Piauí H_2 Valley

European Hydrogen Week, 20th November

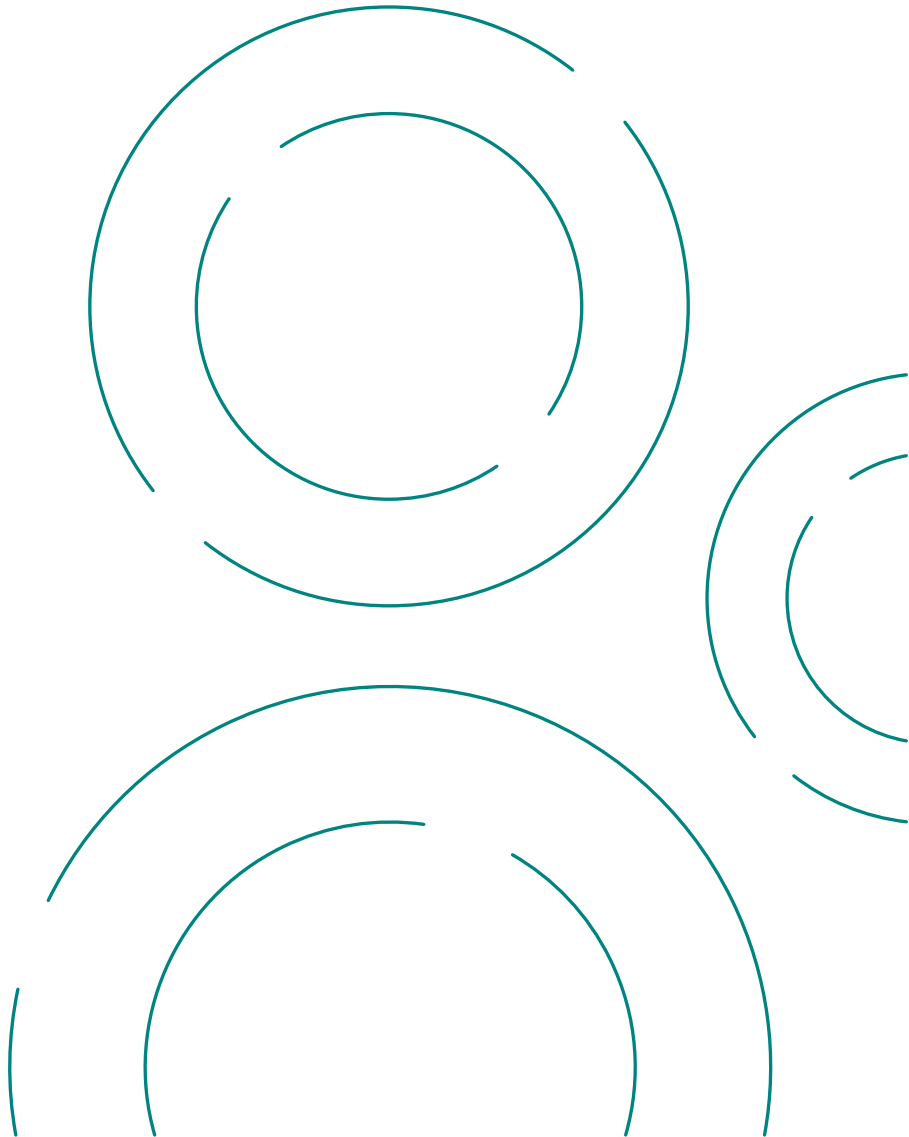
AGENDA

Project Overview

Demand sizing

Cost competitiveness assessment

Next steps



Project overview

As regions think about integrating H_2 into their operations, they typically ask the following questions:

- How does H_2 contribute to my climate goals?
- Where do I start developing H_2 in my territory?
- Who are/will be the off-takers?
- Who are/will be the producers?
- How to transport H_2 and derivatives?
- How much will these projects cost?
- What will be the price of H_2 in the future?
- How competitive would be H_2 made in my region?
- What partners are needed to build these projects?
- What regulatory/policy enablers are required?

ENGIE Impact

Piauí H_2 Valley study aims at strategic positioning the state in the H_2 economy

Project objectives

Assessing the real potential of the state

- The state of Piauí in Northeast Brazil has ample RE resources
- Piauí is a leader with >5GW installed in solar and wind power and plans to enter the green H2 economy

Building momentum with stakeholders

- Green H2 produced in Piauí might be used for local industries
- Piauí plans to scale up green H2 production to meet global exports

Understanding investment dynamics

- Piauí initiated campaigns to attract H2 players and investors
- Several companies have signed MoU to initiate RE/H2 projects

To identify concrete project opportunities in promising H2 hubs to kickstart the H2 economy in the region

The project is being developed in consultation with relevant stakeholders, including H_2 producers and consumers

Producers

Aiming at producing green **H2 at lowest cost** for **secured offtakers** on domestic market and/or export

Green Energy Park
SOLATIO
SUNFARMING
QUINTA SOLAR ENERGIA
STARK
celeo

Consumers

Aiming at procuring green H2 to ensure **security of energy supply** and **predictable costs**

LION MINING
MABANAFT
ASHLEY GLOBAL
TERESINA OGR AEROPORTOS
NASSAU

Other stakeholders

Aiming at attracting **players** in the whole **H2 value chain**, ensuring **necessary infrastructure** and **authorizations**

ZPE PARNAÍBA · PI
HPA Hamburg Port Authority
APS Administração dos Portos de Sines e do Algarve S.A.
Estonian Association of Hydrogen Technologies
PORTOPI

