PROTON VENTURES

AEA presentation

dd 17-11-2022

Empowering green ammonia and energy solutions

Ammonia – The oil of the future

AEA, Phoenix, USA,
November 17th, 2022

by

Hans Vrijenhoef

Founder and shareholder

EVP – President Elect Ammonia Energy Association

Do you also want to drive a green car?

- **Sportive**
- **Fast**
- **Green**
- **Sustainable**
- **Practicle**

Kansas City : november 2009! My first AEA meeting with experts on the field to make impact in the energy transition

Do you remember this one?

Kansas City : november 2009! My first AEA meeting with experts on the field to make impact in the energy transition

NH3 in the news:

Germany's Olaf Scholz heads to Canada for energy talks

During the visit, the chancellor is set to sign a long-term deal to receive green hydrogen from Canada. German carmakers are keen to source minerals for electric vehicle batteries from the North American country.

Hydrogen Bank announcement

By ARNES BIOGRADLIJA 14/09/2022

In order to invest EUR 3 billion in the development of a potential market for hydrogen, the European Commission intends to establish a new European Hydrogen Bank.

BP evaluates hydrogen shipping options

Not all customers want fuel in the form of ammonia, says CEO Bernard Looney

BP is evaluating different transport options for its nascent hydrogen supply business and will provide updates on its plans in February next year. The firm is investing in green hydrogen supply projects and has acquired a 40.5pc equity stake in, and become operator of, the Asian

nergy solutions

Renewable Energy Hub—a planned

08 November 2022

Cop 27: UAE to help develop 10GW windfarm in Egypt

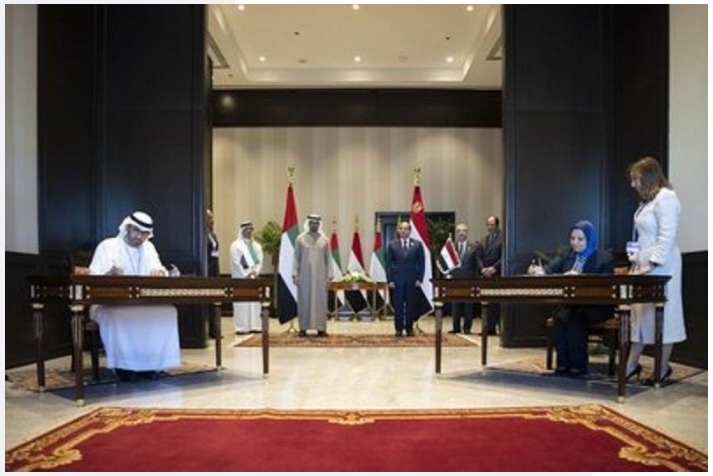
Abu Dhabi's state-owned renewables company Masdar is partnering with two Egyptian firms to develop a 10GW onshore wind farm project in Egypt — one of the largest in the world.

Today over 100 projects to produce some 100 million tons ammonia

November 9, 2022

Masdar and partners sign MoU to build 10GW wind project in Egypt

The project is estimated to save around $5bn in annual natural gas costs for the country.



➡️ #BlueAmmonia:
KBR, Inc. has announced capability for 10,000 MTPD green/ blue #ammonia facilities. Huge scale. North of 3.5 million tons per year. For the blue variant, very concentrated CO2 streams are available for CCS'ing: https://lnkd.in/eqqpC_Gs
➡️ In case you haven't seen it:
Novozymes are working on #enzymatic carbon capture: https://lnkd.in/evBiD_T4. How does it scale?
➡️ Techno-economic feasibility report from Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping on On-board Carbon Capture (OCCS) for marine applications: https://lnkd.in/eGFaAg6r. Does it make sense with the high abatement cost?
➡️ Biogenic CO2 and point-source capture technology will be crucial for A.P. Moller - Maersk to reach the #eMethanol production target 🎯 for the announcement linked to Spain: https://lnkd.in/eck8ajb3
➡️ DAC project to be progressed on Iceland: https://lnkd.in/eeyKmUPn. But, but, but.... Can the abatement cost of DAC "compete" with other pathways for decarbonization while we still have massive quantities of fossil and biogenic point sources?

