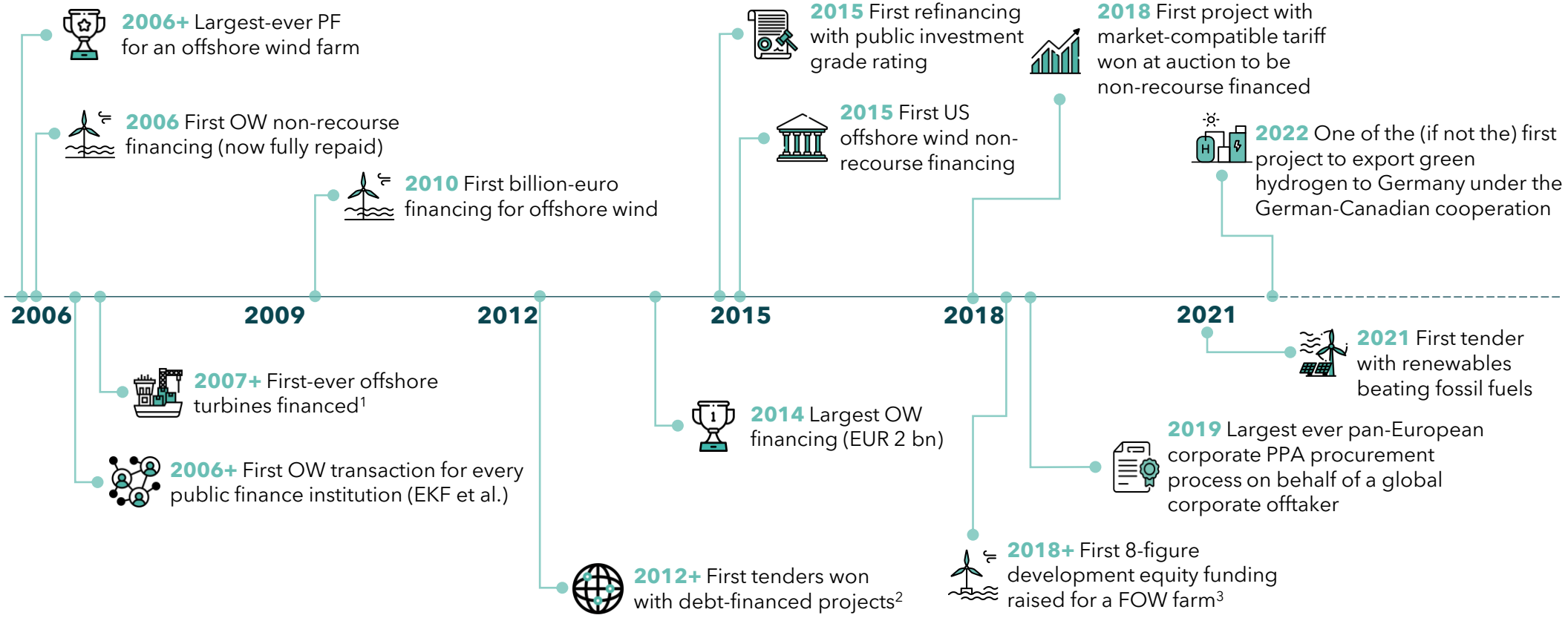
An ambition to provide high quality, specialised advice

- We only work on projects where we can actually add value
- We build long-term relationships with our clients
- We foster a shared approach to transactions and risks

