SHIP>NL
SUSTAINABLE HYDROGEN IMPORT PROGRAM

AGENDA
SHIP>NL SESSIE IV 19 APRIL 2023

16:00-16:05 WELKOM

16:05-16:15 UPDATE: WORLD HYDROGEN SUMMIT | DAVID KOOLE - RVO

16:15-16:45 DEEP DIVE LIQUID HYDROGEN DEVELOPMENTS | ELLEN RUHOTAS – ZENITH ENERGY

16:45-17:00 REFLECTIE HYDROGEN IMPORT TERMINAL DEVELOPMENT| WILCO VAN DER LANS - POR

17:00 AFSLUITING

TNO innovation for life

‘HUISREGELS’

- Camera aan, microfoon op ‘mute’
- Vragen?
  - Plaats *verduidelijkingsvragen* in de meeting chat; of
  - Steek je hand op

  ❯ De moderator zorgt ervoor dat je vraag beantwoord wordt (eventueel achteraf).
- Slides worden na de sessie gedeeld

- We bespreken uiteraard geen marktgevoelige zaken.
- Chatham house rules: De besproken informatie mag gedeeld worden, maar zonder de spreker te onthullen.

MEERJARIG KENNISPROGRAMMA MET 5 LIJNEN

In deze sessie:

1 Technisch economisch	2 Beleid	3 Markt	4 Internationaal	5 Omgeving
▪ Inzicht in importketens productie-conversie-transport-opslag-reconversie-gebruik	▪ Impact van 'Fit for 55', REDII, Delegated acts, ETS/CBAM, etc.	▪ Marktmodellen: bilaterale contracten, vrije handel, waterstofbeurs	▪ Samenwerking met omringende EU/niet-EU importlanden om corridors te ontwikkelen	▪ Ruimtegebruik van ketenelementen
▪ Vraagontwikkeling, scenario's	▪ Impact van certificering en CO2 allocatie: emissiefactoren, LCA ketenanalyse, etc.	▪ Internationale handelsstromen: verwachte vraag- en aanbodvolumes en transportstromen	▪ Concurrentie met omringende EU/niet-EU importlanden	▪ Veiligheid: brandbaarheid, zorgwekkende stoffen, risicocontouren, etc
▪ Infrastructuur & systeemintegratie: corridors, benutten bestaande infra.	▪ Financiering en stimulering (EU & NL): IPCEI, PCI, TEN-E, JTF, EIB, Horizon Europe, MOOI, DEI, MIEK, SDE++, etc	▪ Importtarieven, trade agreements en handelsbeperkingen, WTO, etc.	▪ Geopolitieke aspecten: strategische voorraden, afhankelijkheid, politieke stabiliteit van exportlanden	▪ Milieu: stikstof, lekkage
▪ Technology assessments, R&D				▪ Maatschappelijke acceptatie
				▪ MVO / samenhang met SDG's in exportlanden

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UPDATE: WORLD HYDROGEN SUMMIT