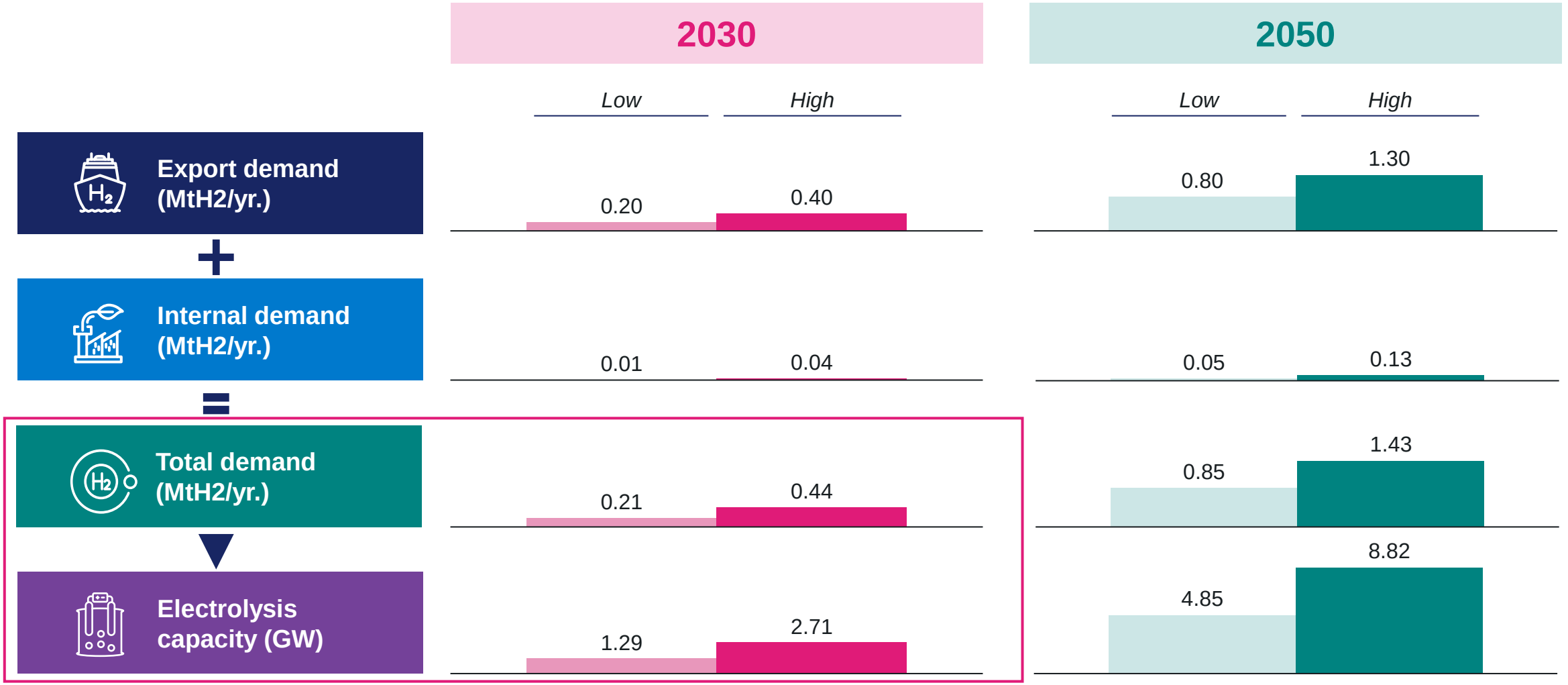
And many more to come

ENGIE Impact

Demand sizing

Internal demand & Export demand

Piauí is well positioned to capture ~0.4 MtH_2 of H_2 demand in 2030 mainly through exports to Europe



1. Main export countries considered for the study are Germany, Netherlands, Belgium, United Kingdom, these are seen as net importers in 2050, full explanation is in the export demand chapter | 2. Full breakdown of energy carriers required will be presented in future phases of the study | 3. The conversion to electrolyzer capacity considered an efficiency of 54KW/kgH_2 in 2030 and 50KWh/KgH_2 in 2050 operating on base load, full RE operation will require a larger installed capacity due to the intermittent nature of RE

Piauí rely on three competitive advantages to better position against other H_2 exporters to Europe

Renewable resources

Piauí has vast areas with world-class capacity factors to produce RE

RE capacity factor		
Piauí	25%	47%
Chile	34%	41%
Australia	28%	48%
UAE	25%	32%
Morocco	27%	41%

Geographical proximity

Piauí is closer to Europe than other H_2 export candidates

Port distance to the EU	Nautical miles
Piauí	4,000
Rio de Janeiro	5,200
Newcastle	11,600
Jebel Ali	7,100
Casablanca	2,100

EU Regulatory advantage

Piauí could produce H_2 and derivatives that meet a strict regulatory framework

Regulations	A[1]	HM[2]	GHG[3]
Piauí	✓	✓	✓
Chile	!	!	✓
Australia	!	!	!
UAE	!	!	✓
Morocco	!	!	✓

1. Additionality applies to geographies where RE account for less than 90% in the power mix, it forbids the use of the grid to power the electrolyzer and forces H_2 producers to develop their own RE supply thereby adding a bottleneck in the development of H_2 production projects | 2. Hourly matching applies to geographies that are not allowed to use the grid and forces the production of H_2 to operate at the same time as the RE sources thereby limiting the operation of the electrolyzer | 3. GHG emissions requirement compels producers to assess H_2 lifecycle emissions (incl. transportation) and prove a reduction of at least 70% compared to grey H_2, thereby significantly limiting far distant countries like Australia.

10 ports and 4 countries in Europe have been identified as potential key players in H2 imports