At Alfa Laval - Energy we have a range of options to support the CC-related industry: https://lnkd.in/emWBneeP

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5,5 meter

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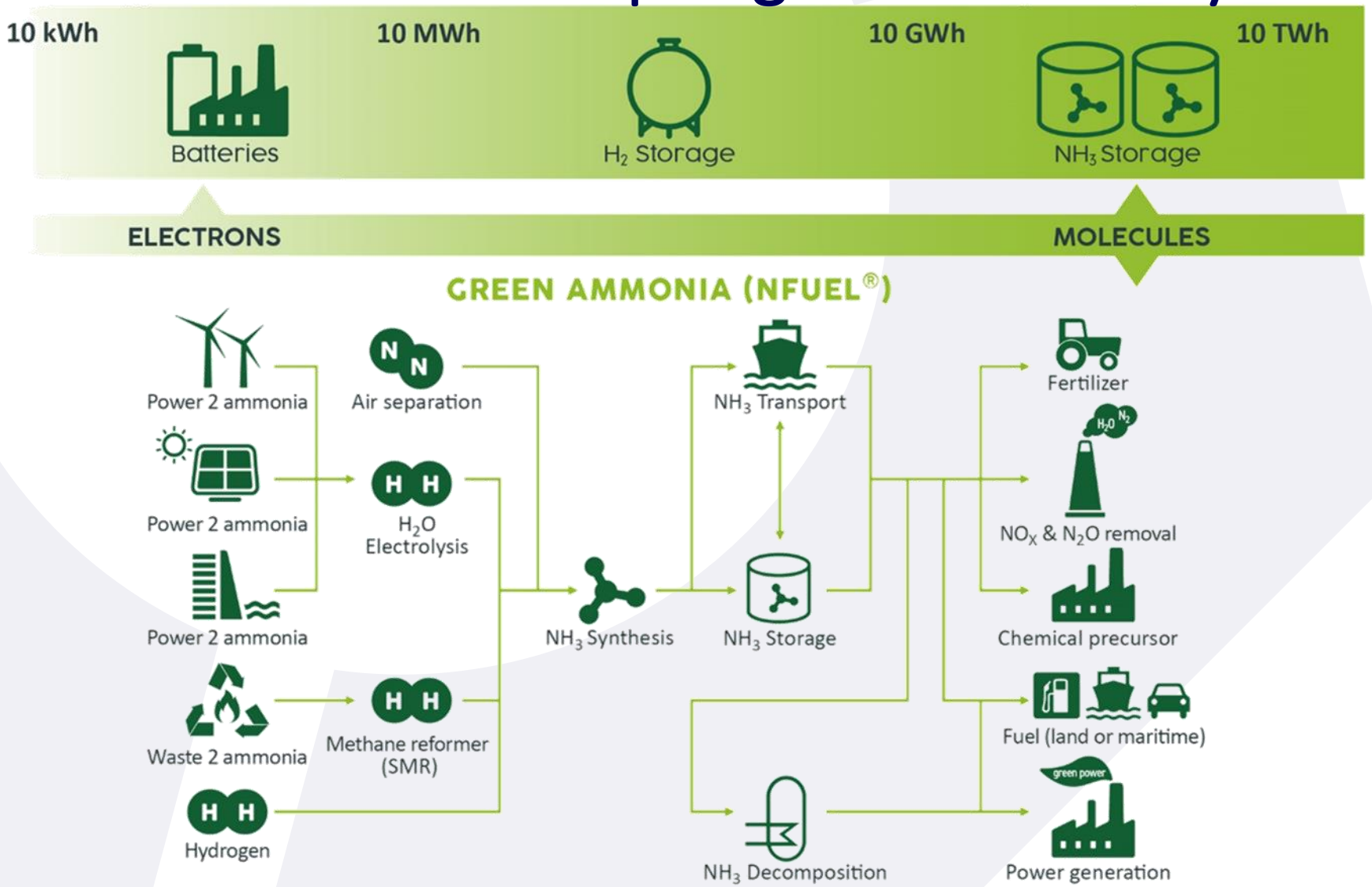