David Koole | RVO

DEEP DIVE: LIQUID HYDROGEN DEVELOPMENTS

Ellen Ruhotas | Zenith Energy

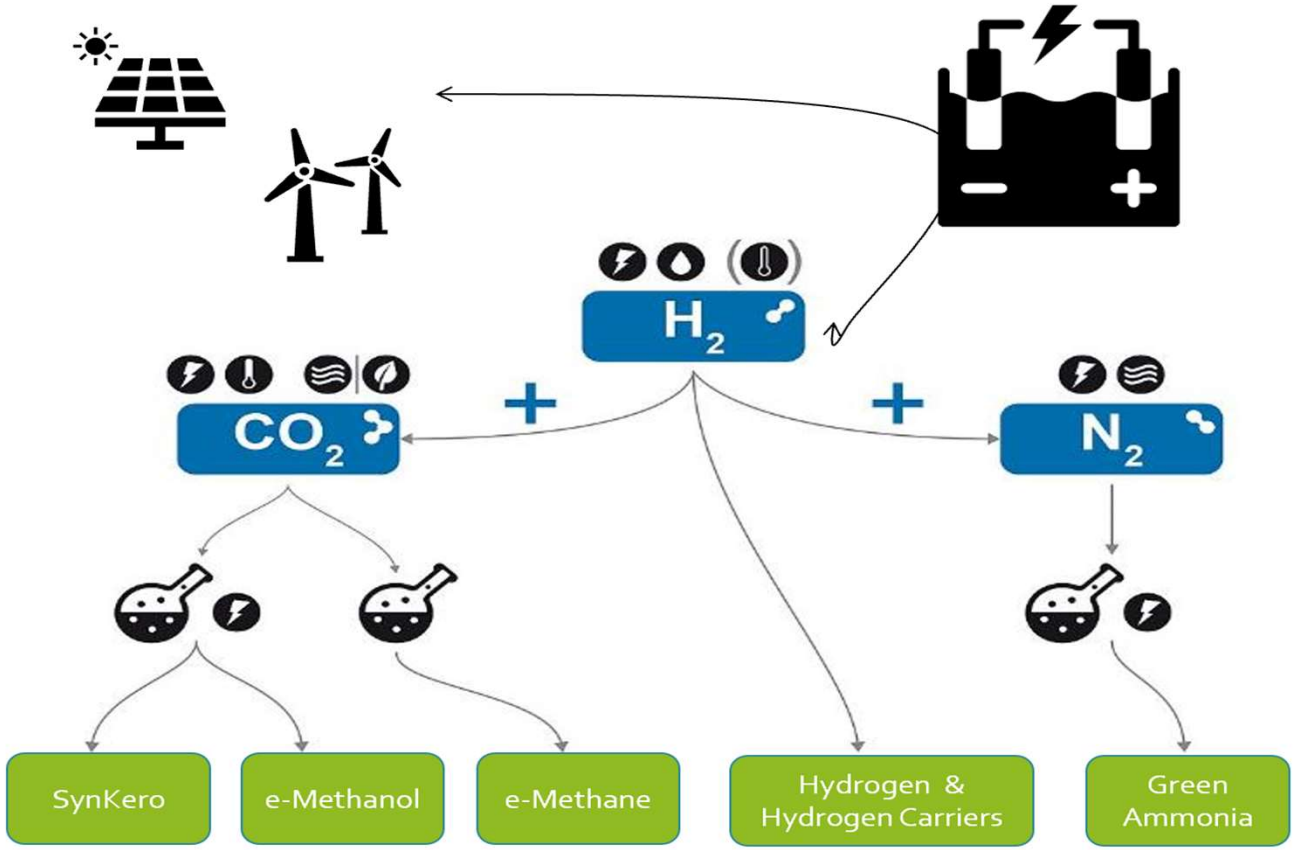
Deep Dive: Liquid Hydrogen Developments

Sustainable Hydrogen Import Program Netherlands
19 April 2023

Zenith Energy

Hydrogen to the Netherlands

- Green Electricity generated from wind, solar, geothermal, hydro and wave energy
- Hydrogen production from electrolysis of water
- Chemical reaction with Carbon Dioxide (CO_2)
- Chemical reaction with Nitrogen (N_2)



Source: Öko-Institut - https://www.flickr.com/photos/oekoinstitut/48378513216/in/album-72157709574720357/

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NOW LET'S GET YOUR OPINION ON SOME TOPICS

- Please go to www.menti.com
- Use code: **5429 3537**

Which hydrogen vector will be used to import H_2 to the Netherlands in 2030 and in 2040?