Green Giraffe follows a simple strategy

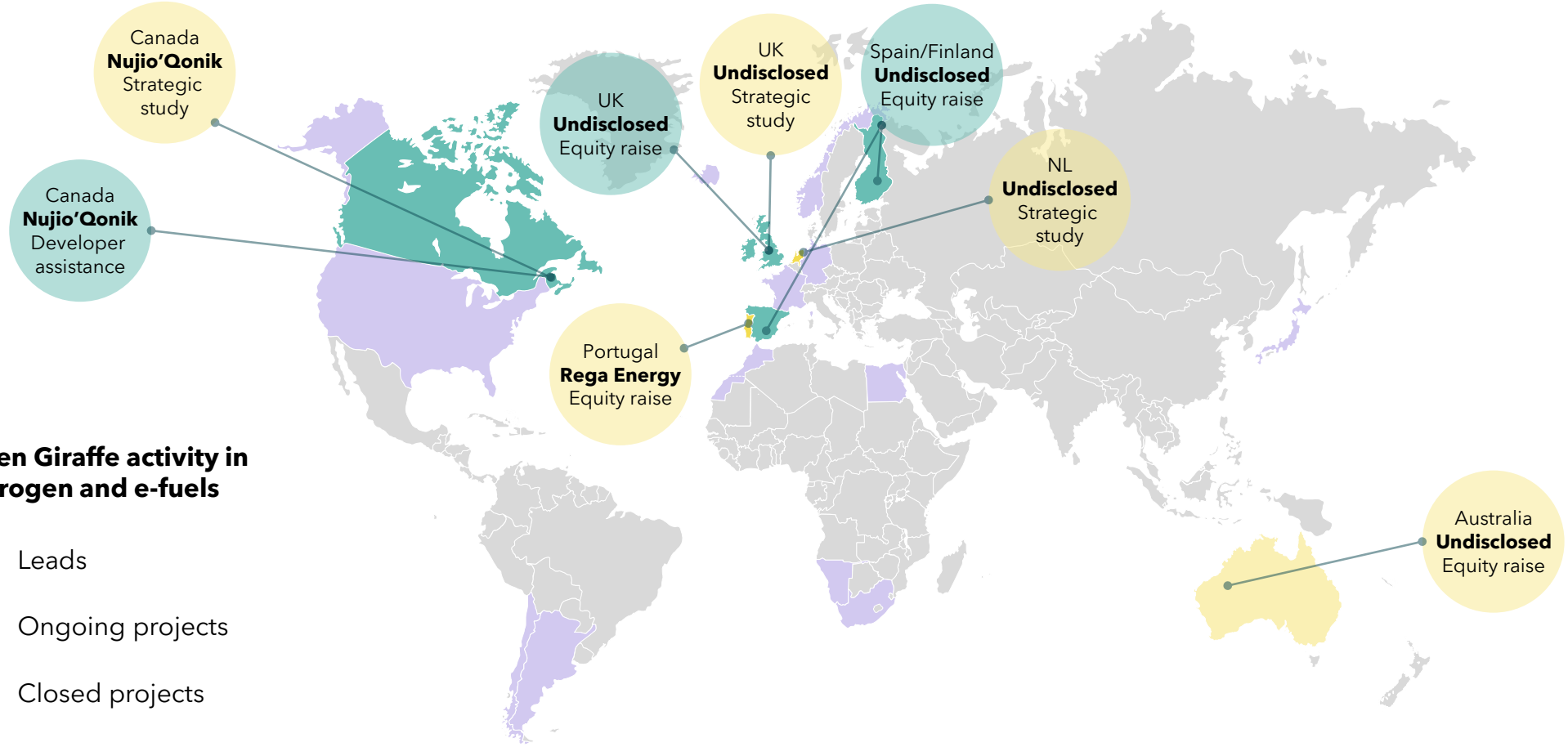
- Provide a holistic approach, coupling sector-specific tasks and traditional debt or M&A advisory services
- We continue to outperform the competition in Europe whilst growing in developing markets on other continents
- We are committed to the industry, we believe in the countries we are active in and we have the skillset it takes to **get deals done**

Transaction "firsts" with Green Giraffe (or, prior to 2010, Green Giraffe officers) actively involved



[1] For wind turbines of 5, 6, 8 & 9.5 MW size
[2] Won in France, the Netherlands UK and Taiwan
[3] First in the US / Asia / Europe

Green hydrogen and e-fuels are key markets for the energy transition and we are part of it



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Green Giraffe

The hydrogen opportunity

1

Proven technology to integrate with renewables

- Green hydrogen is forecasted to account for 20% of Europe's power consumption in 2050
- Unlocks new offtake markets for renewable energy

2

Investments

- Current stated investment estimates for hydrogen are more than USD 300 bn by 2030
- Governments have already pledged over USD 70 bn to support hydrogen initiatives

3

Cost reductions

- The industrialisation of electrolyser manufacturing will likely lead to a 60% decrease in electrolyser costs by 2050, whilst green hydrogen production costs are estimated to decrease by 60% by 2030

4

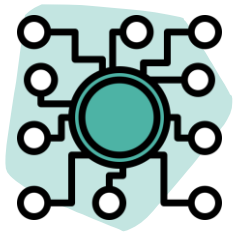
Governmental support

- 75 countries have net zero carbon ambitions, 30+ countries have hydrogen-specific strategies
- The EU has announced a 40 GW electrolyser capacity target for 2030

Sources: Hydrogen Council, Reuters

Green hydrogen – a key element of the energy transition globally

Green hydrogen is zero-carbon hydrogen, produced from renewable electricity and water



Hydrogen has a wide range of application markets, from heavy industry to transportation

Directly linked to renewables, green hydrogen is already competitive with fossil fuels

Hydrogen is distinguished based on its production method

- Grey: produced using natural gas, with significant CO2 emission
- Blue: same as grey but with CCUS, reducing CO2 emission
- Green: produced using renewable electricity, zero CO2 emission

Hydrogen is an existing market, with potential to grow even further

- Current grey hydrogen, used in fertiliser production and petrochemical industry, is responsible for 2% of carbon emissions globally
- Additionally, green hydrogen can be used to decarbonise heavy industry, long-haul transport and even heating

Decreasing costs of renewables make green hydrogen competitive

- Cost-competitive green hydrogen requires low-cost, high-capacity factor renewable energy

Governments recognise the role of hydrogen in the energy transition

- European governments have set ambitions targets for green hydrogen production and are designing regulatory frameworks
- Korea, Japan and the US are also supportive of green hydrogen

Source: ING, Wood Mackenzie, CMS

Renewable energy complements the hydrogen business case

The main drivers of the levelised cost of hydrogen (LCOH) for green hydrogen are capex and electricity price