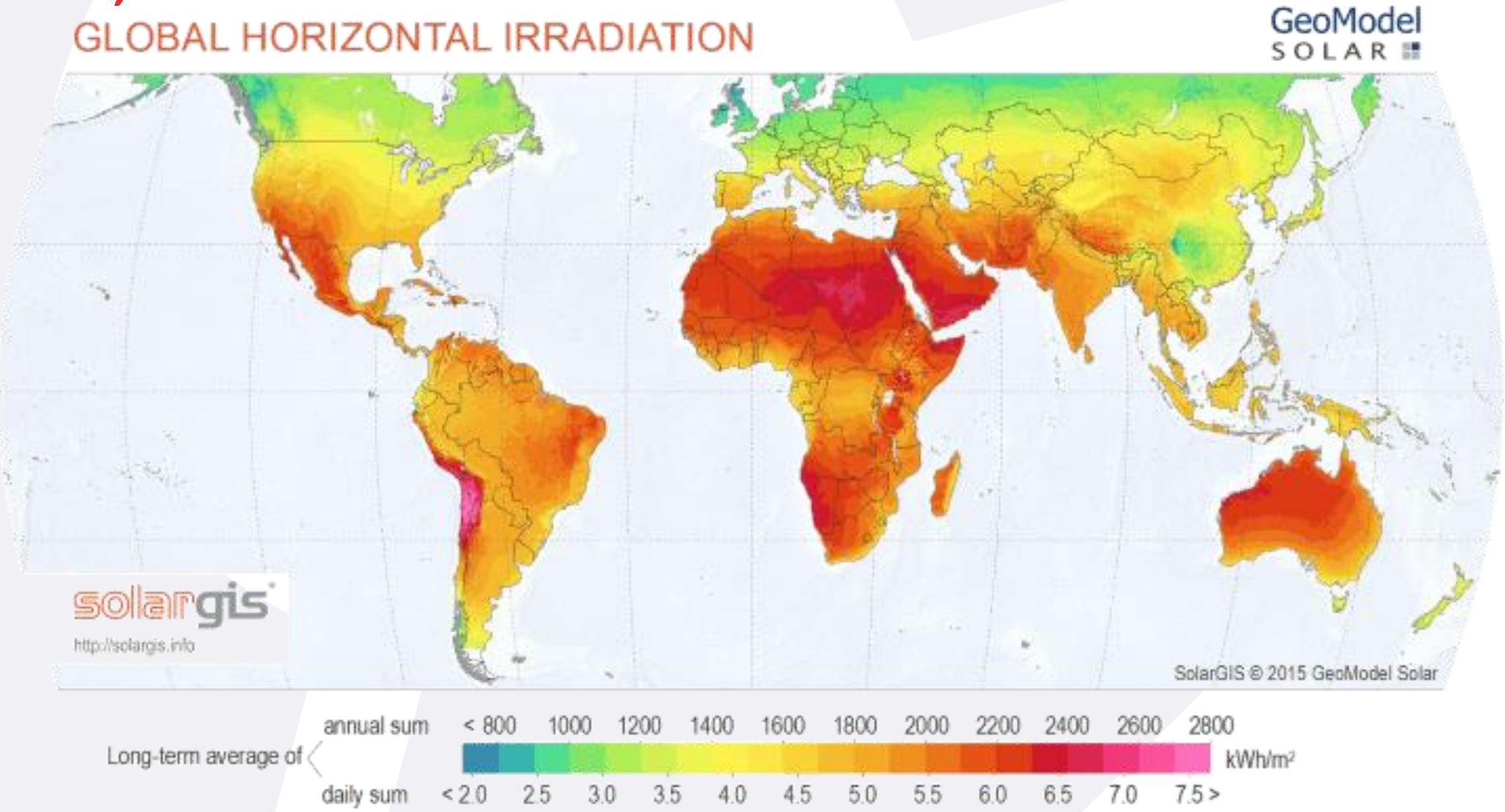
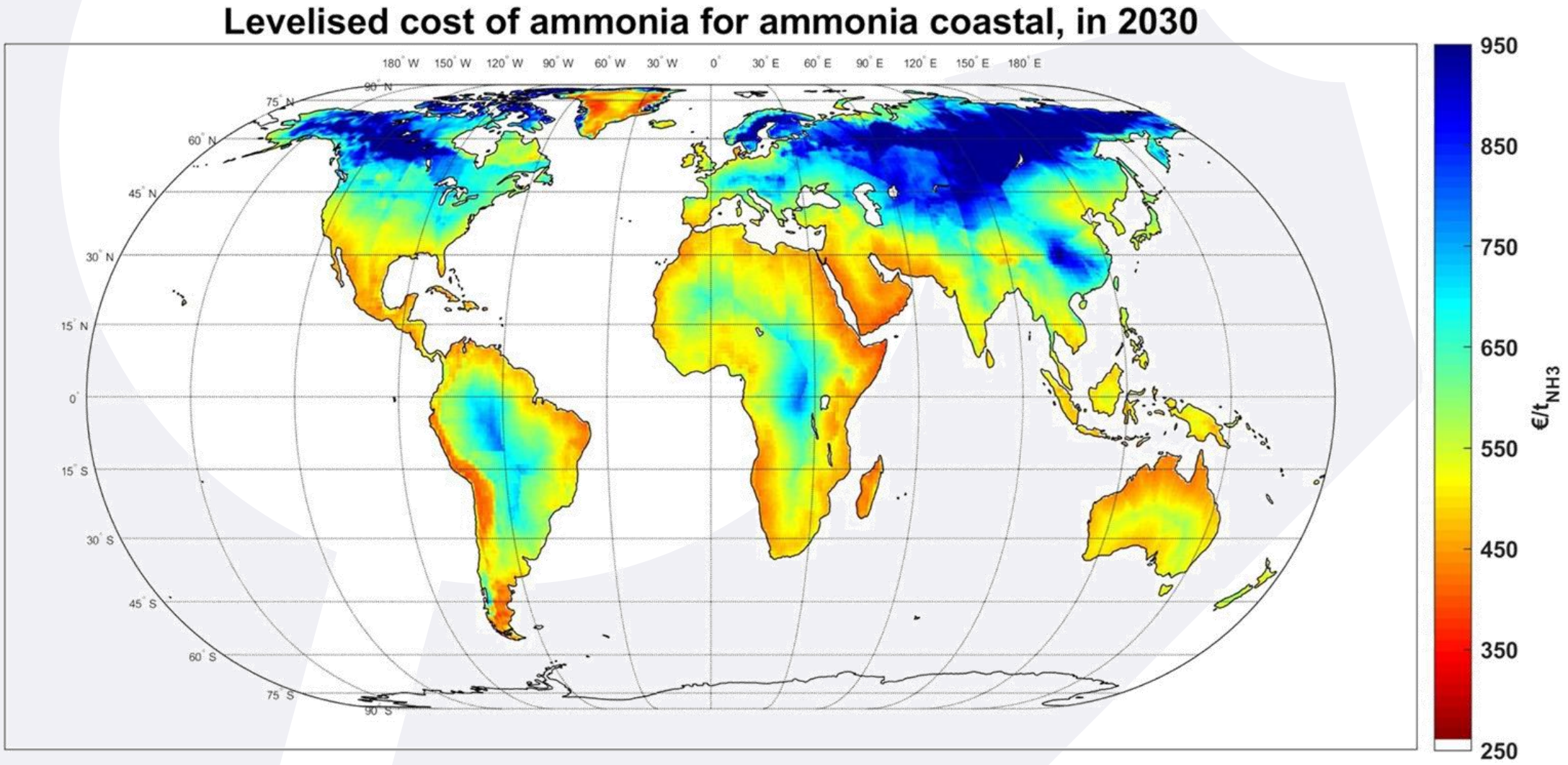
Why ammonia : HD flexible liquid green electricity