A. Compressed Hydrogen

B. Liquid Hydrogen

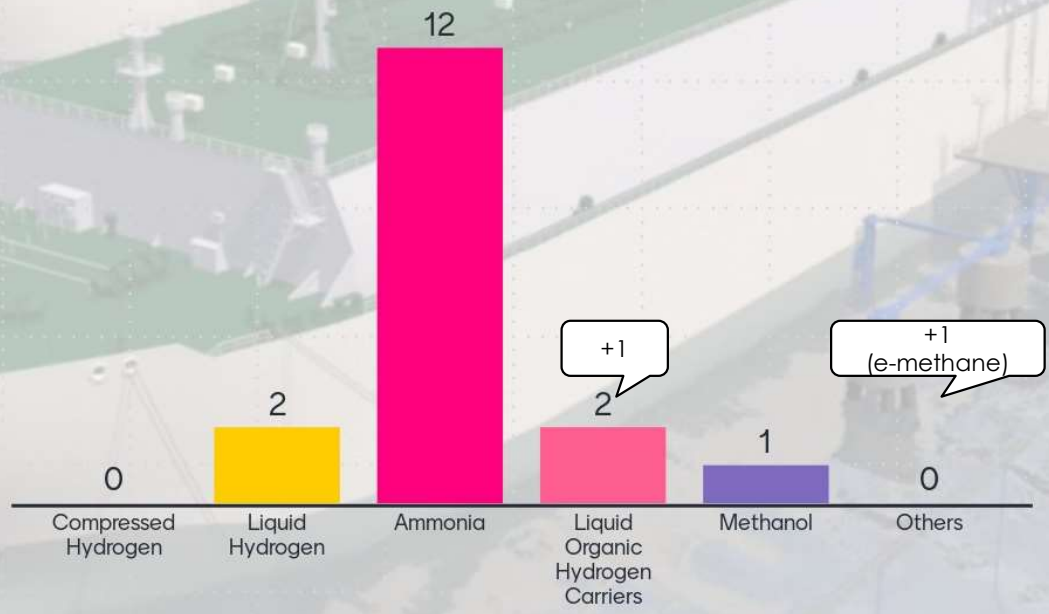
C. Ammonia

D. Liquid Organic Hydrogen Carriers

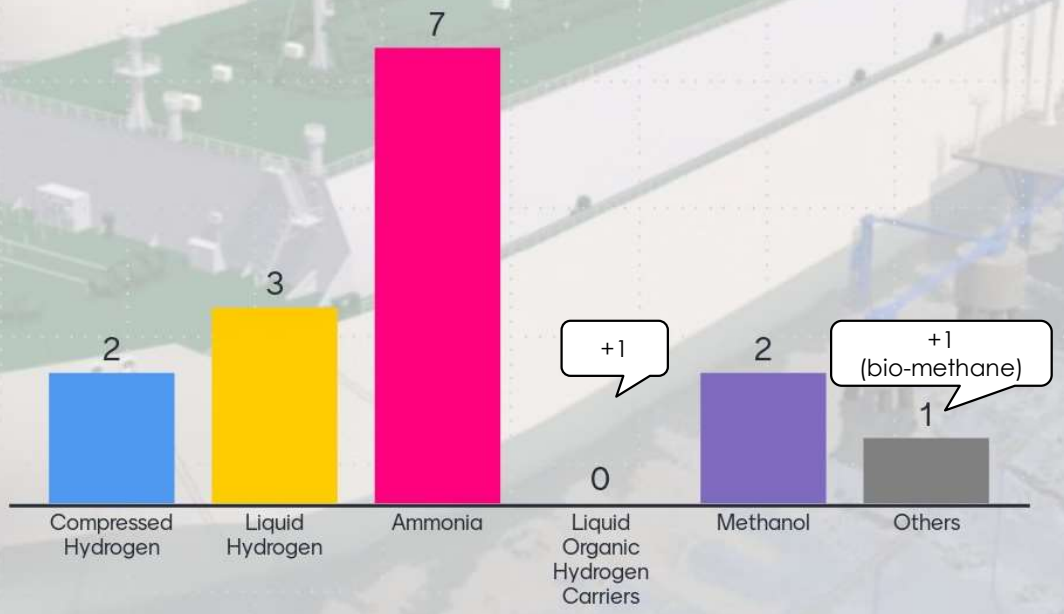
E Methanol

F Other

Which hydrogen vector will be used to import H2 to the Netherlands in 2030?



