URUGUAY - PORT OF ROTTERDAM
HYDROGEN SUPPLY CHAIN

Ministerio de Industria, Energía y Minería

Port of Rotterdam

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THE WORLD IS GEARING UP

GREEN HYDROGEN PROJECTS ALL OVER

HyGreen (France)

Start: 2030
Capacity: 900 MW
CAPEX: 1.2 US$bn
Production: 13 kt/yr

H2 Fifty (The Netherlands)

Start: 2025
Capacity: 250
MW CAPEX: US$bn
Production: 45 kt/yr

North H2 (The Netherlands)

Start: 2027
Capacity: 10GW
CAPEX: 20
US$bn
Production: 800 kt/yr

Jingneng (China)

Start: 2022
Capacity: 5GW
CAPEX: 3.2
US$bn
Production: 183 kt/yr

Sundance (Canada)

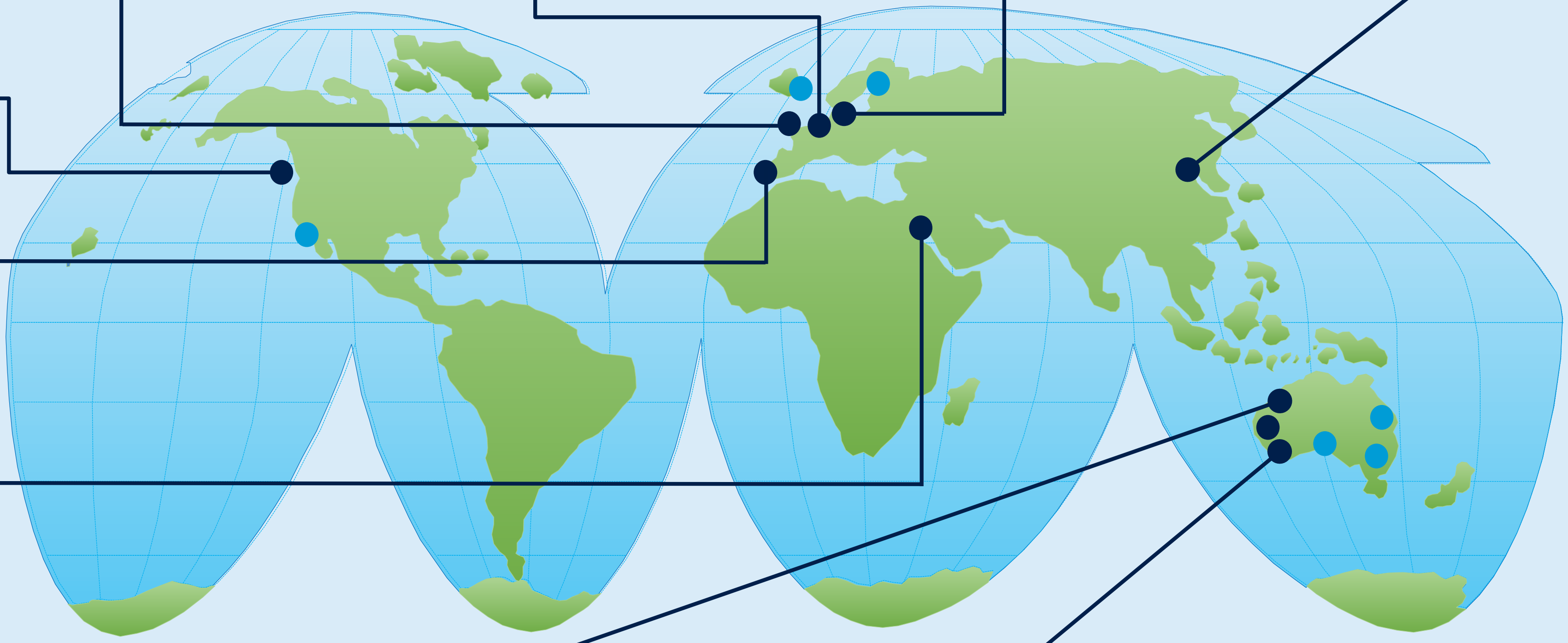
Start: 2024
Capacity: 100-200MW
CAPEX: 0.2 US$bn
Production: 22 kt/yr

Iberdrola (Spain)

Start: 2023
Capacity: 100MW
CAPEX: 0.2 US$bn
Production: 7 kt/yr

NEOM (Saudi Arabia)

Start: 2025
Capacity: 4GW
CAPEX: 7
US$bn
Production: 207 kt/yr



Arrowsmith (Australia)

Start: 2022
Capacity: 200MW
CAPEX: 0.3
US$bn
Production: 9 kt/yr

AREH (Australia)

Start: 2027
Capacity: 11GW
CAPEX: 15
US$bn
Production: 562 kt/yr

Source: based on IEEFA, 'Great Expectations', (Aug 2020)
PoR Analysis

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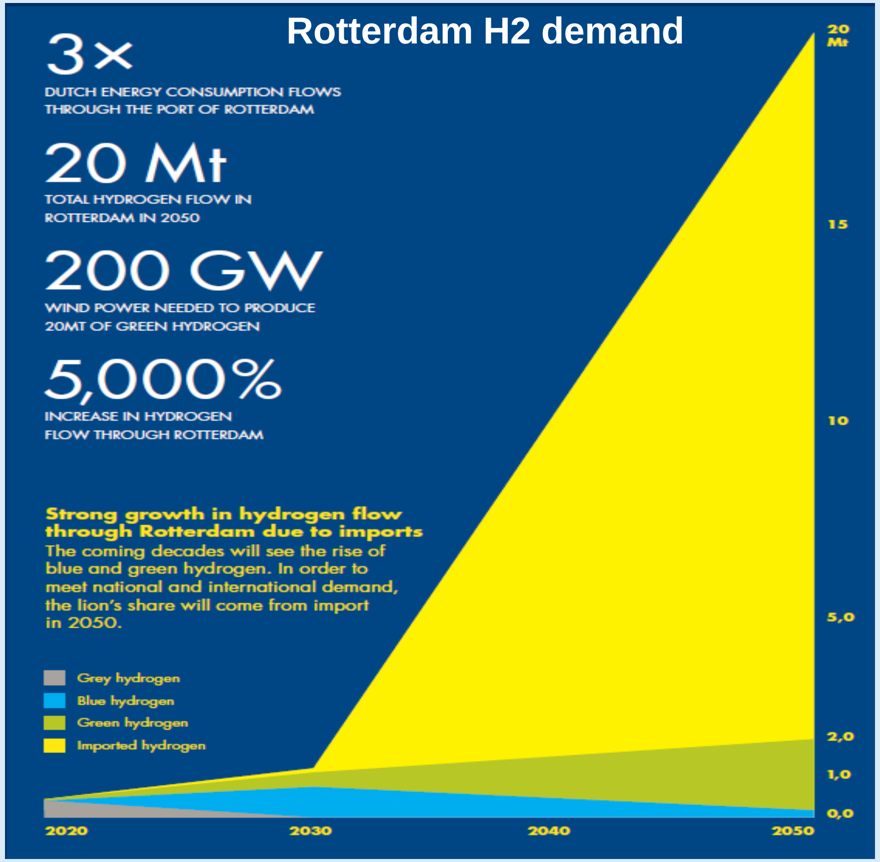
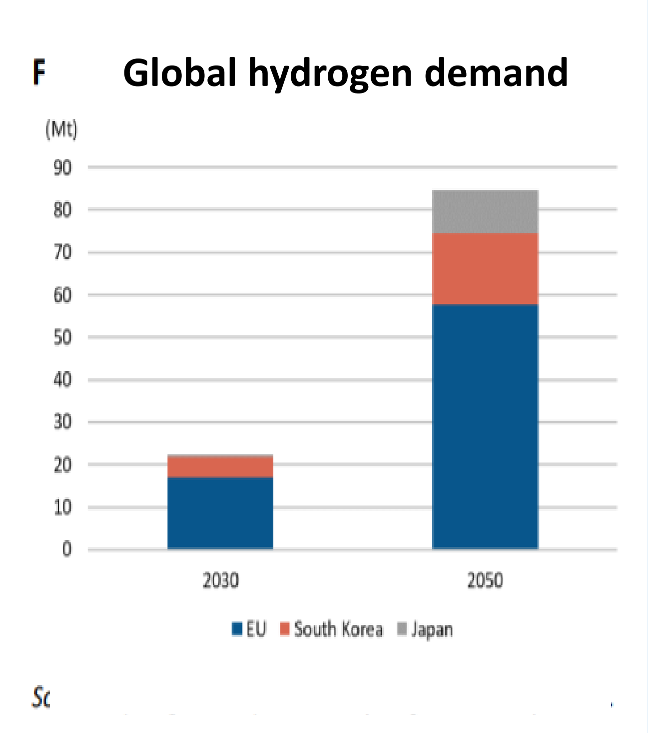
"THE HOCKEY STICK" DEMAND