2030

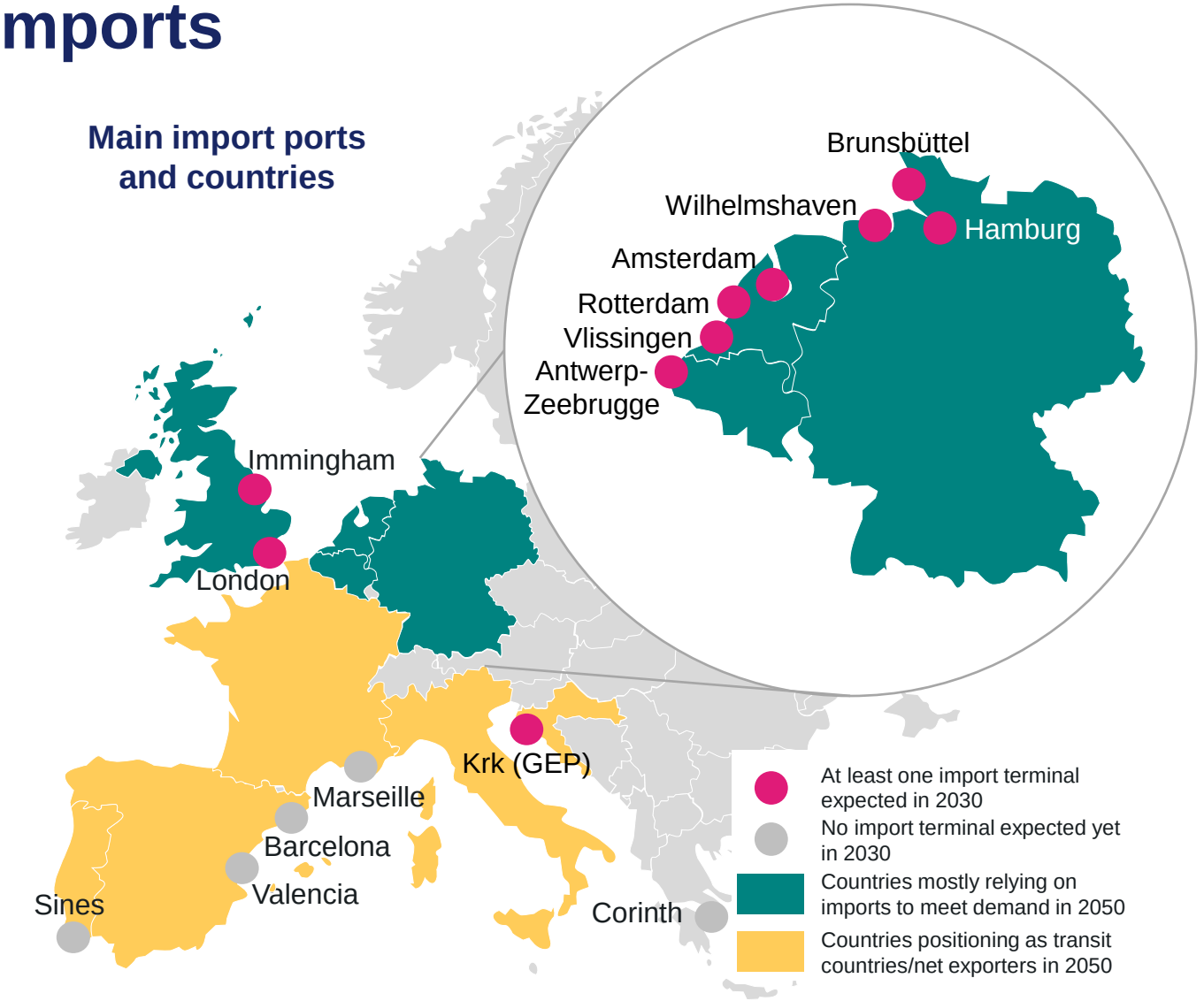
Where are the H_2 terminals?

- **10 ports** already expressed ambitions in terms of H2 imports

2050

What countries will rely on imports?

- **4 countries see imports as a core pillar** of they H2 strategies[1]
- **5 countries position themselves as transit countries and/or net exporters** prioritizing energy self-sufficiency[2]



1. The UK has an ambiguous strategy, initially focusing on local production (2021) and recently leaning towards both imports to support energy security and exports targeting continental Europe (2023)
2. The domestic demand of transit countries is not considered in this study

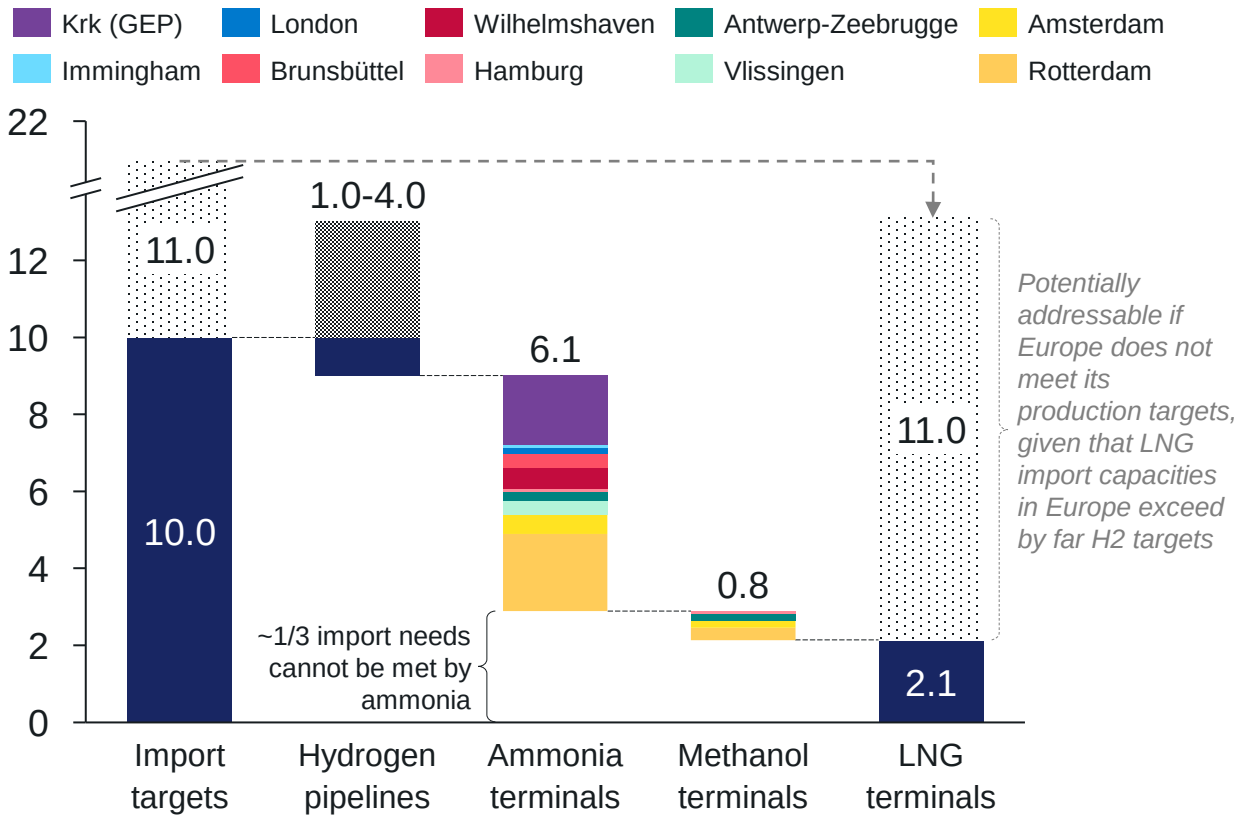
WIP

European imports will amount to 10 MtH_2 in 2030, 90% will come from international shipping using mainly ammonia as a carrier

What is the import capacity?

2030

European H2 import capacities and targets in 2030, MtH_2



- **9 MtH_2** expected from **international shipping,** which means 90% of RePowerEU target
- About **1/3 of the import volumes** will have to be exported through **alternative carriers** other than ammonia (methanol or e-LNG)
- **Additional 11 MtH_2** can be needed from export if European countries **fall short of their production targets** and need to import **e-LNG to meet their demand target**.