Which hydrogen vector will be used to import H2 to the Netherlands in 2040?



Which hydrogen vector will be the cheapest to import H_2 to the EU?

A. Compressed Hydrogen

B. Liquid Hydrogen

C. Ammonia

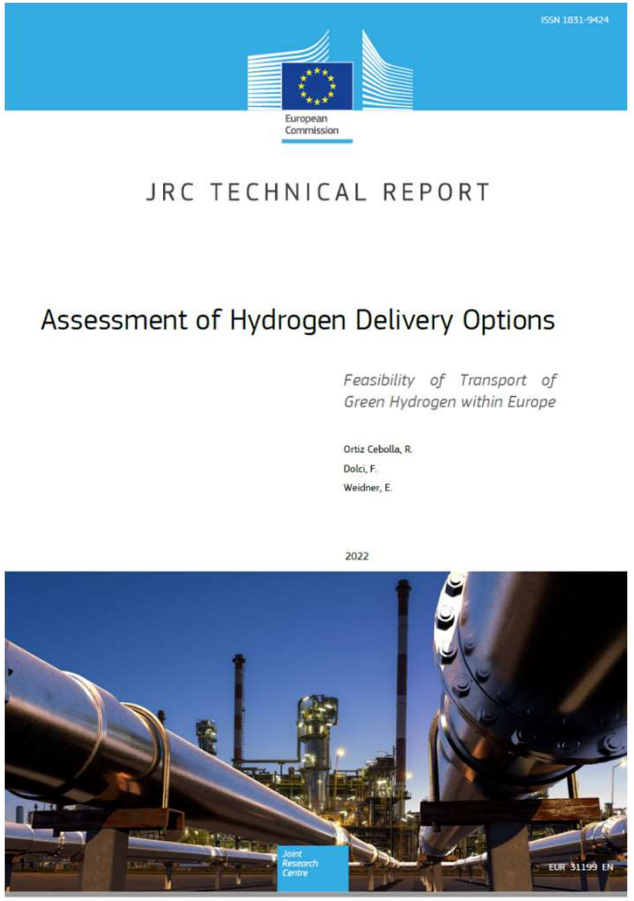
D. Liquid Organic Hydrogen Carriers

E Methanol

F Other

Assessment of H_2 Delivered to the EU

- Joint Research Centre Technical Report issued October 2022
- Feasibility of transporting Green Hydrogen within Europe
- Assessed delivery cost and energy demand per kilogram of H2
- Two scenarios:
  (i) Single producer to one port
  (ii) Multiple destinations for mobility distribution