HYDROGEN GROWTH TREND





Source: Port of Rotterdam Hydrogen Vision, 2020 & Hydrogen Europe

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H_2 DEVELOPMENT ROADMAP

URUGUAY MOVING UP PROGRESSIVELY

1

Start larger scale renewable projects

2

Real driver for Renewable ~30% of powergrowth

3

First national hydrogen masterplans

4

First hydrogen pilots for local use

5

First pilots for export

6

Hydrogen Industrial Port complex

Uruguay today

Steps ahead

Largescale Export of H2

Port of Rotterdam's role:

Assist with developing a vision and support with planning and determining requirements.

Support finding partners and setting up pilot projects first locally and then export related.

Support the development of Port Industrial Complexes, which are the main supply chain nodes.

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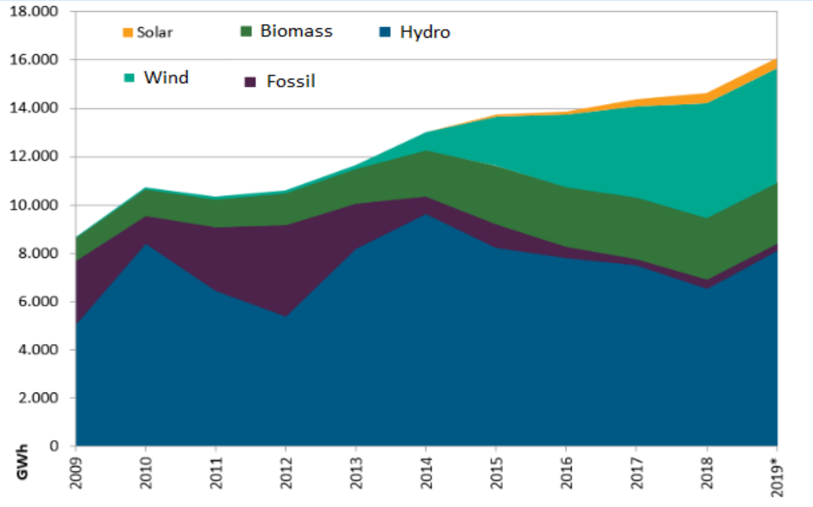
URUGUAY'S SUCCES STORY

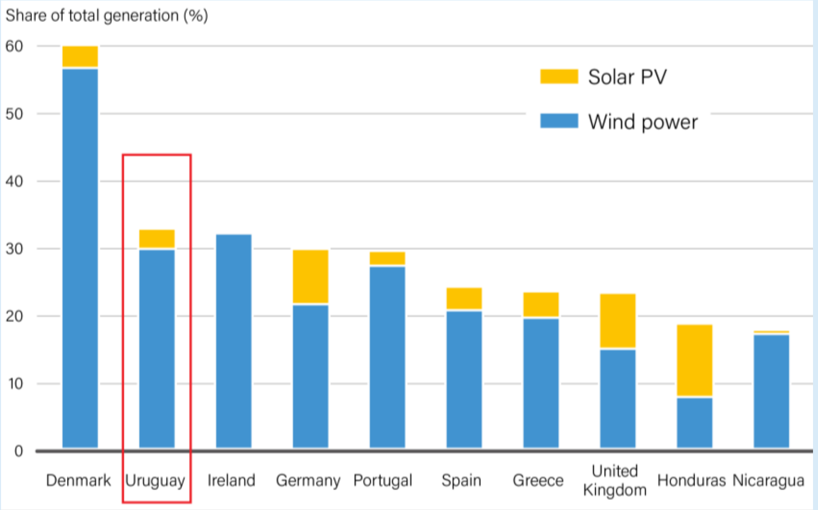
URUGUAY HAS SHOWN GREAT POTENTIAL

SETTING THE STAGE

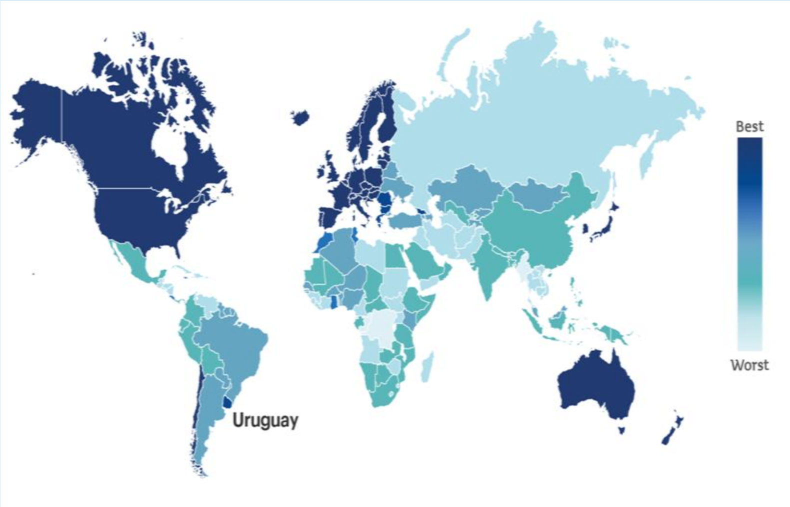
Power generation by source in Uruguay



Share of electricity generation from VRE



Highest performance in ESG factors



Due to progressive policy measures, Uruguay has reached 98% renewable power production and thus has become number 2 in % renewable power (from solar and wind) in the world (see graphs below).

Uruguay is one of only two countries outside the OECD in the highest ESG score category.

Source power generation: MIEM
Source VRE generation: REN21 – Renewable 2019 Global Status Report
Source ESG factors: JP Morgan, Bluebay Asset Management – Verisk Maplecroft