Assumptions: • H_2 pipeline capacity = 1 MtH_2 out of 4 MtH_2 announced for 2030 from the SouthH_2 Corridor assuming production projects in Algeria will not be ready on time • Port of Rotterdam's import capacity = 2 MtH_2 out of 4 MtH_2 announced for 2030, assumed exclusively in the form of NH_3 • e-LNG: Liquefied Natural Gas produced through methanation

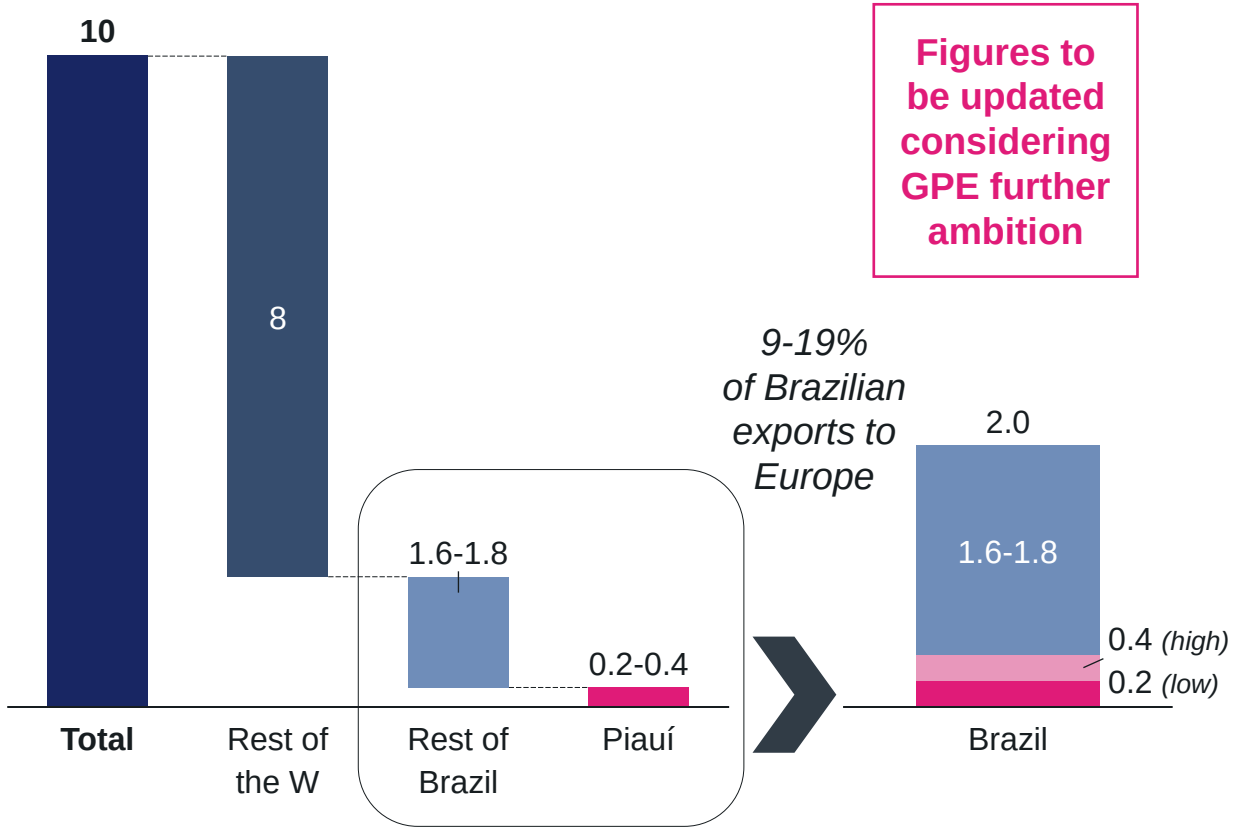
WIP

Piauí could aim at exporting 0.2-0.4 MtH_2 in 2030, capturing 2-4% of total exports to Europe

How much could Piauí take?

2030

Market shares of total exports to Europe in 2030, MtH_2



Figures to be updated considering GPE further ambition

- Piauí's export potential was calculated by a **funnel approach**, removing competing H2 delivery from:
  - i) **Pipelines to the EU**
  - ii) **International competitors** (e.g., UAE, Australia, Chile)
  - iii) **Rest of Brazil**
- About **0.18 MtH_2** (1 $MtNH_3$) of Piauí export would come from **Green Energy Park's partnership**

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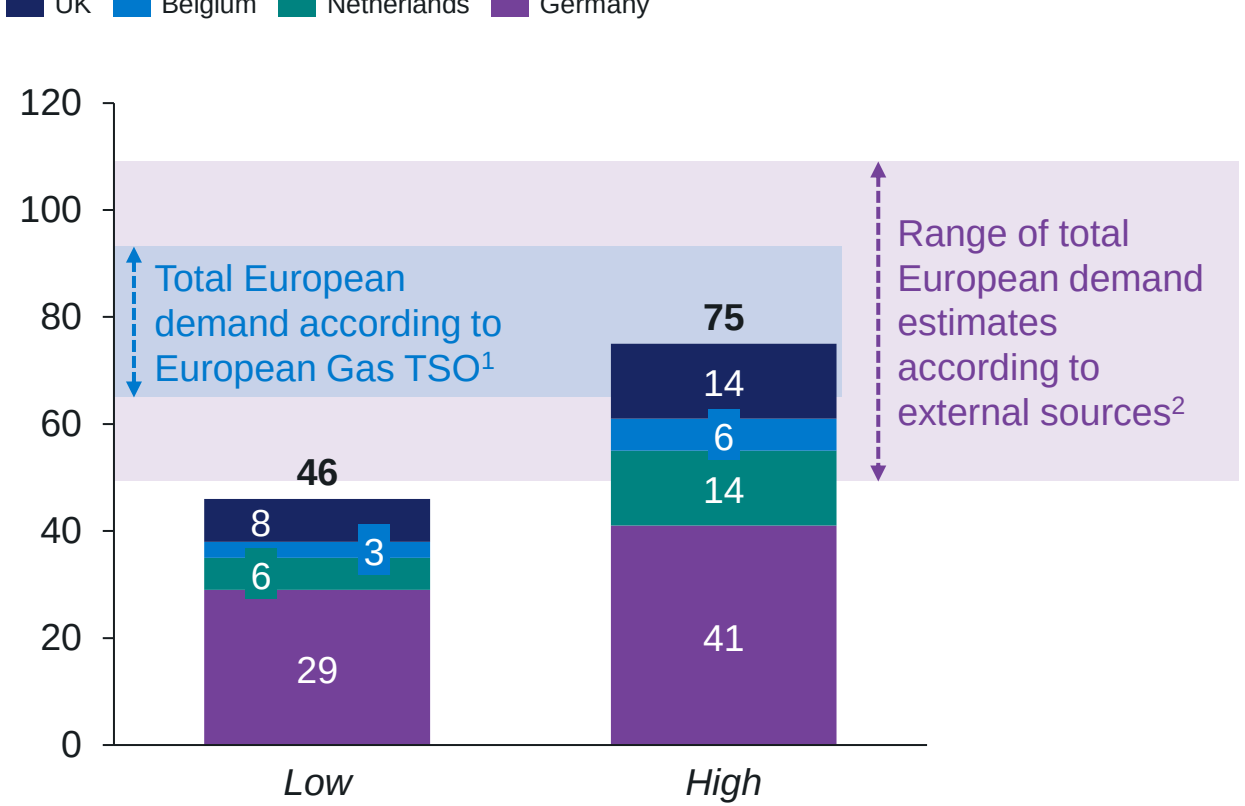
WIP