Cost of electricity

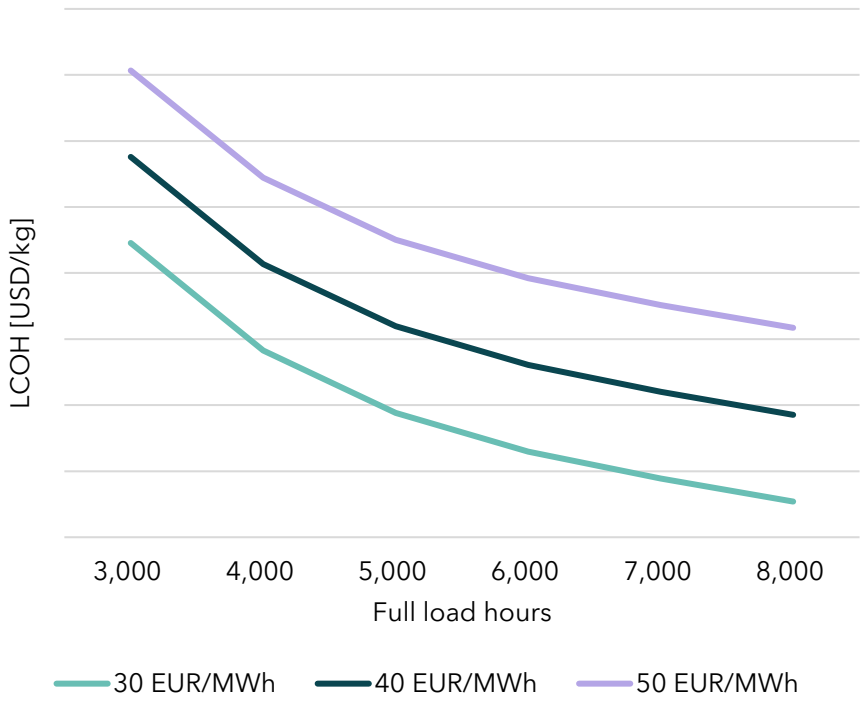
- Electricity costs make up 60-80% of the LCOH
- The electricity component can be decreased by using low-cost renewable electricity

Capex of the electrolyser

- Large upfront investment, requiring an electrolyser to run as many full load hours per year as possible
- Running an electrolyser a low number of hours increases the capex component of the LCOH

Using electricity directly from renewable energy projects gives projects access to cheap renewable electricity, however not all technologies (e.g. solar and onshore wind) can provide sufficient full load hours per year to reach a low LCOH

LCOH for an electrolyser with a given electricity price and full load hours



To make hydrogen competitive with fossil fuels, low-cost and high-load factor renewables are needed

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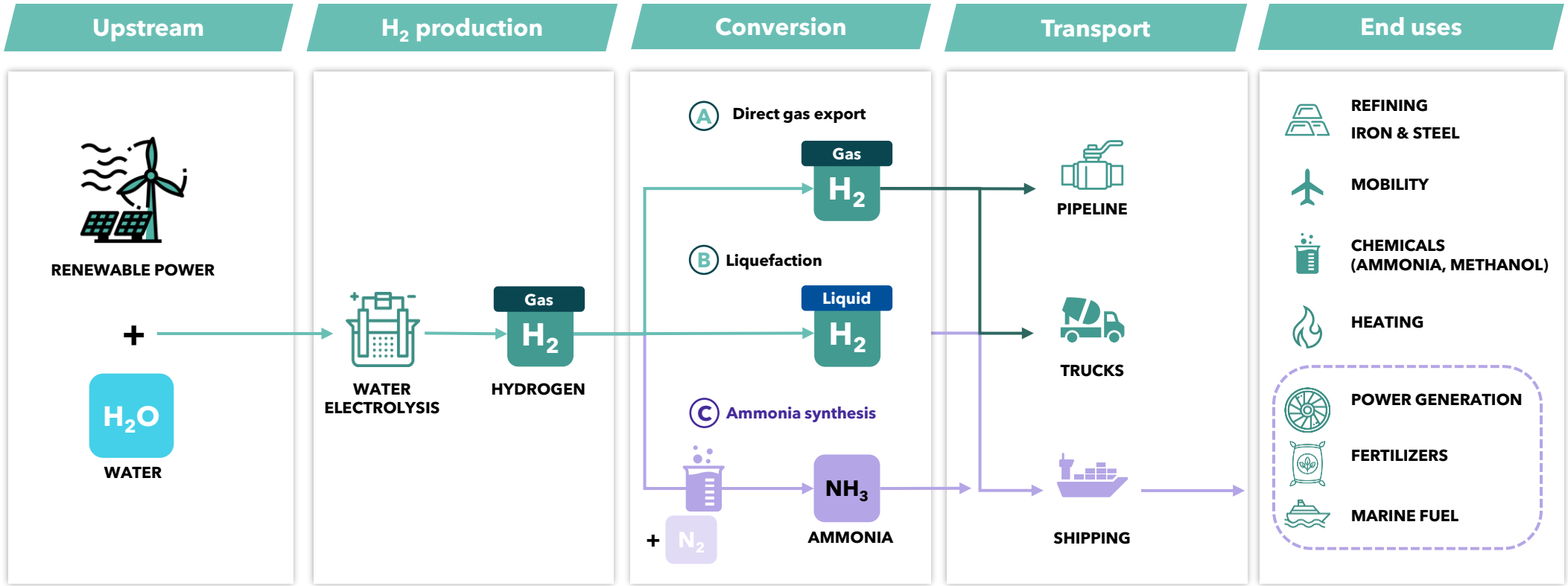
The green hydrogen value chain includes various stages, from green power production to the final use