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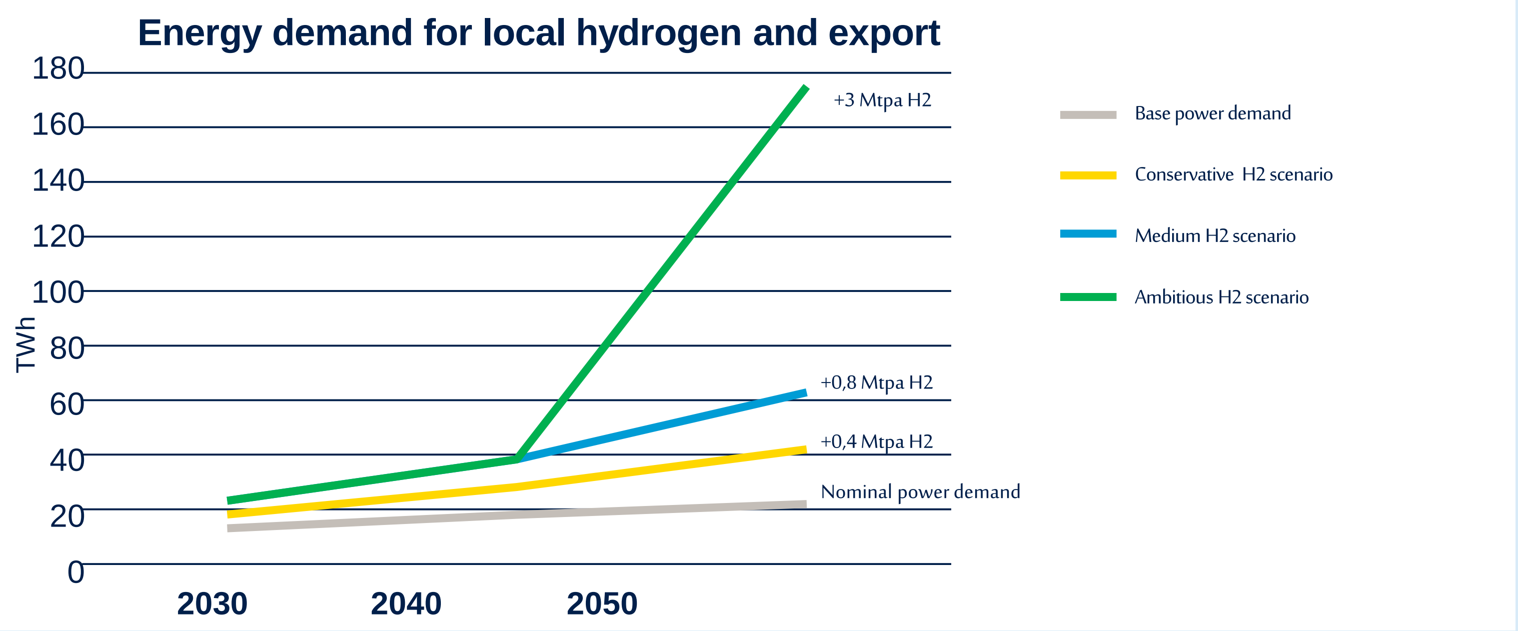
TARGET VOLUME URUGUAY

PRELIMINARY TARGETS EXPLAINED IN THREE SCENARIOS



Scenarios for 2050

Conservative would mean doubling Uruguay's national power production.
Local consumption small, most hydrogen produced for export

Medium Scenario would mean tripling Uruguay's national power production.
Large local hydrogen consumption growth and slightly more for export

Ambitious Scenario signifies Uruguay becomes one of the leading hdyrogen economies of South America with large local and regional consumption as well major exporter to Europe and Asia

INTEGRATED GLOBAL SUPPLY CHAIN

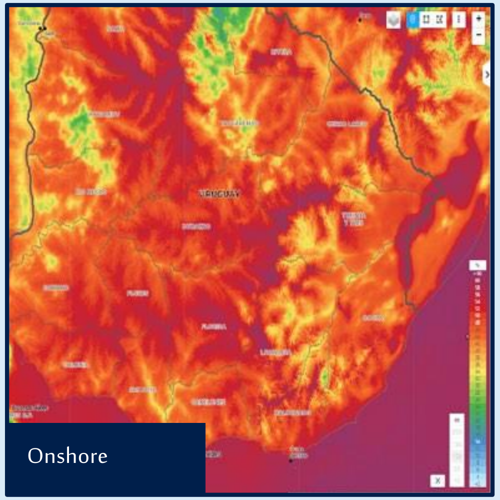
FACING A CHICKEN AND EGG DILEMMA

The logistic infrastructure development will await actual trade, yet the trade will not be made if there is no logistic infrastructure. Only with a Joint Vision presented in a national hydrogen masterplan will all supply chain components be developed simultaneously, achieving this new supply chain to take off.

RENEWABLE POWER PRODUCTION

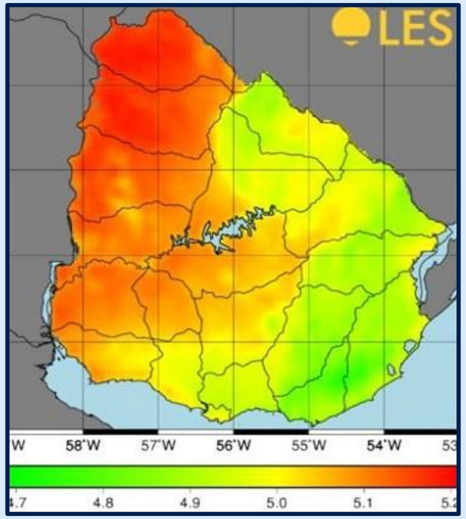
A COMBINATION OF BOTH WIND AND SUN WITH STRONG GROWTH POTENTIAL

Wind



	Onshore wind	Offshore wind
Installed capacity now	1,5 GW	0
Potential capacity	30 GW	276 GW
Capacity factor (100m high)	41%	-
Potential capacity factor (150m+ high)	41% and up	55% and up

Solar



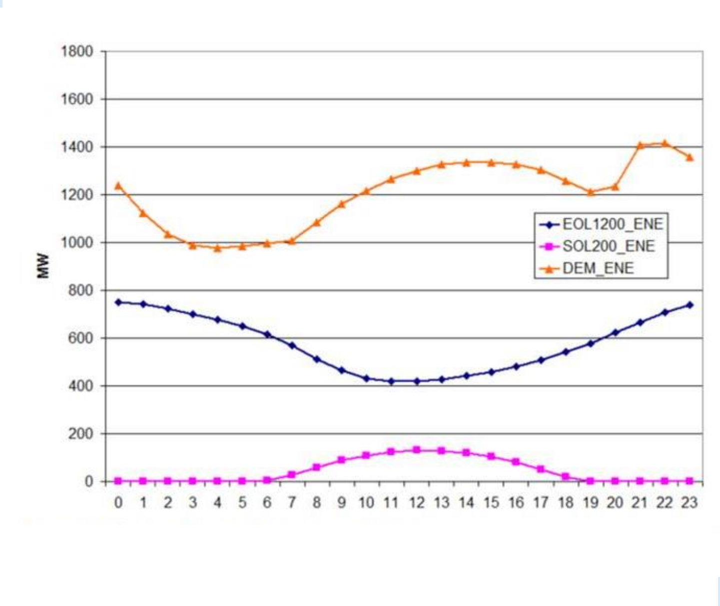
	Solar
Installed capacity now	0,23 GW
Potential capacity	450 GW
Capacity factor (fixed tilt)	20%
Potential capacity factor	t.b.d.