Ammonia, the new oil



Ammonia; liquid electricy- let ‘s say “oil”



Empowering green ammonia **and energy solutions**

[1] https://www.sciencedirect.com/science/article/pii/S0306261920315750

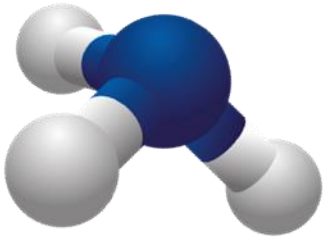
It is all about logistics and its “associated”costs Power2ammmonia and back ammonia-power (at decentralised sites)

The Dillemma is :

how to make clear why ammonia is the better option als energie Carrier in various parts of the world:

- Comparing fossil with non-fossil products
- Comparing H2 versus ammonia or vs methanol or other fuels
- Comparing for various applications and technical requirements between blue, grey and green ammonia
- Compare costs, margins and premium markets
- Flexibility in usages
- Long term storage / **strategic** storage as part of energy system

- Maybe companies make suboptimised conclusions and do not look to full value chain
  - Per type of product/ carrier
  - Per LCA
  - Per application
  - Per country of use



H2 –chains for transport (Pro's & Con's, @ 2,670 ton H_2)

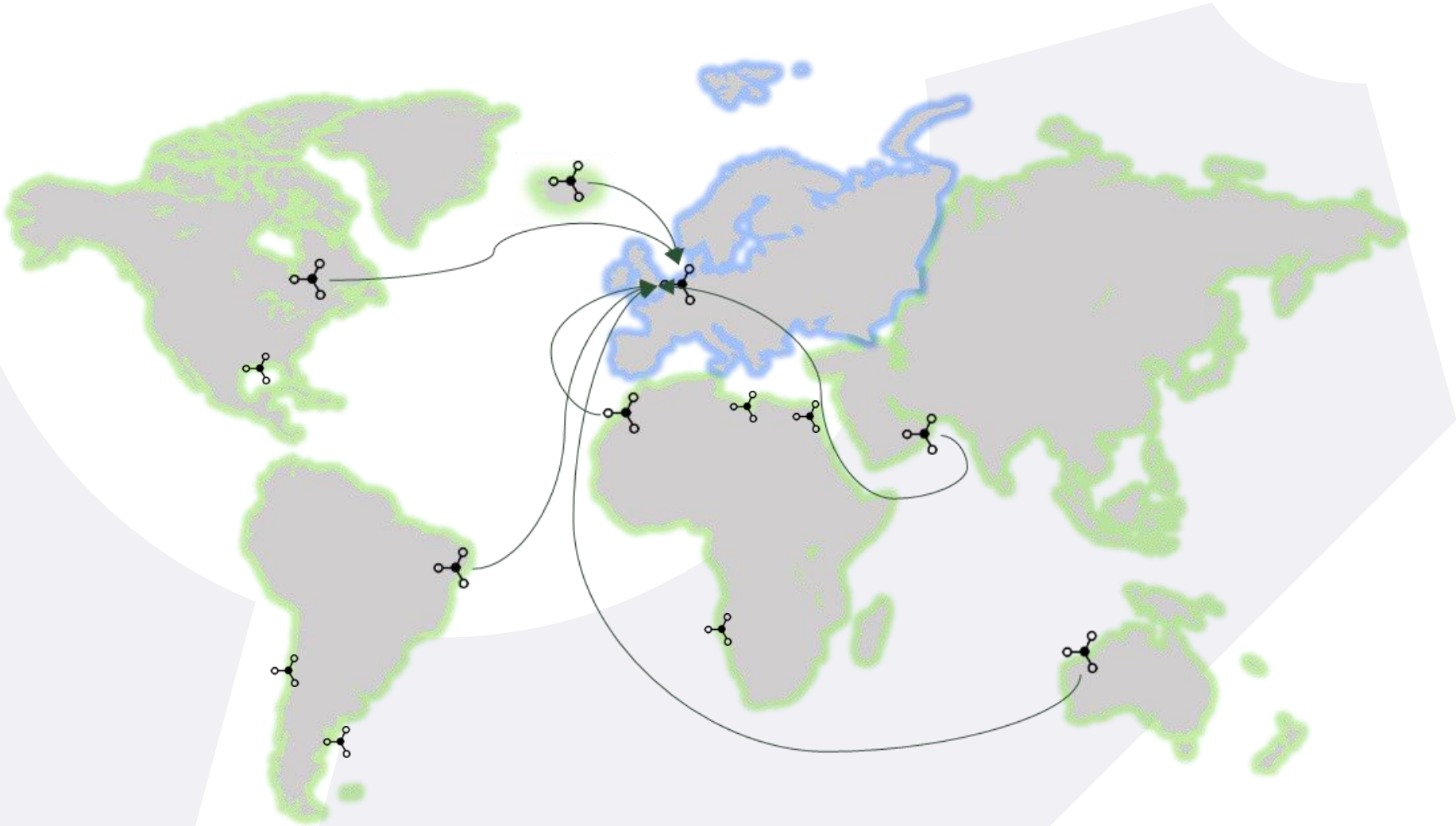
- **NFuel (Ammonia)**
- $3H_2 + N_2 \Rightarrow 2\ NH_3$ or 1,5 molecule H_2 gives 1 molecule NH_3 **(no loss** of H_2 in the formation reaction)
- Approx. 178 kg H_2 per ton NH_3
- Cracking NH_3 to H_2 takes approx. 20-23% of initial H_2 quantity (why do this and not use directly the NH_3?)
- 15,000 ton NH_3 requires some **20,000 m³** storage volume