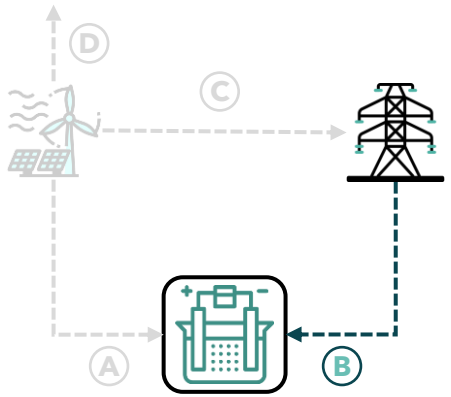


Several H_2 use cases have no low-carbon alternative which makes green H_2 the best option for their decarbonisation

A number of business models are emerging for hydrogen electrolysers

Upstream | H_2 production | Conversion | Transport | End uses

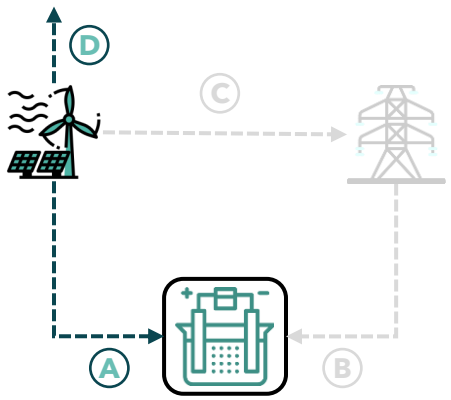
Stand-alone grid-connected



Electrolyser is grid-connected

- Can run at 95% load (inflexible) or choose to work on cheap power hours to minimise LCOH (flexible). Potential grid fees

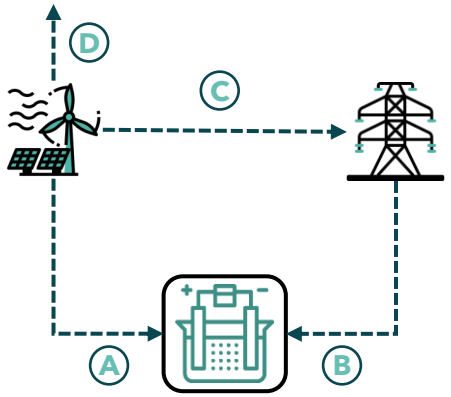
Co-located, island mode



Electrolyser is connected to the RES asset only (without grid)

- Runs on RES load factors, 100% green, no regulatory risk

Co-located, grid connected



Electrolyser and RES asset are both connected to the grid

- Combines the benefits of NL Hydro grid-connection w/co-located RE model

(A) Electrolyser imports power from RES

(B) Electrolyser imports power from grid

(C) RES exports power to grid

(D) RES spills power

Co-located, grid connected mode is the preferred one to ensure a stable production of green hydrogen

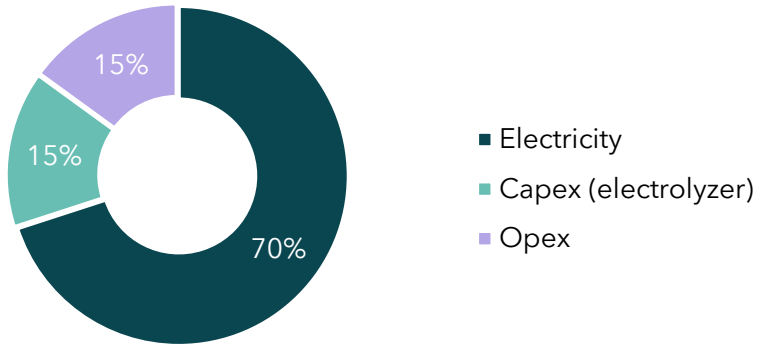
Green Giraffe

Green hydrogen production can be distilled into four key design parameters (1/2)

Upstream | **H_2 production** | Conversion | Transport | End uses

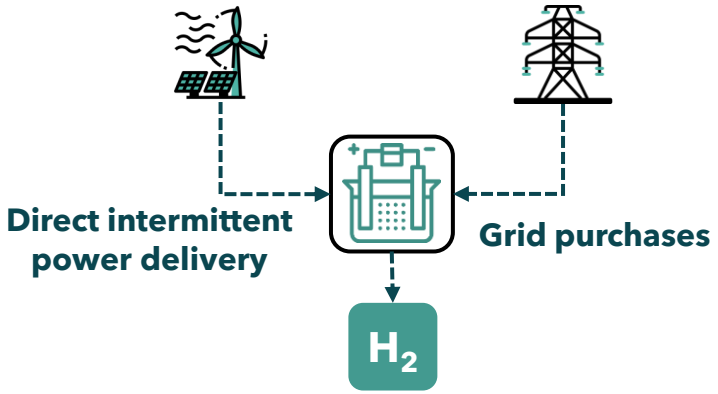
1. Electricity cost is typically 60%-80% of LCOH

Breakdown of LCOH (at site)



- Electricity cost varies significantly by location and technology
- The next phase of H_2 production buildout globally will likely see production where renewables are cheapest in exchange for higher processing and transportation costs to end-markets
- Through 2030, renewable energy LCOEs will continue to see meaningful reductions