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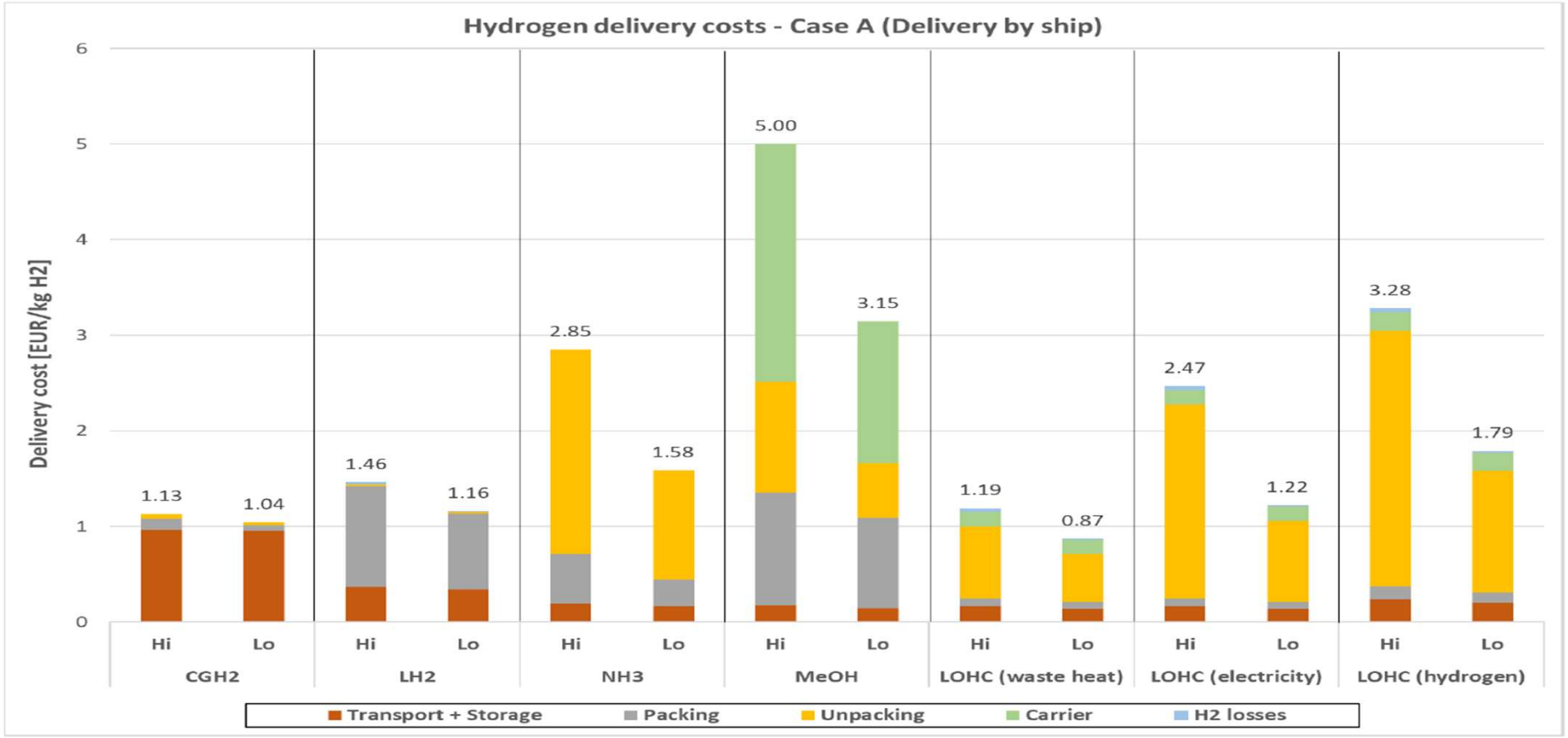
Source: https://publications.jrc.ec.europa.eu/repository/handle/JRC130442

Cost of H_2 Delivered to the EU



Source: https://publications.jrc.ec.europa.eu/repository/handle/JRC130442

Which hydrogen vector is the most energy intensive to deliver H_2 to the EU?