Addressable demand in Europe in 2050 amounts to 46-75 MtH_2 with the largest share in Germany

What will be the demand?

2050

European addressable demand for H2 derivatives in 2050, MtH_2



- **European addressable demand** is expected at **46-75 MtH_2 in 2050**
- Other major H2-consuming countries' strategy is to act as transit countries and/or as net exporters (e.g., France, Spain, Portugal, Italy, Croatia)
- External sources expect a **total European demand of 50-108 MtH_2 in 2050** (including in countries planning to focus on local production)

1. Transport System Operators gathered into the Gas for Climate Coalition, part of the European Network of Gas TSO (ENTSO-G).
2. IEA, H2 Council, Bloomberg, Deloitte. Based on their global forecasts, assuming Europe will make up 15% of world consumption.

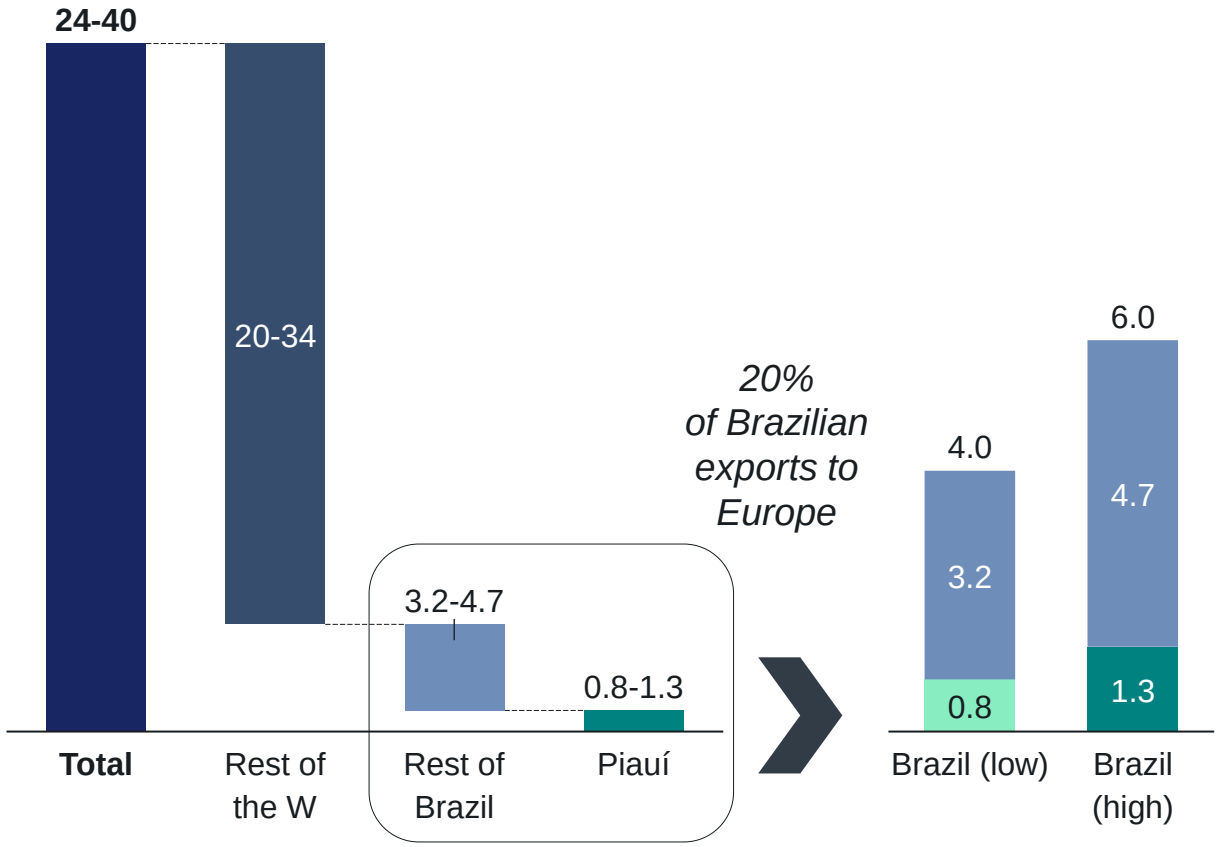
WIP

Piauí could aim at exporting 0.8-1.3 MtH_2 in 2050, capturing ~3% of European H_2 imports

How much could Piauí take?