- **LOHC (Liquid Organic Hydrogen Carrier)**
- Thermo-chemical bonding of H_2 to organic hydrocarbons (e.g. MCH)
- Approx. 62 kg H_2 per ton LOHC
- Thermal energy needed to release H_2 from LOHC required, typically 25% energy loss
- Re-use existing infrastructure related to Oil & Petro Chemical Industry
- 43,000 ton LOHC requires some **55,900 m³** storage volume (but simpler system)

- **LH_2**
- Liquid at -253 °C, requirs some 3.9 (theoretical minimum) up to 16 kWh/kg H_2 in energy (10 - 50% of energy value is lost)
- 2,670 ton liquid H_2 requires some **38,000 m³** storage volume
- To compare, compressed H_2 gas at 200 barg would require for the same 2,670 ton the impossible volume of ca **188,000 m³**

- $CH_4 – CH_3OH$ (MeOH) : with fossil carrier
- The formation reaction requires CO_2 and generates less H_2 due to H_2O being formed, hence less attractive for energy purposes other than niche or difficult to abate sectors. Will the CO_2 resource be there in the future?
-

Hubs for clean ammonia



Optimising new chains of ammonia P2A-A2P

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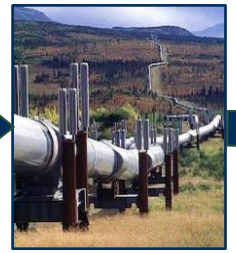
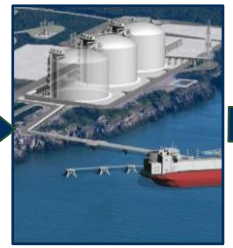
Partnership possibilities

Renewable Power

H_2 Production & Conversion

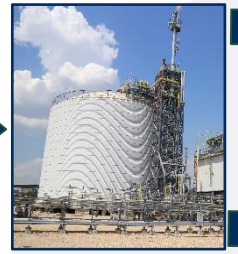


Local gas distribution



Storage & Export

Transport



Storage Design & operation

Local distribution

Transport

Decomposition H_2 or NH_3 sales

heat for apartment buildings

H2 stations

Optimising new chains of ammonia P2A-A2P

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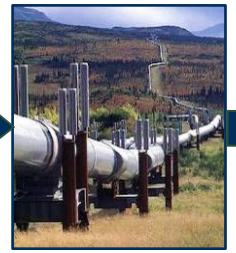
Renewable Power

H_2 Production & Conversion



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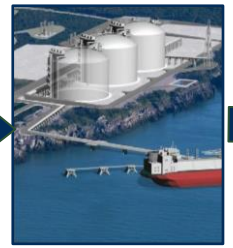

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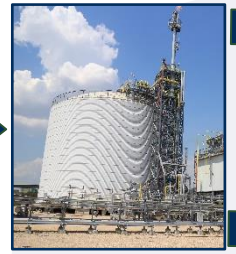

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The alliance
e.g. THA

Optimising new chains of ammonia P2A-A2P

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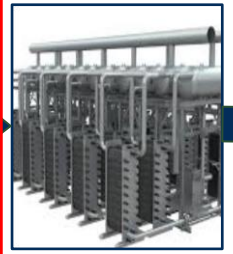
Renewable Power