A. Compressed Hydrogen

B. Liquid Hydrogen

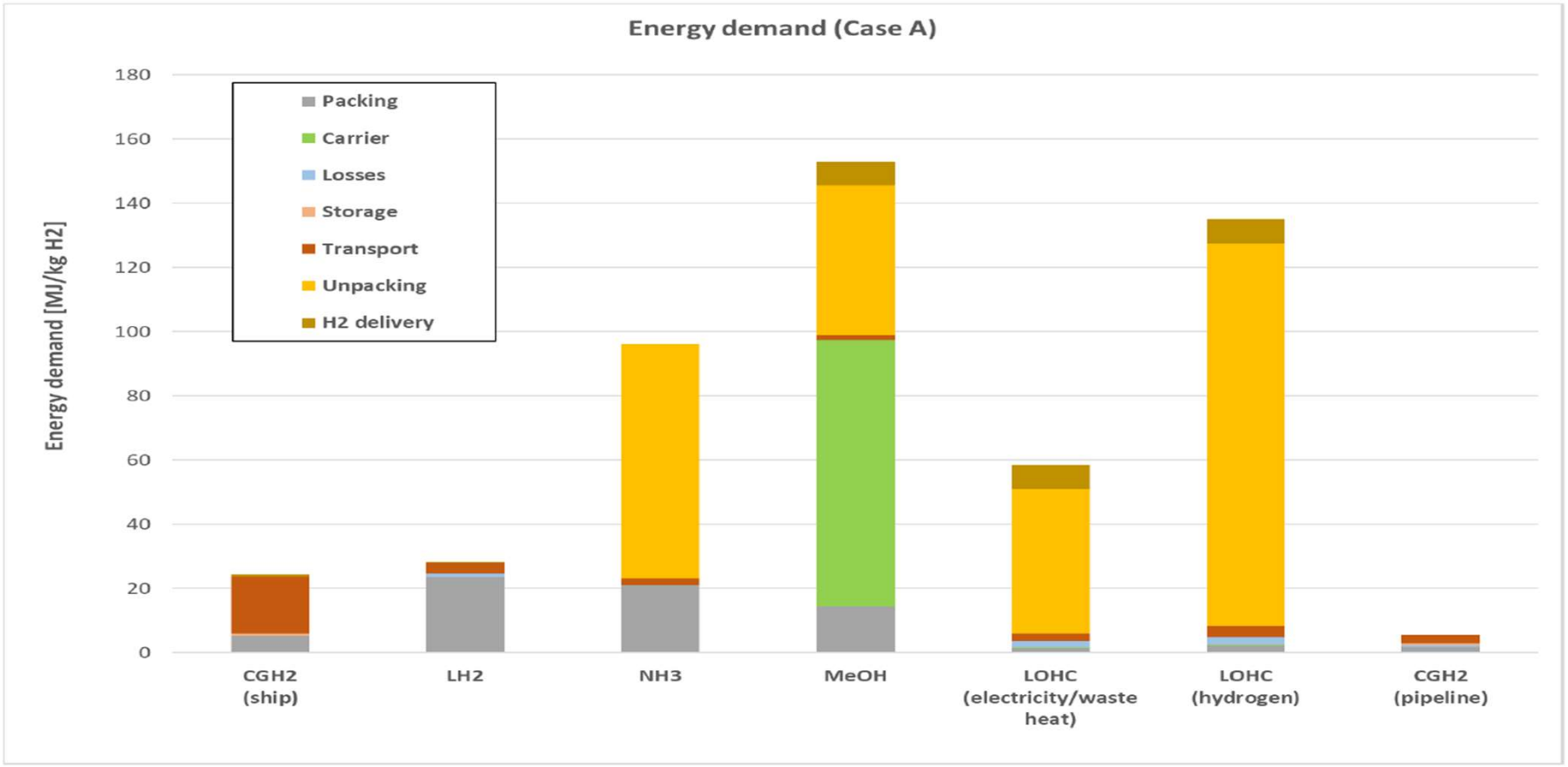
C. Ammonia

D. Liquid Organic Hydrogen Carriers

E Methanol

F Other

Energy Demand to Deliver H_2



Source: https://publications.jrc.ec.europa.eu/repository/handle/JRC130442

Liquid Hydrogen

Can you really do it before 2030?

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Liquefaction

- Air Liquide commissioned the World's largest liquefaction plant in May 2022 @ 30 tonnes/day
- Construction of a 90 tonne/day plant announced in South Korea
- Currently developing liquefaction trains of > 100 tonnes/day
- Electricity consumption at 18 -22 MJ/kg of H_2

Liquid Hydrogen Storage

- Liquid Hydrogen storage tanks in use for over 50 years
- NASA in Kennedy Space Centre commissioned the world's largest storage tank in May 2022 (4,732 m^3)
- Boil off reduced to 0.03% per day (0.1 kg/day)
- US Department of Environment studying LH_2 storage tanks of 20,000 m^3 – 100,000 m^3

Liquid Hydrogen Vessel

- Suiso Frontier maiden voyage January 2022 from Australia to Japan
- Demonstration scale of 1,250 m^3, 85 tonne of liquid hydrogen.
- Japan Suiso Energy announced investment of $2.35 bn for development of liquid hydrogen to Japan up to 225,000t/year