2050

Market shares of exports to 4 European countries in 2050, MtH_2

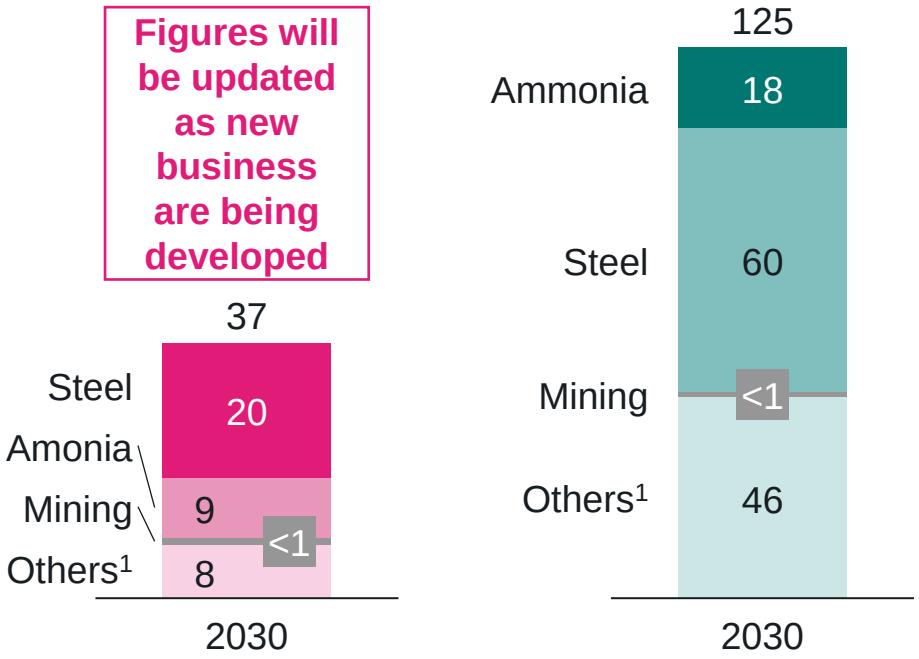


- In **2050, 50%** of **Europe local demand** will be met by **imports**
- **Fierce competition** is expected between nearby countries (e.g., Morocco, Norway) and distant **shipping competitors** (e.g., UAE, Chile, Australia)
- **Piauí** could meet **3% of export share to Europe** by leveraging its **RE potential**, **geographical location**, and **potential regulatory advantage**.

WIP

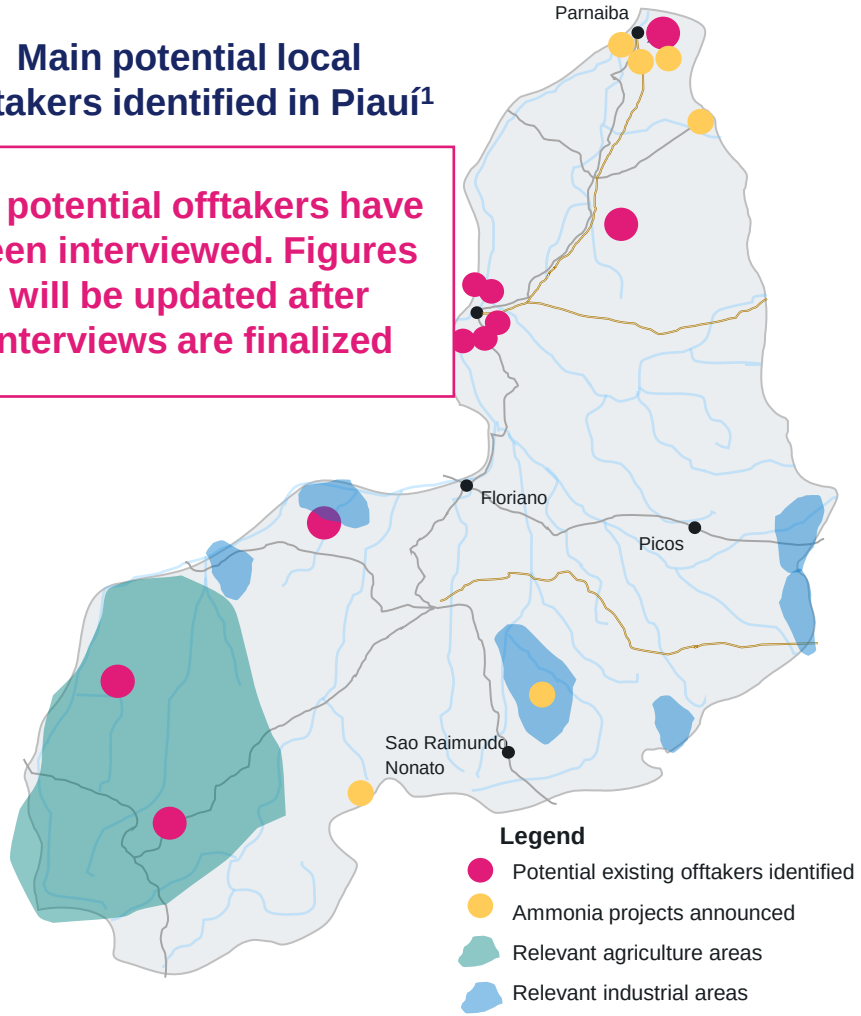
Additional demand from green steel, fertilizers and mining sectors is added on top of the natural uptake curve

	2030	2050
Low	Local H_2 demand was estimated using uptake curves applied to the energy demand of relevant economic sectors of Piauí[1]	
High (ktonH$_2$/yr.)	Figures will be updated as new business are being developed	



Main potential local offtakers identified in Piauí[1]

16 potential offtakers have been interviewed. Figures will be updated after interviews are finalized



Relevant sectors are considered industry, transportation and energy. Industry and transportation are assumed to be early H_2 adopters

Cost Competitiveness Assessment

WIP

To select the hubs, key factors such as renewable resources, potential off-takers and available infrastructure were considered

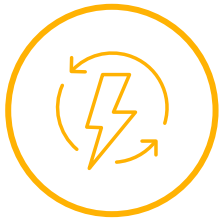
Demand side | **Supply side**

Potential off-takers

- **Grouping off-takers** allows **economies of scale**, improving competitiveness
- **Transportation costs are 5% to 10%** the H_2 cost

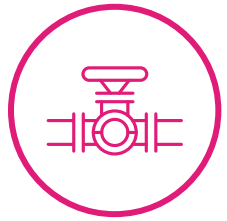
Renewable resources

- **H_2 production** should be located nearby **renewable resources or good access to a low-carbon grid**



PPA price

- Electricity costs account for **50% to 60%** of the **total cost of H_2**
- The cost of H2 (LCOH) considers **an optimal mix of onsite RE** and **green PPA prices**



Available infrastructure

- **Infrastructure** is crucial when defining optimal production locations
- **Leveraging existing infrastructure** could reduce H_2 production costs

Water context

- **Water availability is key for H_2 production**
- Understanding **water context is key** (e.g., people reluctancy for water usage for H_2)

Future H_2 investments

- Future H_2 off taking projects will **push the development of the H_2 economy**
- **H_2 infrastructure can be leveraged** between all projects