Source: MIEM Solar and wind maps, Port of Rotterdam analysis

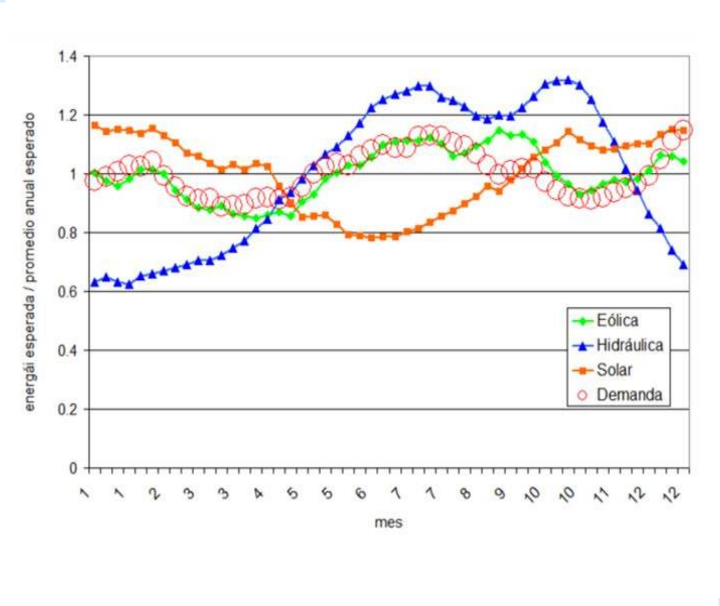
RENEWABLE POWER PRODUCTION

WIND AND SUN COMPLEMENT EACH OTHER VERY WELL

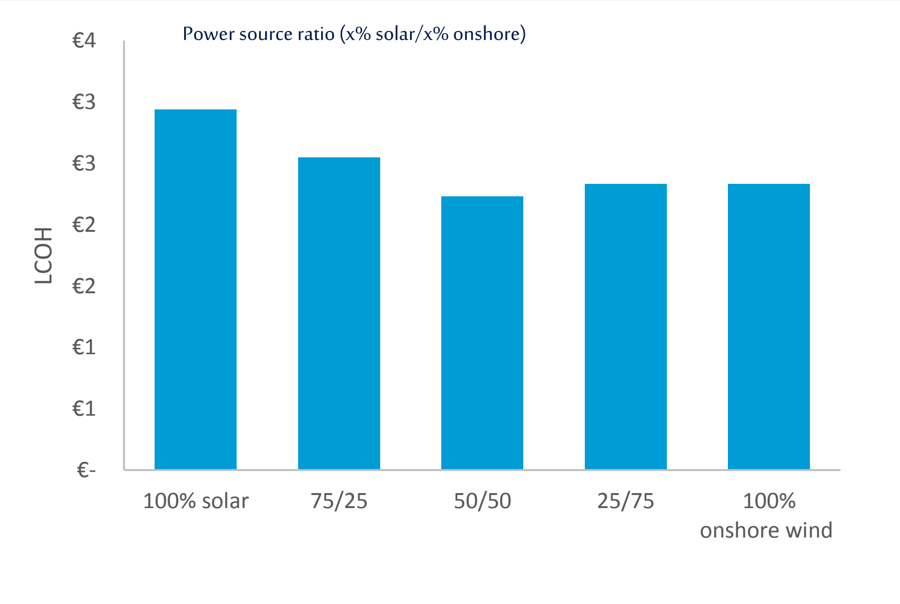
Daily production cycles



Annual production cycles



Sensitivity analysis of Wind-Solar ratio



Both daily as well as seasonally the wind and solar production complement each other allowing for high-capacity factors of the electrolysers. During the day and in the summer the wind sags but the sun shines bright.

Sensitivity analysis shows that a 50-50% ratio wind to solar allows for optimal capacity factor of the electrolyser and thus total lower cost of H2

Source: SIMSEE model based on MIEM Solar and wind maps, Port of Rotterdam analysis

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LOCAL H2 UTILISATION

EXISTING AND NEW HYDROGEN APPLICATIONS

Uruguay H2 transport project

Pilot project tender in 2021 for:

- Green hydrogen production by electrolyser
- Starting with 10 heavy vehicles: road trucks and buses with a range of ~ 400 km

Potential diesel demand of 670.000 m^3/year for heavy duty transport for 2025 (equivalent to 150 kTon of Hydrogen per year)

Ammonia to fertilizaer

- Uruguay Agricultural sector, produce food for 28 million people (3,4 million inhabitants)
- 100 kton of hydrogen per year as substitution of local fertilizer consumption

Other potential local uses of H2:

- Ammonia as marine fuel
- Green steel

In future:

- Hydrogen train link from pulp plant
- Green Methanol production
- Green diesel (HVO)
- Synthetic fuels
- Marine fuels

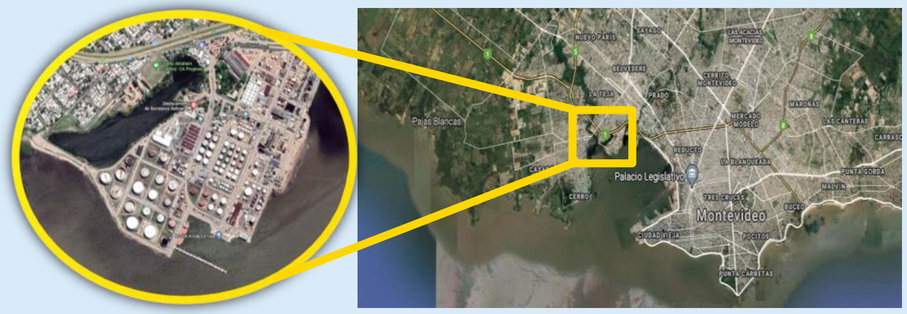
2

PORT INDUSTRIAL CLUSTER

PRELIMINARY RECOMMENDATION

Pilot phase: ANCAP's La Teja refinery at Port of Montevideo*:

- Using smaller vessels with suitable draft (max 8m) for existing channel.
- Make use of existing oil and gas operations and its permitting zone.
- Facilities already include 4 LPG spheres & 15 heavy fuel tanks (ammonia and LPG have similar characteristics).
- *this proposed location is subject to detailed study and approval by ANCAP



Next phase: New Deepsea port on the Atlantic Ocean

- Lower social and environmental impact due to remoteness.
- Ample space to develop industrial complex with various hydrogen related industries, among others.
- Secondary and tertiary industrial developments as well as new urban hub.
- Opportunity for a regional deepsea port and green industrial cluster.

Source: Port of Rotterdam green seaport artist impression

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LOCAL LOGISTICS AND STORAGE

UTILIZING BOTH EXISTING AND NEW INFRASTRUCTURE

The Pilot project at La Teja Refinery in Montevideo

Two business cases to consider:

a) buy electricity from the grid

b) build a dedicated solar and wind farm in addition to buying surpluses.

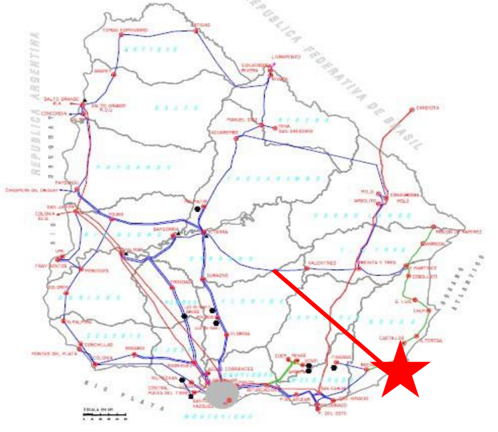
The new Deepsea Port on the Atlantic Coast

Two alternatives for logistics:

a) Production of hydrogen in the same place of wind and solar farm. Dedicated hydrogen gas pipeline from solar and wind farms to deepsea port. Producton of carrier at the industrial complex in deepsea port.

b) Production of hydrogen and carrier at industrial complex in deepsea port. Connecting renewable power to hydrogen production from a dedicated transmission line and national grid (see image)

Uruguay's transmission network



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SHIPPING

Comparing carriers

LH2

New

Density	0,071
Type	LNG Tanker
DWT*	27 600 t
H2 equivalent	27,600 t
LOA**	284 m
Draught	12 m

AMMONIA

Bu Sidra

Density	0,769
Type	LPG Tanker
DWT	50 534 t
H2 equivalent	9 000t
LOA	225 m
Draught	12 m

LOHC (DBT)

Golden State

Density	
Type	Oil/Chemica l
DWT	48 933 t
H2 equivalent	9 000t
LOA	183 m
Draught	9.7 m

LOHC (MCH)

Manchac Sun

Density	0,792
Type	Chemical
DWT	50 000 t
H2 equivalent	9 000t
LOA	186 m
Draught	10,6 m

Source: HyChain - energy carriers and hydrogen supply chain (2018)

**DWT = dead weight tonnes*
***LOA = length of overall*

2

IMPORT FACILITIES

ROTTERDAM WILL BE READY TO RECEIVE ALL TYPES OF H2 CARRIERS

- **Green ammonia terminal**
  Existing Europoort terminal operated by OCI.
  New dedicated green ammonia terminals by 2025.

- **LOHC terminals**
  First pilot with DBT at existing Botlek terminal in 2023.
  Other pilots also being planned before 2030.

- **Liquid hydrogen terminal**
  Feasibility study started with Kawasaki.
  Expected operational after 2030.

- **Green methanol terminals**
  Methanol has not been considered as a hydrogen carrier because of high dehydrogenation costs. However green methanol may be one of the future derivatives of hydrogen for which there will also be a market in Europe.