2. Load factor is constrained by renewables intermittency



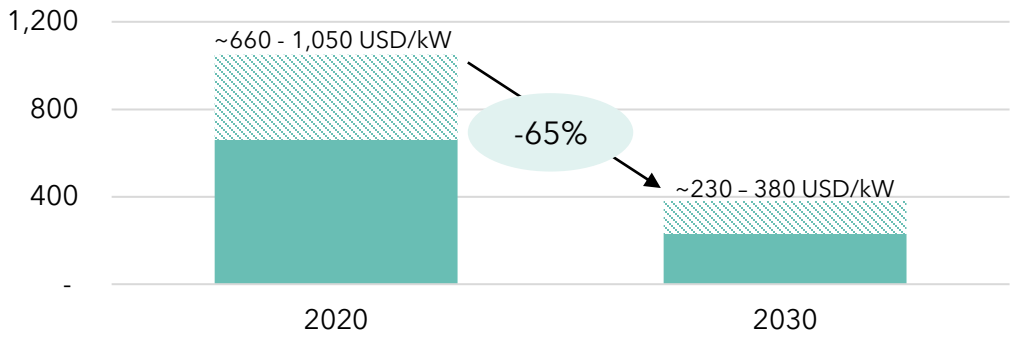
- A grid connection can significantly enhance project performance by offering ability to trade in/out electricity
- Smoothing intermittent power delivery allows the electrolyser to run at an elevated baseload capacity which reduces ramp-up/ ramp-down costs and generates meaningfully lower LCOH

Minimizing LCOE and maximizing load factor have the highest impact on green hydrogen project competitiveness

Green hydrogen production can be distilled into four key design parameters (2/2)

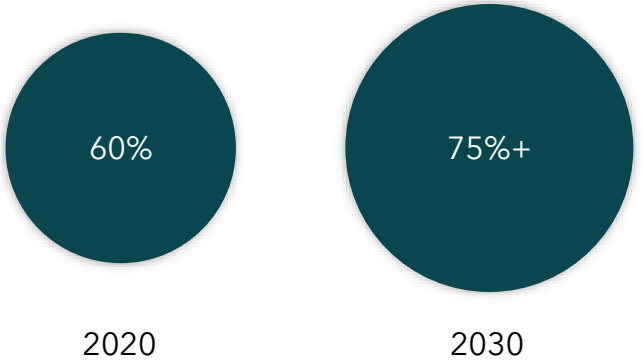
Upstream | **H_2 production** | Conversion | Transport | End uses

3. Electrolyser capex will come down significantly by 2030



- Electrolyser capital cost reductions are expected to be driven primarily by economies of scale as industry build-out progresses, supply chain enhancements, and efficiency improvements
- The industry will need to balance capex reductions against maintaining high system efficiency

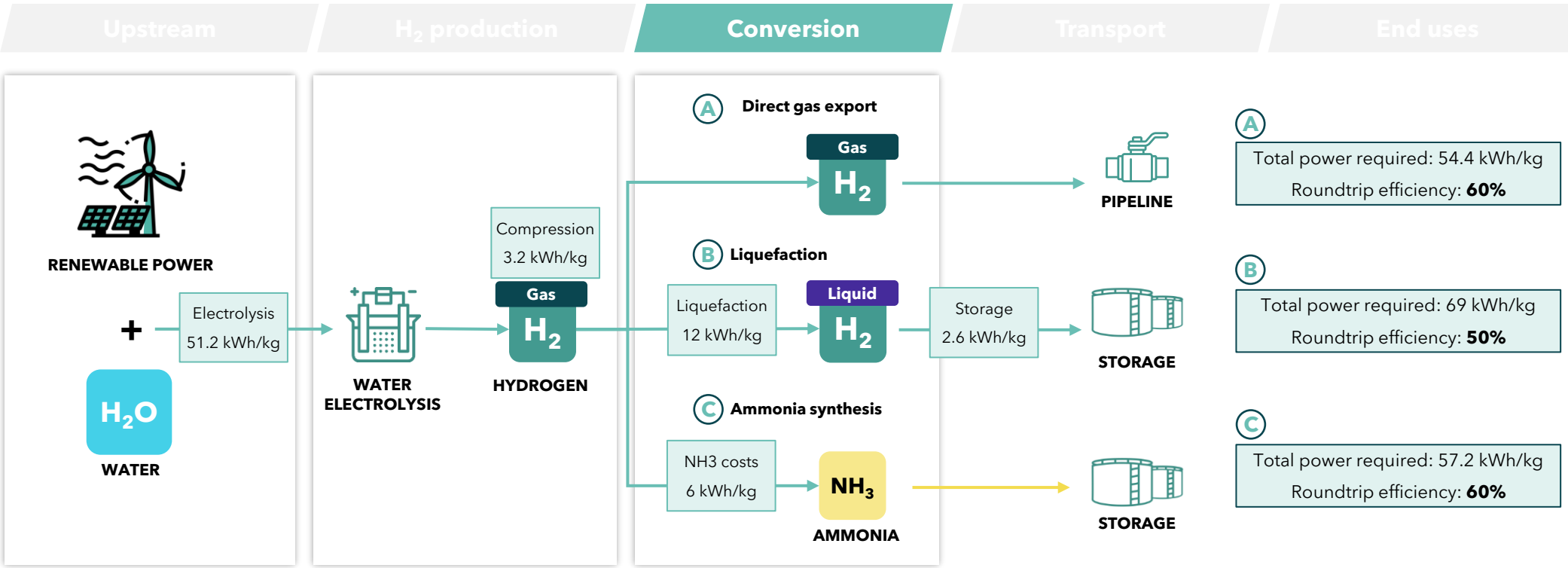
4. Electrolyser efficiency will also continue to improve