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Moving Liquid Hydrogen to Europe

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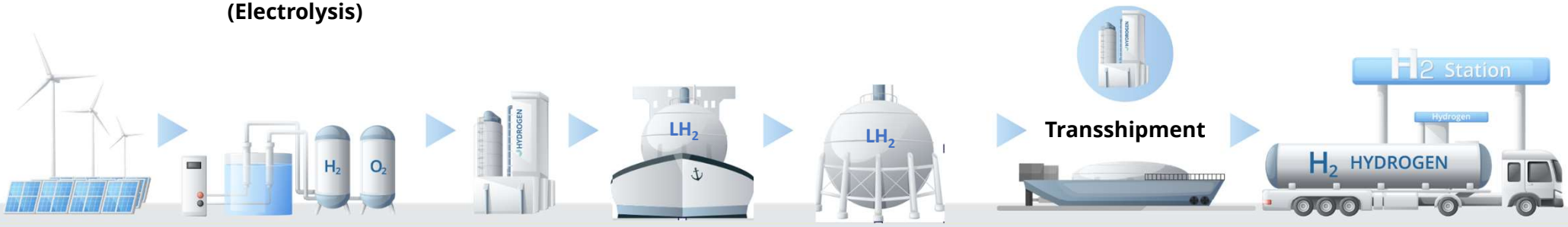
Zenith's Liquid Hydrogen Chain to Europe

Renewable Electricity | **Green Hydrogen Production (Electrolysis)** | **Hydrogen Liquefaction** | **Vessel Transport** | **Storage** | **H_2 Gasification** | **End use**



Liquid Hydrogen Producers

- Saudi Arabia
- Ireland
- United Kingdom
- United States
- Oman
- Norway
- Iceland
- UAE

Project Eos - Zenith Energy Amsterdam

- Design of l**iquid hydrogen vessels** with various capacities
- **Regasification at Zenith Energy's Amsterdam** Terminal
- Importation of Liquid Hydrogen to the **Dutch HyNetwork**
- Reticulation of Hydrogen in the Port to adjacent industries
- **Export of Hydrogen by Barge and Truck to hinterland**

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Zenith & Port of Amsterdam's BioPark

Masdar's Green Hydrogen to Zenith

In January 2023, Zenith Energy entered into an MoU with Masdar Green Hydrogen for the development of a **liquid hydrogen supply chain to support the export of Masdar's green hydrogen to Europe**.

Together with our shipping partners, Zenith Energy has developed a feasible route to market for liquid hydrogen to our terminal in Amsterdam and delivery to Dutch and German industries.

Zenith's **open access, liquid hydrogen import** terminal will provide regasification to the Dutch **Hydrogen Backbone** and transhipment of both liquid and gaseous hydrogen by **barge** and **truck.**

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Renewable Fuels | Exploration & Production | Fuel Oil | Hydrogen | Climate Change

1 minute read · January 13, 2023 4:56 PM GMT+1 · Last Updated 14 days ago

UAE's Masdar signs MoU with Dutch companies to develop green hydrogen supply chain

Reuters

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Energy Transition
The next steps ...

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Energy in World History

Humans depend on harnessing energy for our existence

Global Energy Transitions:

1st - Wood to Coal
2nd - Coal to Oil
3rd - Oil to Natural Gas
4th - Fossil Fuel to Renewable

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Source: Vaclav Smil, Energy and Civilization: A History (2017)