2

DISTRIBUTION

ROTTERDAM HAS EXCELLENT INTERMODAL CONNECTIONS

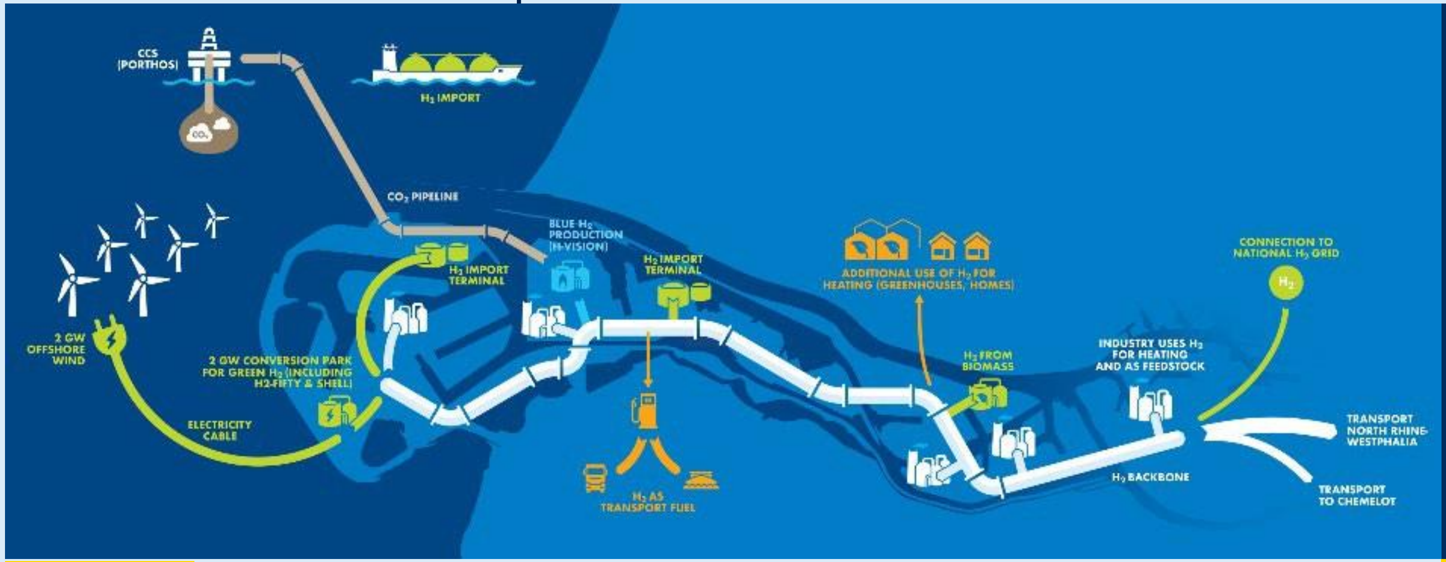
Hydrogen backbone

Hydrogen infrastructure within the Port of Rotterdam.

Interlink

Connecting the Port of Rotterdam to the rest of the country and neigbouring countries.

European connected hydrogen networks



2025

2030

2035

Source: Port of Rotterdam Hydrogen Vision, European Hydrogen Backbone (2020)

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USAGE

MOBILITY AND STEEL FIRST SECTORS TO ADOPT HYDROGEN IN EUROPE

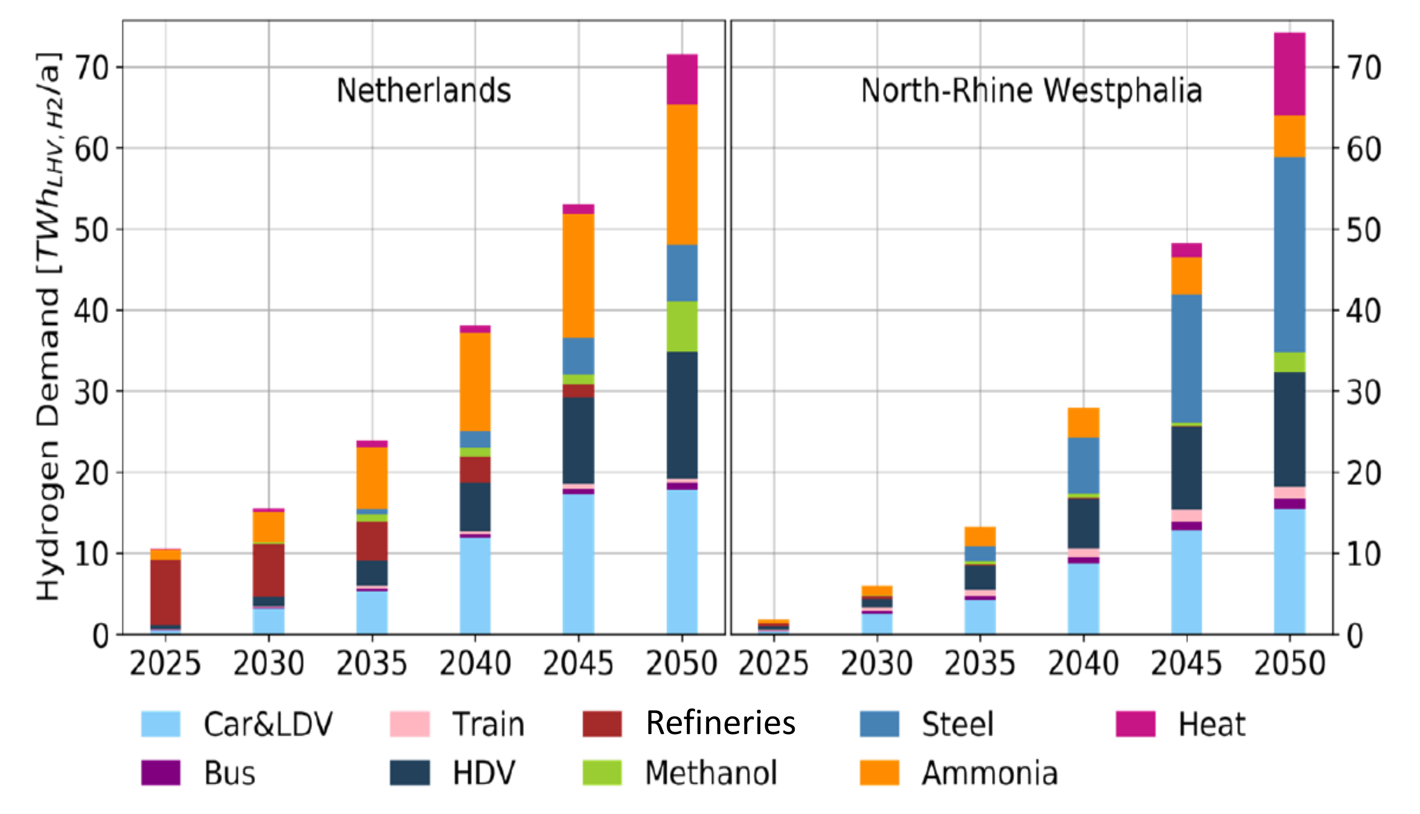
Use of hydrogen stimulated through European and national climate policies.

An inflection point in demand is expected in 2030 when Europe embraces the next target.

At this time that European consumption forecast
is 60 Mtpa hydrogen in 2050.

Mobility (Car&LDV, HDV, Train, Bus) and Steel could the first sectors to adopt hydrogen (see graph).

The Netherlands and Germany recognise the need
for largescale imports because local production capacity will never be able to meet demand.