- As with capex, electrolyser efficiency will benefit from technological development and at-scale deployment
- Combined with lower capex, improved electrolyser efficiency implies significantly lower green LCOH by 2030 even before accounting for changes in renewable power delivery

Green hydrogen capex and efficiency improvements imply significantly lower LCOH by 2030

Hydrogen gas can be converted, stored and transported in several different forms



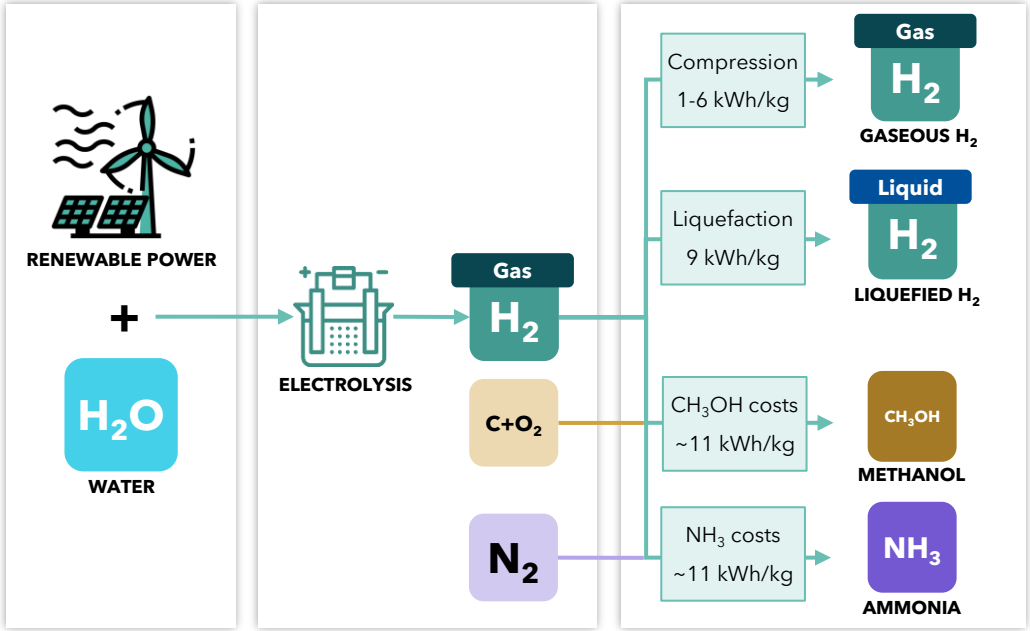
Note: These roundtrip efficiencies calculation do not include transport to end users – which will involve more costs – and excludes efficiencies of fuel cells (35%) and gas turbines (60%).
Hydrogen lower heating value (energy content) is 33.3 kWh/kg

H_2 gas is flexible, which is why it is claimed to be able to decarbonize many sectors; however, this comes at a price

Hydrogen in ambient conditions has low energy density meaning conversion is needed for transport

Upstream | H_2 production | **Conversion** | **Transport** | End uses

	Gas - 100 bar	Gas - 1000 bar	Liquefied H_2	Methanol	Ammonia
Energy density (kg/m³)	~10	~50	~70	~100	~120



Local distribution Retrofitted pipelines or trucking	✓ Mature tech ✓ No reconversion loss	x Flammable as gas x Challenging to handle (volume)
Mid/long distance distribution Pipeline, trucking, shipping	✓ LNG tech retrofit ✓ Global trade benefit	x High energy intensity and losses
Mid/long distance distribution Pipeline, trucking, shipping	✓ Existing tech retrofit ✓ No compression	x CO_2 emissions at reconversion
Mid/long distance distribution Pipeline, trucking, shipping	✓ Existing tech retrofit ✓ Active market	x Toxicity and corrosive effect at reconversion

End-product from green hydrogen must be tailored to the transportation distance and the end-use requirements

Hydrogen end-products offer unique advantages and drawbacks

Upstream | H_2 production | **Conversion** | **Transport** | End uses

Liquid hydrogen

Pros

- Offers the lowest cost of reconversion to gaseous hydrogen
- The **highest purity of hydrogen** is offered throughout the value chain

Cons

- **Higher cost** associated to compression and storage/transport
- No existing trading markets for H_2
- No existing port infrastructure for the conversion

Ammonia

Pros

- Can leverage existing mature storage and conversion technology and **existing shipping infra.**
- **Can be used directly**, without requiring reconversion in some end use applications such as power
- More liquid trading markets than H_2

Cons

- **Less application variations** than H_2
- Lower efficiency due to additional conversion cycle unless direct use

Methanol

Pros

- Can leverage existing mature storage and conversion technology and **existing shipping infra.**
- **Can be handled at atmospheric temperature and pressure**
- More liquid trading markets than H_2

Cons

- Need for **additional feedstock of CO_2** nearby (e.g. heavy industries)

Source: WoodMac "Energy Transition Service"

Various transport vectors can play a role in the green hydrogen and ammonia markets