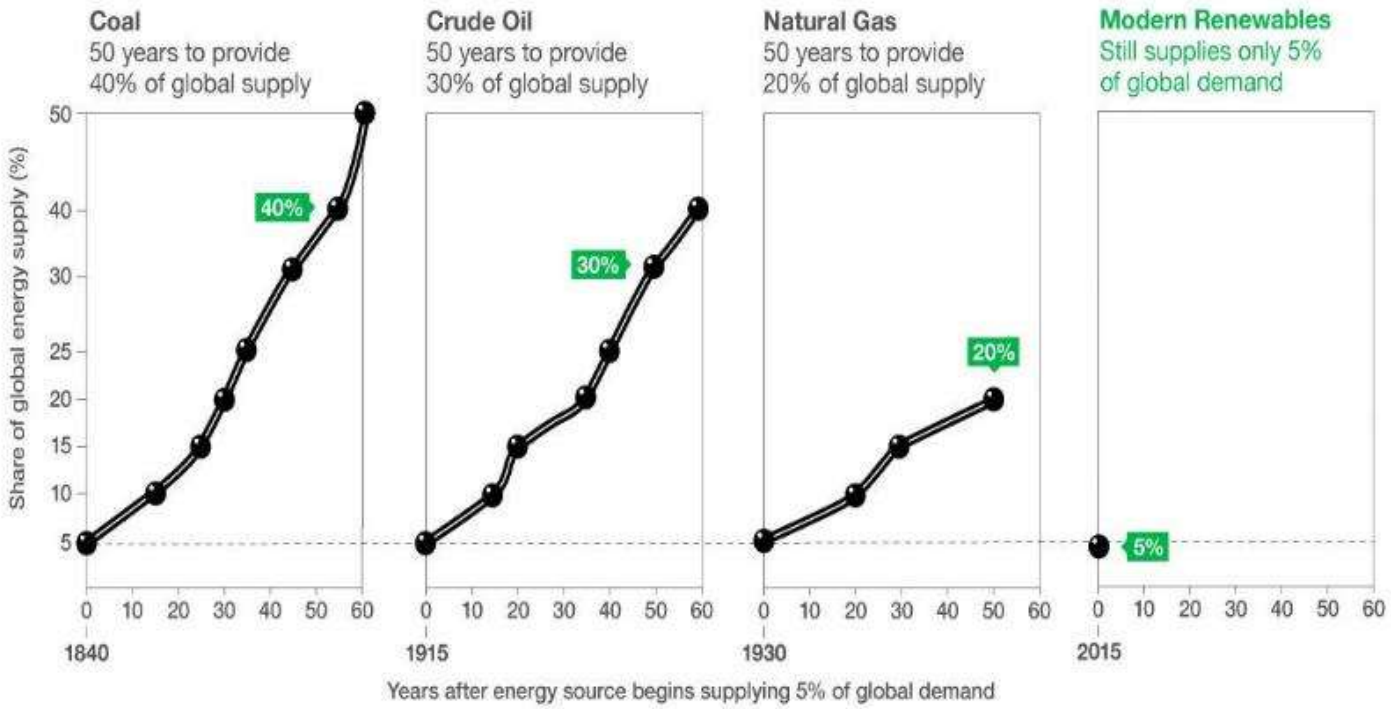
Energy Transitions Take Time

Fossil fuels still supply over 80% of our primary energy

2 – 3 generations to capture a large share of the global energy market

Requires enormous infrastructure investments

Existing technologies have a lot of Inertia



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Source: Vaclav Smil, Energy and Civilization: A History (2017)

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Word Map ….

What are the key road blocks to realising hydrogen importation to the Netherlands ?

VOLGENDE KENNISSESSIE WOENSDAG 17 MEI

Face-2-Face

- Ministerie van EZK – Bezuidenhoutseweg 73, Den Haag

15 maart	Voorlopige agenda
14.30 – 15.00	Ontvangst
15.00 – 15.30	Tour de table
15.30 – 17.00	• Deep dive: Energiediplomatie | Min.EZK • Deep dive: Pre-feasibility studie NH3 kraken in Rotterdam | t.b.d.
17.00 – 18.00	Borrel

- Data overige F2F kennissessies
  - 5 juli
  - 20 september
  - 15 november
- Overige maanden online deep dives

HARTELIJK DANK VOOR UW AANDACHT

Vragen? Neem gerust contact met mij op:

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+31 6 23 34 65 16

De slides van alle sessies zijn te vinden op:

SHIPNL: Sustainable Hydrogen Import Program Netherlands | Nationaal Waterstof Programma