LOCAL INVESTMENT FORECAST

INVESTMENTS REQUIRED FOR NEW HYDROGEN SUPPLYCHAIN

Preliminary estimates for local CAPEX include:

- Renewable power (solar, onshore and offshore wind)
- Electrolyser cost
- Hydrogen pipeline with compression

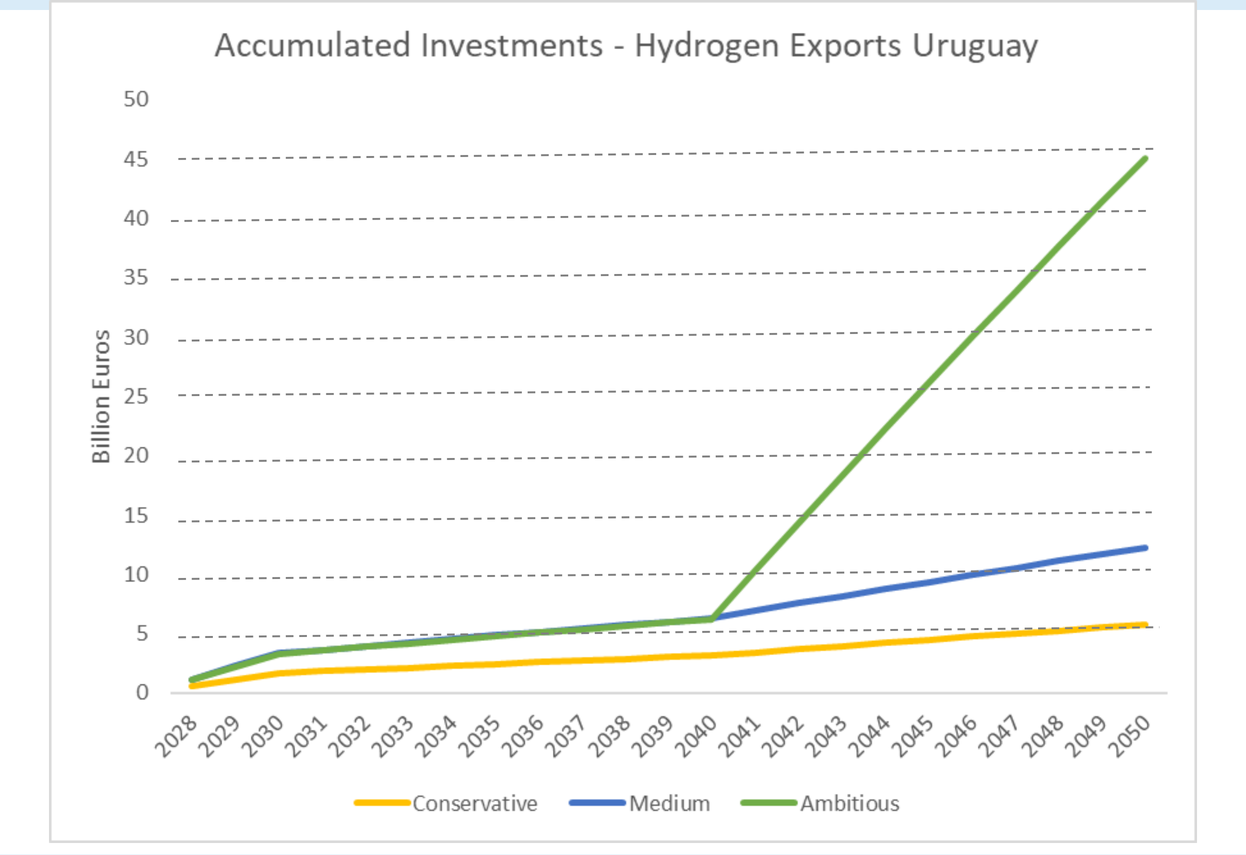
Investments to be added:

- hydrogen storage
- carrier production & storage
- port facilities.

These investments will depend on carrier choice and port location choice. They may also be significant. To be worked out in next stage.

Preliminary local investments per decade

	Total Investment per decade (Bill EUR)		
	Conservative	Medium	Ambitious
2020s	1.67	3.34	3.34
‘30s	1.49	2.97	2.97
’40s	2.62	5.98	38.86



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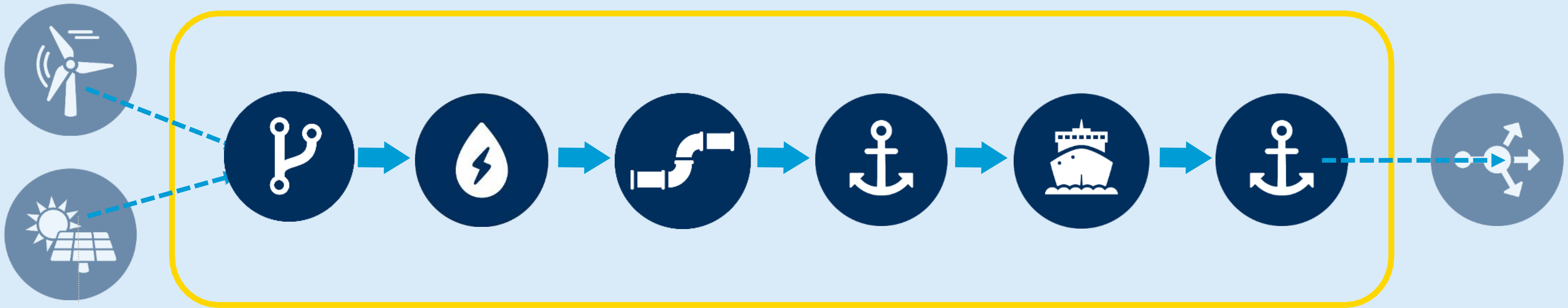
BASE CASE: MID SCENARIO IN 2030

COST PARAMETERS AND COST PRICE ADJUSTED FOR 2030

Focus of this cost model



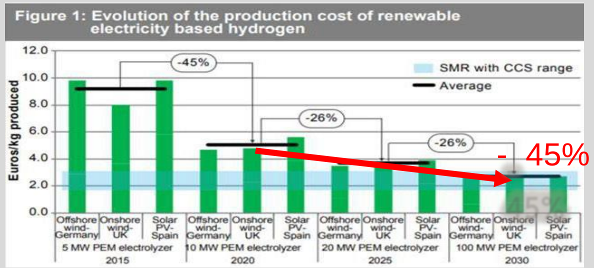
50% onshore wind, 50% solar energy	~16 ct/kWh renewable electricity	200 kton hydrogen production per year in 2030	300km inland local transport	Storage & carrier production in Montevideo	Overseas shipping	Import & Retrieval in Rotterdam	Hinterland Transport, out of scope

Disclaimer: the cost model is based on cost parameters which were available at this time. Some of these are guestimates for the future.
The results presented are therefore indicative only and not to be relied upon. The accuracy is in the order of +/-xx%. The purpose of this cost exercise was to get a better feel for relative ratios and relations. A more detailed study will be needed before hard conclusions can be drawn.

Local renewable power cost basecase

2020	Solar	Wind
CAPEX	675 EUR/kW	1012 EUR/kW
EUR/MWh	26,8	30,5

Cost price development by 2030*



2030	Solar	Wind
EUR/MWh	14,7	16,7

*** These forecasts are being reviewed**

Source cost price development: IHS Markit – The role of hydrogen (2020)