A robust hydrogen end-market already exists…

Upstream | H_2 production | Conversion | Transport | **End uses**

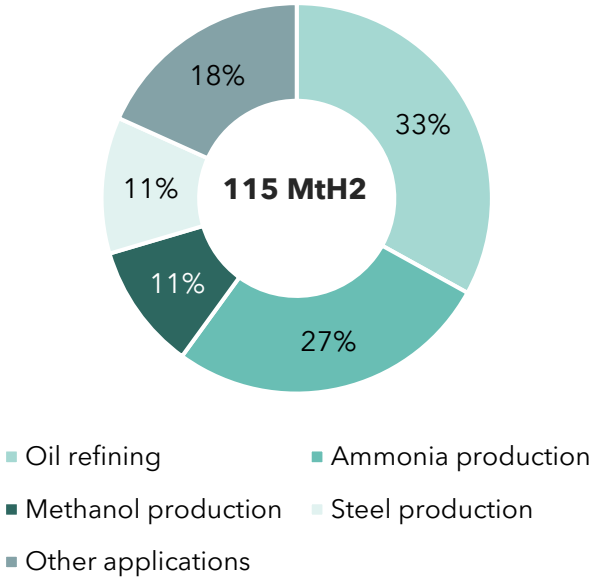
Industrial feedstock

- Oil refining
- Chemicals (NH_3, methanol)
- Steel production
- Food industry

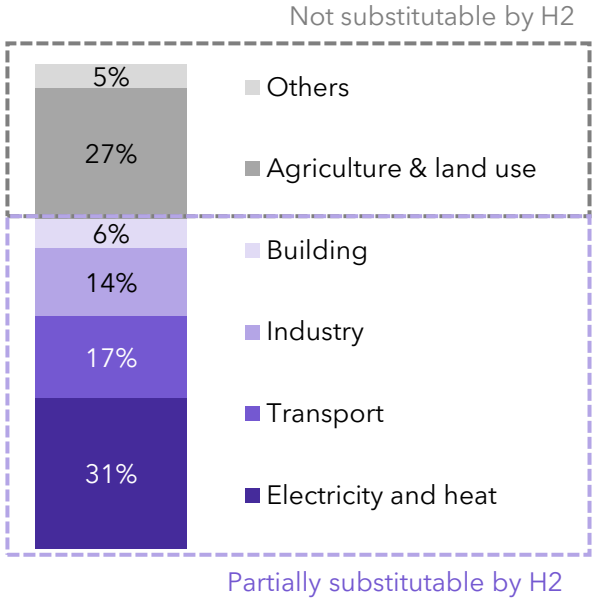
80% of hydrogen produced today is consumed by the chemicals, oil refining and steel industries

70 Mt of the total hydrogen produced today (i.e. 115 Mt) is produced in dedicated fossil-fuel based hydrogen production plants

Hydrogen consumption today, MtH2 per year



Current GHG emissions by segment



Source: Kearney, Energy Transition Institute (2020)

Decarbonizing the current grey hydrogen market would already help to abate 2% of the global carbon emissions

Green Giraffe

… with potential to grow even further

Upstream | H_2 production | Conversion | Transport | **End uses**

Industrial feedstock

- Oil refining
- Chemicals (NH_3, methanol)
- Steel production
- Food industry

Power-to-X

Industrial energy

- High-temperature heat

Mobility

- Fuel cell electric vehicles
- Synthetic fuels for shipping, rail, aviation

Gas energy

- Pure H_2 , blended H_2 or methanation for injection into the NGG and replace natural gas uses (heating)

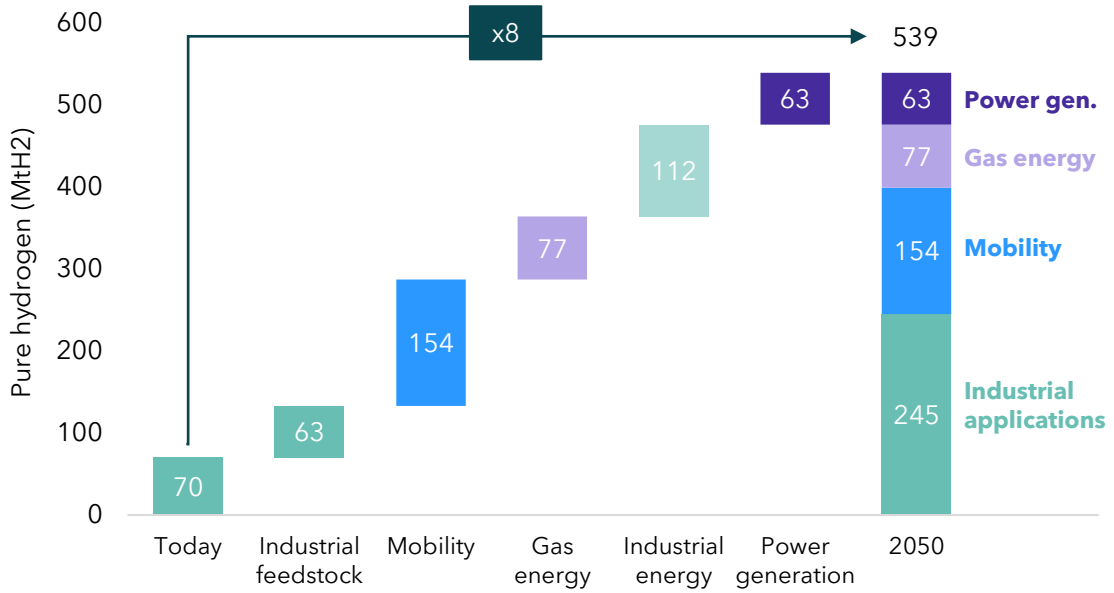
Power-to-gas

Power generation

- Hydrogen as a short-term power storage solution for flexible or off-grid power supply
- Long-term power storage
- Co-firing NH_3 in coal power plants