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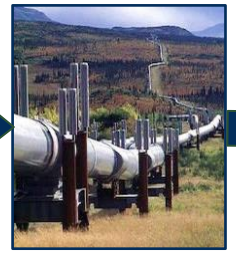

Local gas distribution

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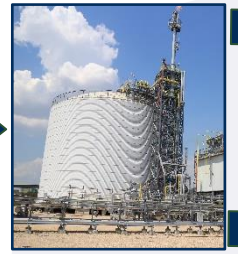

Storage Design & operation

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Decomposition H_2 or NH_3 sales

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H2 stations

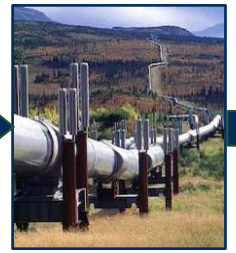
PPA-Production-Sales

Optimising new chains of ammonia P2A-A2P

PROTON VENTURES

Renewable Power

H_2 Production & Conversion



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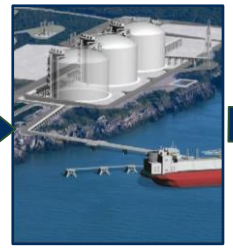

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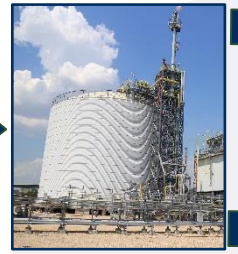

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PPA-Producer-logistics-redistribution-wholesale-detailed sales

Advantages business models

- 1 Alliance

  single line of responsibility
  Co-investment pro rata
  profit pro rata/ risks pro rata low risk/ decent income ll/ Complex to organise

- 2 traditional PPA based

  PPA-Production-Wholesale

  power producer makes guaranteed profit- producer has the risks

  investors feel more safe, but lower margins

- 3 traditional

  PPA (market price) -production agreement (take or pay) - logistics (take or pay)-storage agreement(s) -detailed distribution

  Power producer makes the biggest profit, producer makes a profit, all risks at distriution channels at lower margin for producer.

  Highe income potentially , but more complex to start to have all agreements in place at the same time

Optimising new chains of ammonia P2A-A2P

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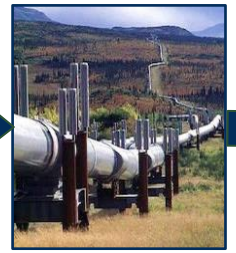
An alternative for a cable from Morocco to Rotterdam?

Renewable Power

H_2 Production & Conversion



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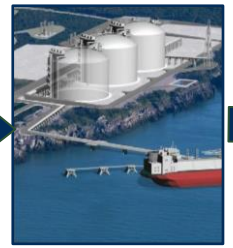

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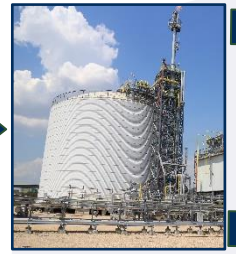

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Empowering green ammonia and energy solutions

Offtake and pricing (Blue and Green)

- **Ammonia can be considered oil!; Does oil have a fixed price?????????**
- **Ammonia green is mainly fuel, but competes as molecule with ammonia for fertilisers (at a premium?)**

- **Ammonia is not a product, but a way to transport energy from A to B**
  - **Thus ammonia (full new chain) = “infrastructure”**

  - **Depreciation of ammonia is thus to compete with other infrastructure projects**
    - **More 40 years than 10-20 years for levelised costs**
    - **Detailed studies (NAM challenge) showed enormous shorter payback for NH3 vs H2**

- **OPEX is most crucial for long term profitability. CAPEX “should be” less determining factor for FID decisons**
- **Lowest Capex per site always is best , but impossible to have one technology being best.**

Costs for clean ammonia (Blue/Green)

- Opex is key for green projects
  - Indicative costs for most green technologies is 9000-11000 kW/ton NH3 green
  - Including all raw metarials costs
  - No manpower included, but usually 20 euro/ton for bigger plants of some 500 ktpa
  - With 1-2 ct/kWh alkaline outcompetes other sources , except hydro