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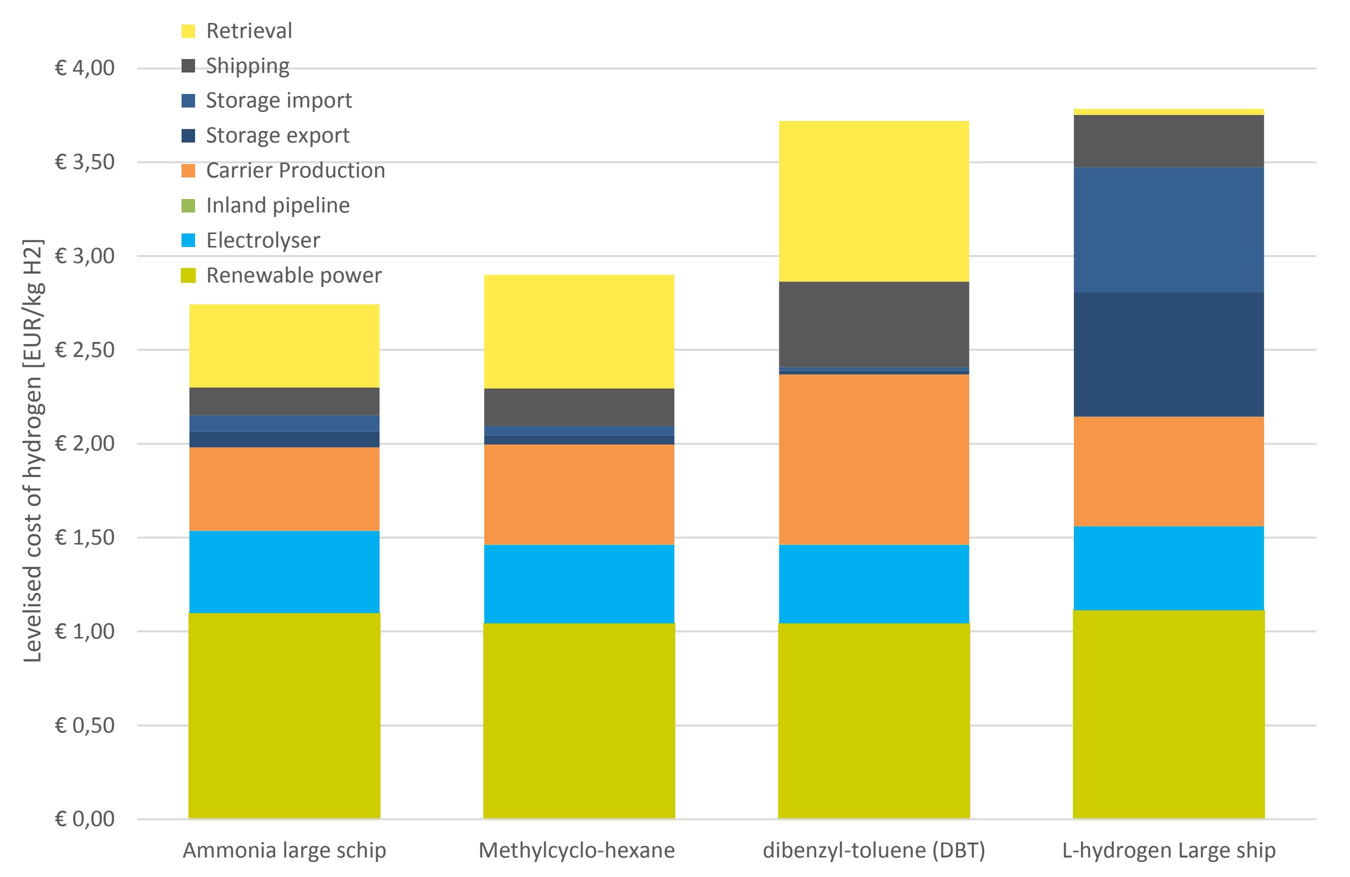
CARRIER COMPARISON RESULTS

PRELIMINARY RECOMMENDATION

Comparing carriers:

Considering the accuracy of the cost parameters used, no final conclusion can be drawn yet on the preferred carrier.

At this time there seems a slight preference to continue to research ammonia and the LOHC methyl-cyclohexane.



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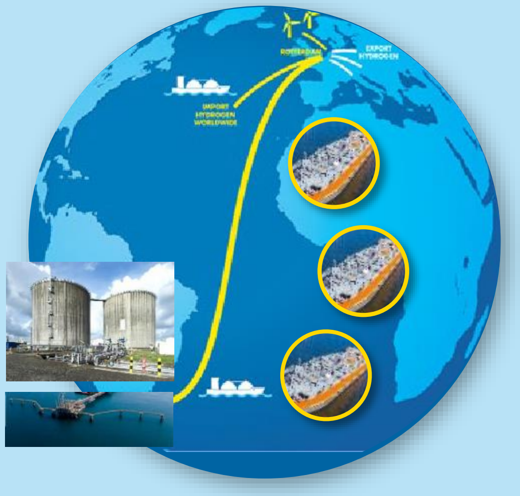
COST MODEL ANALYSIS

EXPORT INFRASTRUCTURE REQUIREMENTS

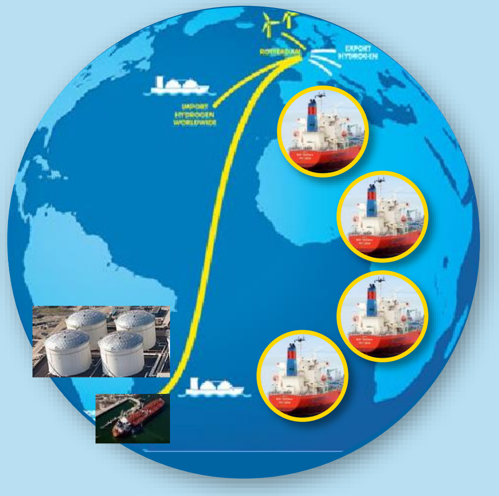
FOR 2030 'MEDIUM' SCENARIO (200KTPA DELIVERED in RDAM)

AMMONIA



Mooring	1 jetty
Storage	2 tanks of 80,000 m^3
Ship	3 x very large gas carrier (VLGC), 56K dwt
Land area (storage)	Min. ~ 15 Ha

LOHC (MCH)



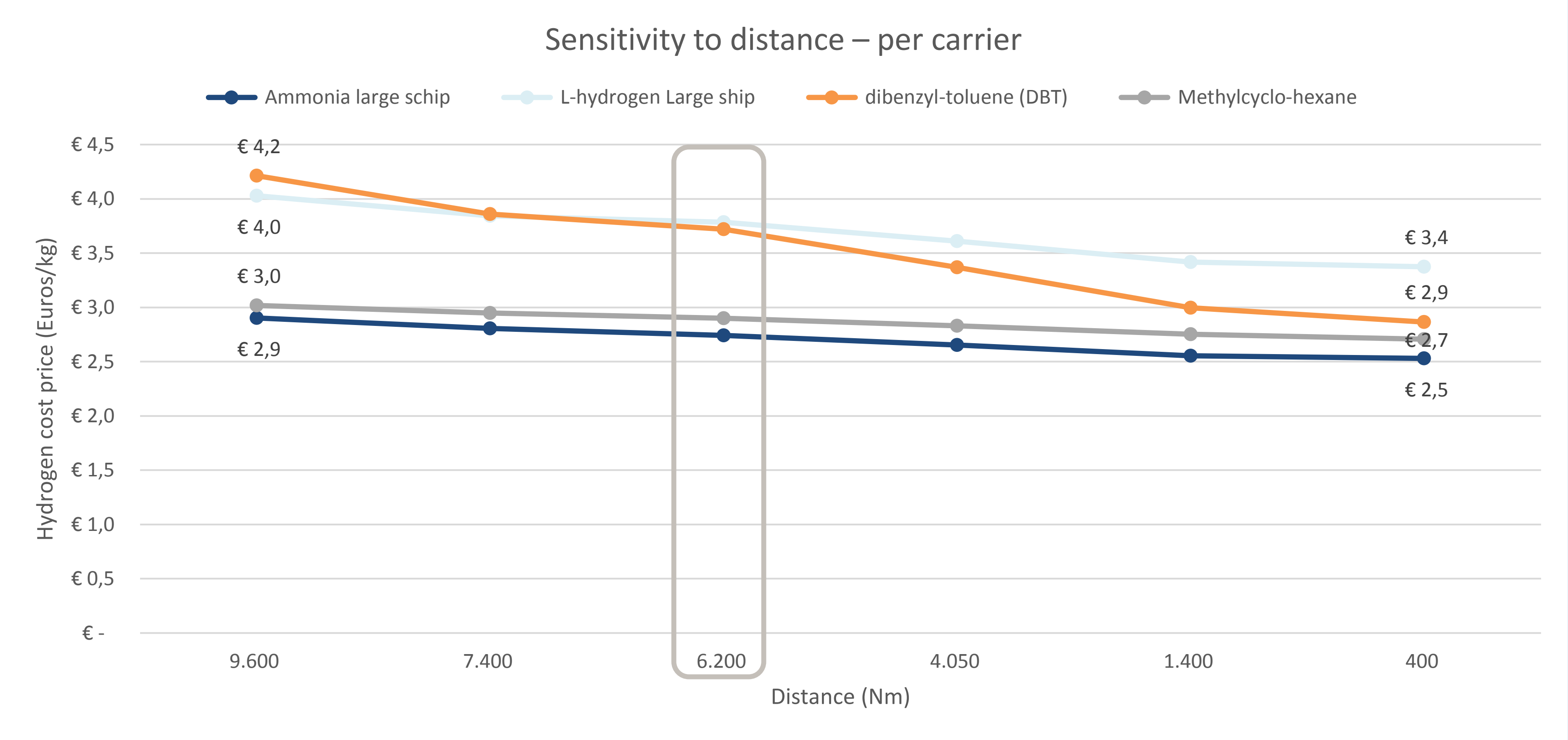
Mooring	1 jetty
Storage	4 tanks of 55,000 m^3
Ship	4 chemical tankers 50k dwt
Land area (storage)	Min. ~ 11 Ha