Power-to-power

Possible hydrogen consumption by 2050 (Mt H_2)



Source: Kearney, Energy Transition Institute (2020); excludes industrial by-product production / consumption (e.g. CO/H_2)

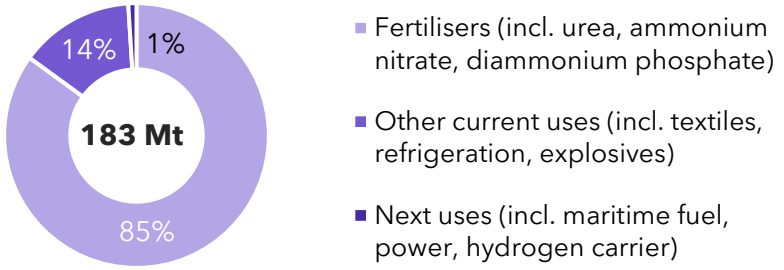
The hydrogen market is massive, new applications could represent ~75% of the hydrogen demand by 2050

Green Giraffe

Green ammonia will also be key (and sometimes more efficient than H_2) to decarbonise certain uses

Upstream | H_2 production | Conversion | Transport | **End uses**

Global ammonia consumption today



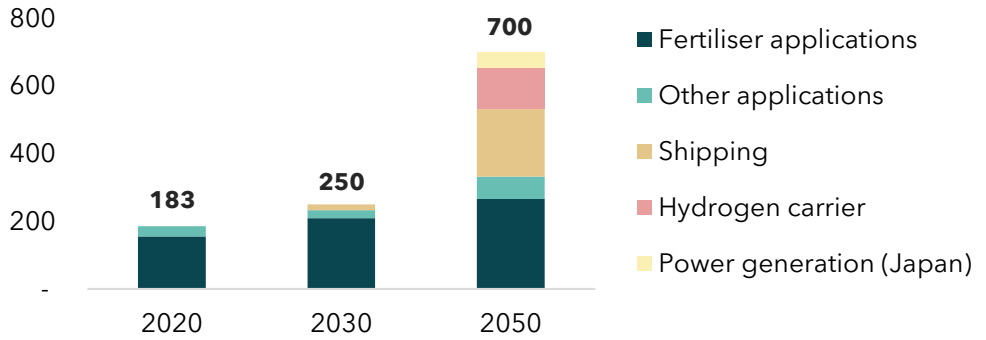
1% of global carbon emissions attributed to ammonia production

<0.01% of ammonia is green today: it is mainly produced from natural gas (72%), coal (22%), naphtha and heavy fuel oil

>50% of ammonia production and consumption is in Asia. The two other large consumers are the US and Europe

Source: Ammonia IRENA 2022 report

Projected ammonia demand up to 2050 (Mt)



- Ammonia is the **2nd most produced chemical worldwide**
- **Existing markets** are expected to increase demand to 223 Mt by 2030 and reach 333 Mt by 2050 – mainly due to population growth – ammonia demand for fertiliser will grow from 156 Mt in 2020 to 267 Mt in 2050
- **New markets** will develop; hydrogen carrier, fuel for stationary power, transport fuel (especially maritime transport)
- **Annual demand** will reach ca. 250 Mt (2030) and 700 Mt (2050)

There is a strong momentum to move towards green ammonia – ca. 54 projects recently announced (15 MtNH3 by 2030)

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Green Giraffe

Governments have set ambitious hydrogen targets, but support is indispensable to ignite the market

1. Without legislative support, no viable green hydrogen projects can be achieved
2. It is vital to compensate the technical and commercial risks taken by the market participants
3. Many countries have already established the overall framework and roadmaps for support regimes
4. Industry has to contribute too – including on hydrogen colour certification

Source: (1) Kearney Energy Transition Institute, Goldman Sachs Investment Research

Legislative support & industrial effort – Hydrogen colour certification

Acknowledging green hydrogen's positive impact on the society, promoting its overall competitiveness

Renewable source

Sources
Direct connection or through PPA, most if not all power used should come from renewables

Correlation
Sources of power should have temporal and geographical correlation with electrolyser

Newly built
Renewable plants need to be newly built, for the specific purpose of hydrogen

Emission reduction

Whole cycle
During electrolysis, but also counts whole life cycles of the plant and the equipment

Reduction
Reduction (e.g. -70%) from a reference level (e.g. 94 gCO_2eq/MJ)

CCUS
Mainly related to "Blue" hydrogen or "Low carbon" hydrogen

Other ESG criteria

Local content
Contribute to the local job creation, supply chain development, social benefits etc.

Protection
Protect water, land, air, labour rights, gender equality, intellectual properties etc.

Others
Other criteria, including but not limited to reporting, governance, anti-corruption etc.

Adaptation to each support's specific requirements

Labelled green

Certified by regulators or industrial bodies

- Direct grant
- CfD & offtake
- EU ETS benefit
- Tax benefit
- Green premium

Regulators and industrial bodies are coordinating and competing in the establishment of widely-accepted certification criteria and process, a widely accepted criteria/certification scheme is yet to arrive

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