WIP

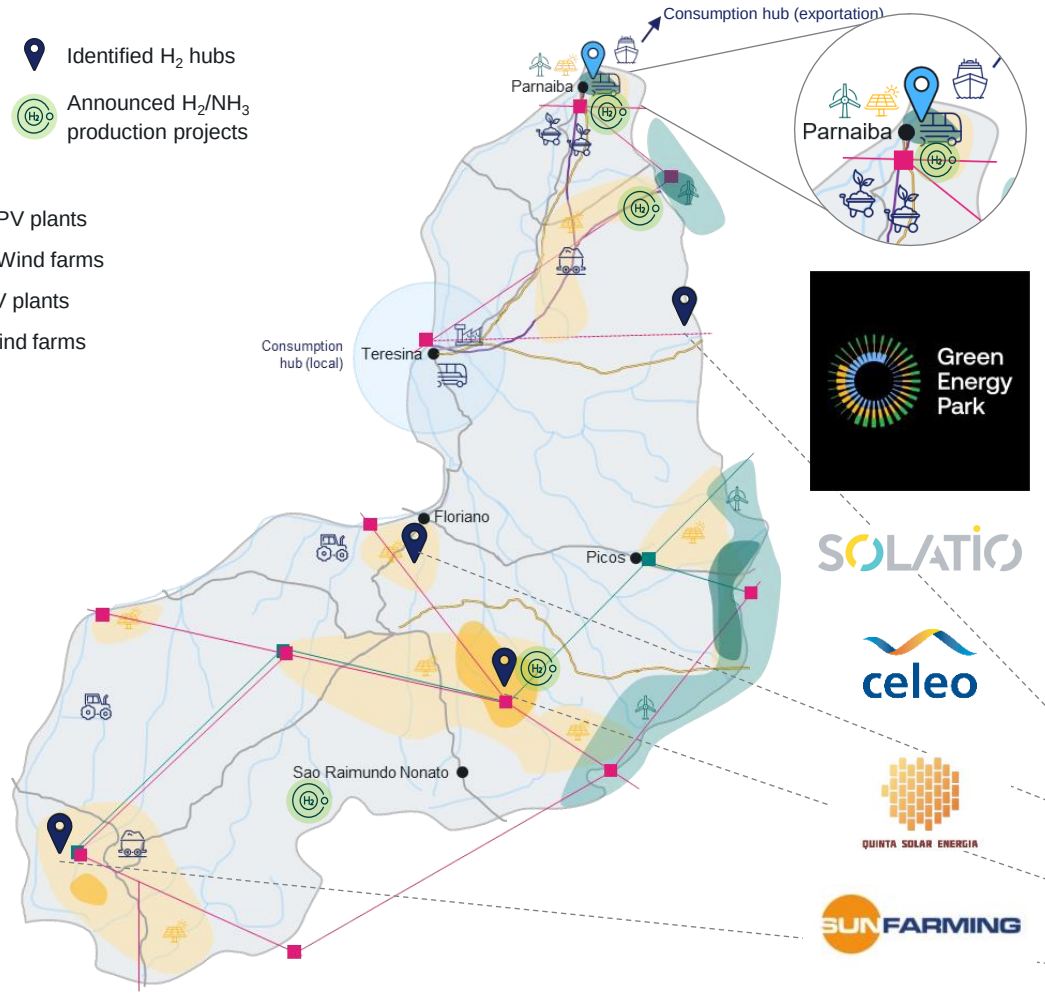
Five potential H_2 hubs were identified, one on the ZPE Parnaiba is confirmed with a main focus of producing H_2 for export

Legend

- Proposed H_2 hub
- Identified H_2 hubs
- City
- Announced H_2/NH_3 production projects
- Road
- Rail
- Area with existing PV plants
- Area with existing Wind farms
- Area with future PV plants
- Area with future Wind farms
- 500 kV line
- 230 kV line
- 500 kV substation
- 230 kV substation
- NG pipeline
- Water resource

Potential off-takers:

- Exportation
- Transportation
- Agriculture
- Mining
- Manufacturing
- Fertilizers/NH_3



Hub 1: Coast Hub (confirmed)

- Exportation potential to Europe; potential local off-takers (transportation); future announced NH_3 projects
- PV CF: 25%
- Wind CF: 47%
- PPA price (USD/MWh): 33 (2030); 29 (2050)
- Close to future ammonia port; near current and future RE plants; electric infrastructure available; next to roads and rails connected to Teresina and Parnaiba
- Water available (Parnaiba river). Water price: 3.07 USD/m^3

Other hubs being considered

- Hub 2: East Hub
- Hub 3: Teresina Hub
- Hub 4: SRM Hub
- Hub 5: South Hub

Note: layers are not exhaustive; the most relevant infrastructure is shown in the map. For more details visit https://rpubs.com/Cleane_/ and Webmap EPE

WIP

LCOH is expected to be ~2.30 USD/kg H_2 in 2030 and reach ~1.70 USD/kg H2 by 2050, in the coastal hub

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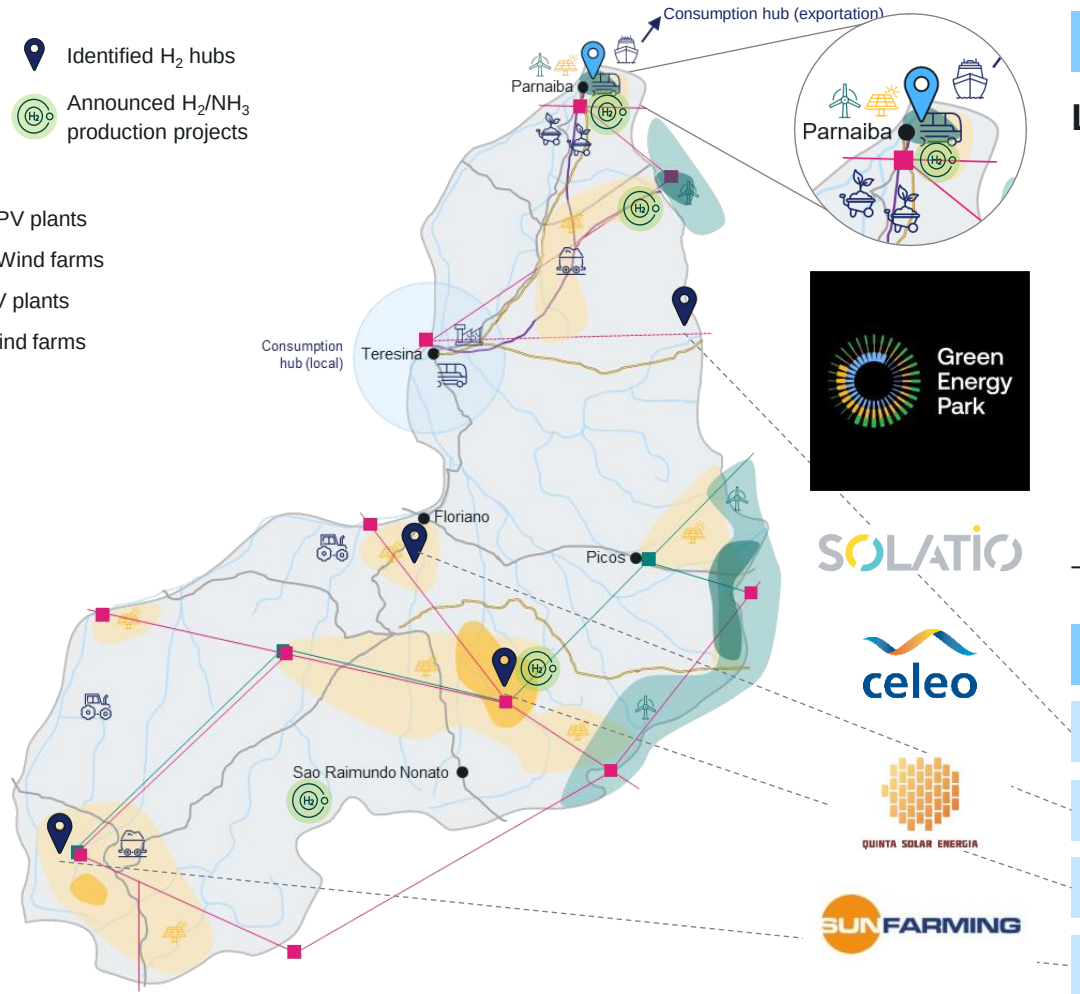
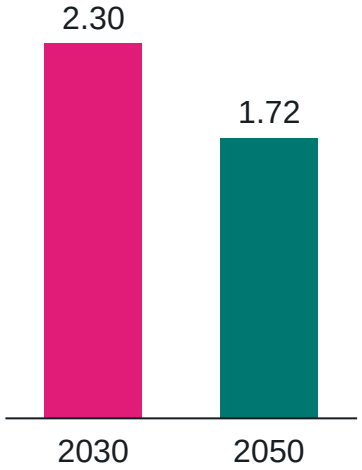