CARRIER COMPARISON RESULTS

PRELIMINARY RECOMMENDATION

Shipping distance & carrier sensitivity:

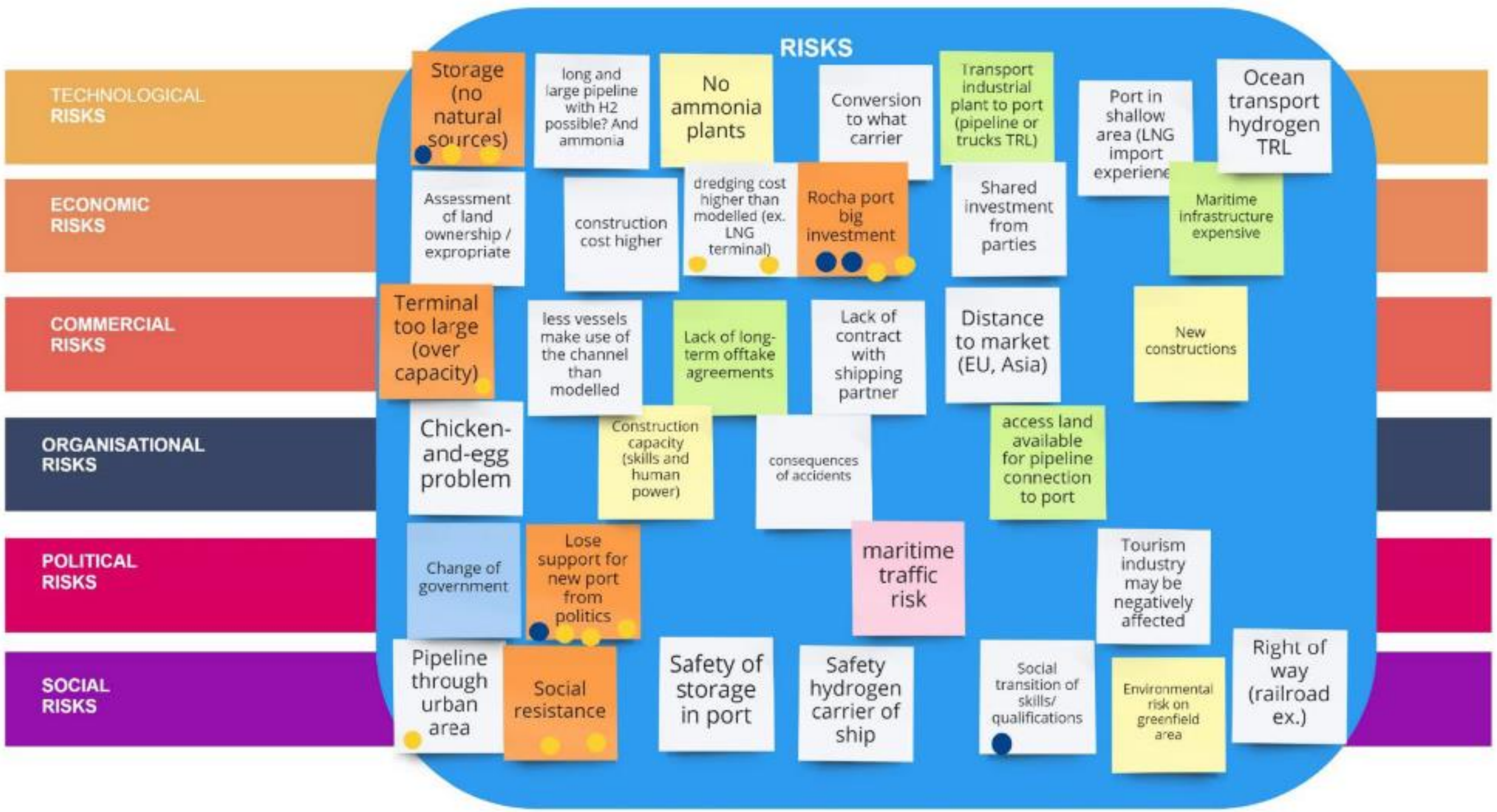
As shipping costs are only a small component of the total hydrogen cost, the shipping distance has some but not significant impact on the final H_2 price. Technological developments may further reduce this delta.



JOINT RISK & BARRIERS WORKSHOP

EXAMPLE OF ONE OF 5 SUPPLY CHAIN COMPONENTS STUDIED

2. Local Logistics & Export



Highest risk

Potential barrier

Collaborative risk analysis workshop on digital whiteboard with all relevant stakeholders.

Example of outcome on 'Logistics and Export' supply chain component.

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La energía que nos une

ANCAP

RISKS AND BARRIERS

LARGEST RISKS	MITIGATIONS
New technologies still to be developed (TRL of large-scale electrolysers).	Consider to develop H2 knowledge center and learn by doing with local pilots in Uruguay. Collaboration with leading Dutch electrolyser developers.
Scale of proposed projects (offtake risk).	Phased development, start with smaller scale local use. Detailed multi-party roadmap. Intergovernmental financial support solutions.
Social and environmental concerns near the export facility.	Careful planning, development and strong stakeholder communication. Consider the use of a citizen council.
Logistics to and at the export facility.	Careful planning and development. Consider strategic partnerships.
Political risk of future governments and changing priorities.	Consider a multi-party commitment to climate and energy goals. Or even a set climate law, similar to the Dutch.
Risk of doing nothing.	Dream big, plan carefully, execute diligently and safely.

CONCLUSIONS

- Uruguay has strong unique selling points for production of competitive green hydrogen (unique combination wind and solar). Sensitivity analysis shows distance to market has a relatively small impact on the H2 price delivered.
- A new greenfield industrial zone and deepsea port on the East Coast are key infrastructure needed to make hydrogen supplychains possible.
- Rotterdam will be the ultimate hub for hydrogen distribution to the rest of Europe and has ample experience with all types of hydrogen carriers (ammonia or in LOHC methyl cyclohexane seem the most attractive options)
- Start with local pilots until European hydrogen demand accelerates further. The price of local hydrogen in Uruguay could by then come down to near €1,3 /kg and the price delivered in Rotterdam near €2,5 /kg.
- Risks foreseen include the scale and social acceptance. The biggest risk for the next generation however is doing nothing
- Uruguay and Rotterdam are a great match to develop key logistics infrastructure that will catalyse the materialization of Uruguay’s potential to become the leading Hydrogen player in South America.

RECOMMENDATIONS & NEXT STEPS

Short-term actions:

- Work towards local hydrogen application pilot projects in sectors such as mobility and small industry.
- Kickstart 2 detailed feasibility studies on both local hydrogen production as well as on an International H2 supply chain wit h which answers can be found on the remainder of open questions (as stated on the following slide).
- Develop Uruguay hydrogen knowledge centers and learn from the first pilots and accelerate dissemination.
- Develop a 'National Hydrogen Masterplan' to align future developments and to warm up all relevant stakeholders.
- Find the right Strategic Development partners, such as but not limited to one or more European governments for pilot subsidie s.

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Port of Rotterdam

- Martijn Coopman
- Wilco van der Lans
- Douwe van der Stroom
- Irene Vooijs
- Reyer Will

For more information please contact:

María José González
MariaJose.Gonzalez@miem.gub.uy

For more information please contact:

Martijn Coopman
m.coopman@portofrotterdam.com

ANCAP

- Juan Tomasini
- Jorge Ferreiro

UTE

- Pablo Mosto
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