- Capex; (new build units)
  - With double Capex , solar (25-35%) will probably be still cheaper than wind (45-60%) or geo or nuclear or CCS based ammonia
  - If new technologies come, this might change , but in such case there should be a big benefit in OPEX mainly say getting closer to theoretical amount of energy for electrolysing water i.e
  - Combination of wind and solar is not always the better picture, but offers flexibility at low or no wind/solar for longer period
- OPEX CAPEX for Blue is depending plants different and should be competitive in shorter period of depreciation (not 40 years!). Earlier 5-8 years payback to be competitive

In 2030 “Green” may outcompete Blue as well in Hydrogen as in Ammonia costs

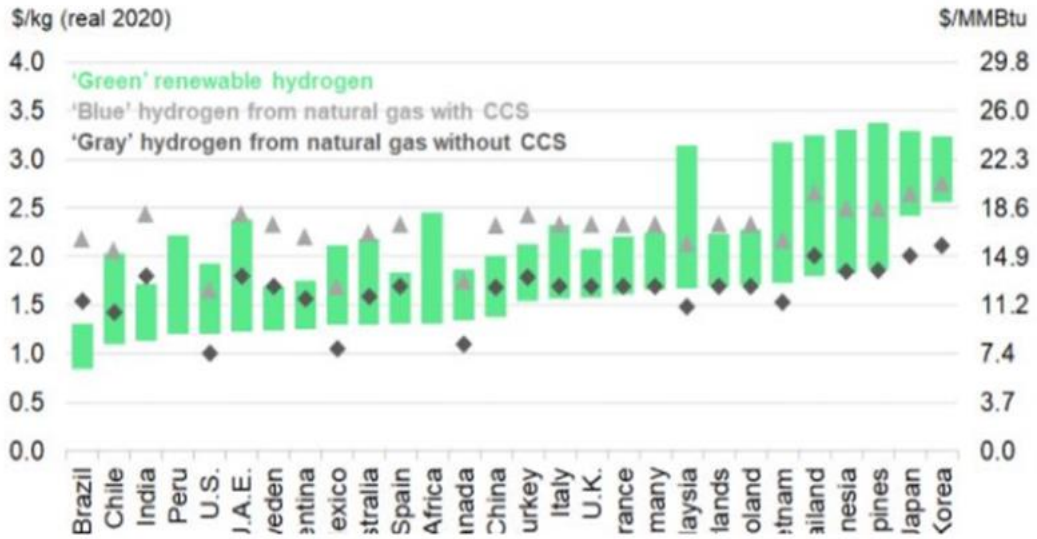
Bloomberg 2021

May 5, 2021

This article first appeared on the BNEF mobile app and the Bloomberg Terminal.

- Fossil hydrogen with CCS currently cheaper than ‘green
- The opposite should be true by 2030 in all major markets

‘Green’ versus ‘blue’ hydrogen costs, 2030



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Blue is an enablerer for green in future to give the volume to start, but temporarely the cheapest till ??????

Supply chain projects in Rotterdam

7 ammonia terminals

5 new ,1 retrofit, 1 existing (total 10 Mton/pa throughput)

CO2 sewer

H2 backbone

Multiple crackers and bunker stations

Grey H2 production

Blue H2 production

New mega electrolysers of total 2 GW

Conditions for succes for a global market

Partnership in the logistic supply chain
Partnership in the mechanical supply chain
Partnership with the government/society

Think globally and act locally
Certification
Pricing mechanism locally
permitting

Most important take aways for progress of the Clean Ammonia industry

- Certification should in place for many countries, worldwide accepted
- Public perception improvement
- Correct narrative for information about ammonia safety for “downstream”usage
- Further costs reduction by new technologies/Innovations are helpful
- Scaling of electrolysers production facilities

- Ammonia is to be considered the new **oil** and pricing should be accordingly fossil based oil
- Clear pricing mechanism for different markets

And

- Partnerships are an accelerator to scale the business

NH3 Event Europe 2023

- Organiser of the yearly European (green) NH3 event since 2017
- > 200 participants last year
- In 2023 the event takes place on 8 & 9 June, 2023
- Call for papers is open.
- www.nh3event.com

•Thank you

See you in:

AFA-NH3event Cairo
Februari 21-23rd 2023

And/or

Stichting NH3event Rotterdam
June 7-9th 2023