Hub 1: Coast Hub (confirmed)

LCOH (USD/kg H_2)



RE Sources

0% 60% 40%

LCOE (USD/MWh)

2030→ 31.3
2050→ 25.9

Capacity factor (%)

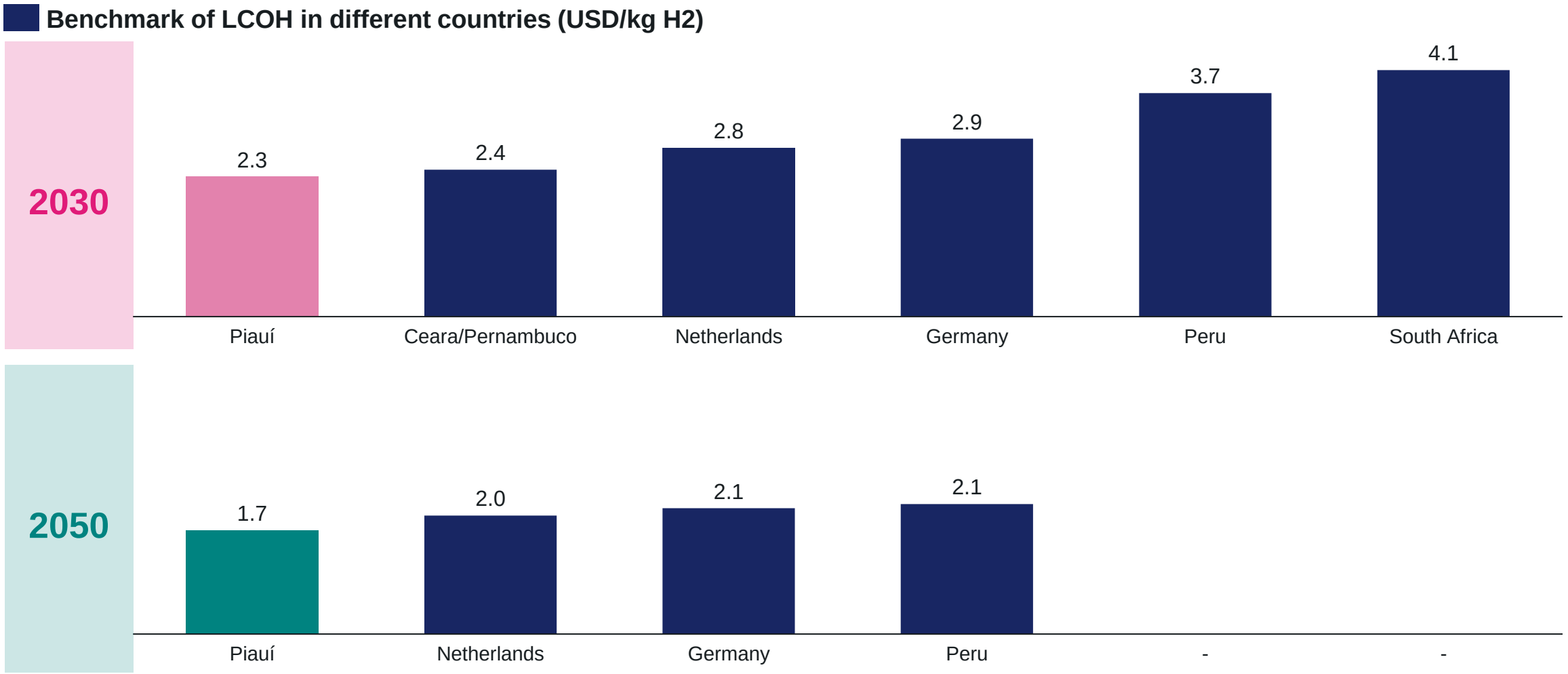
25% 47%

Other hubs being considered

- Hub 2: East Hub
- Hub 3: Teresina Hub
- Hub 4: SRM Hub
- Hub 5: South Hub

2. Results from Prosumer, ENGIE's optimization tool that finds the optimum sizing of the H2 value chain equipment based on inputs such as CAPEX/OPEX and efficiencies of equipment, grid price, renewable profile, H2 demand, lifetime, etc. | 2. Key assumptions (2030/2050): PV CAPEX 730/600 USD/kW; Wind CAPEX 1,000/730 USD/kW; electrolyzer CAPEX 25,000/12,000 USD/(kg H2/h); compressor CAPEX 3,800 USD/(kg H2/h); storage CAPEX 1,000 USD/kg H2. | 3. Technology development is expected for H2 and RE technologies, meaning a decrease in CAPEX and therefore a decrease in LCOE and LCOH.

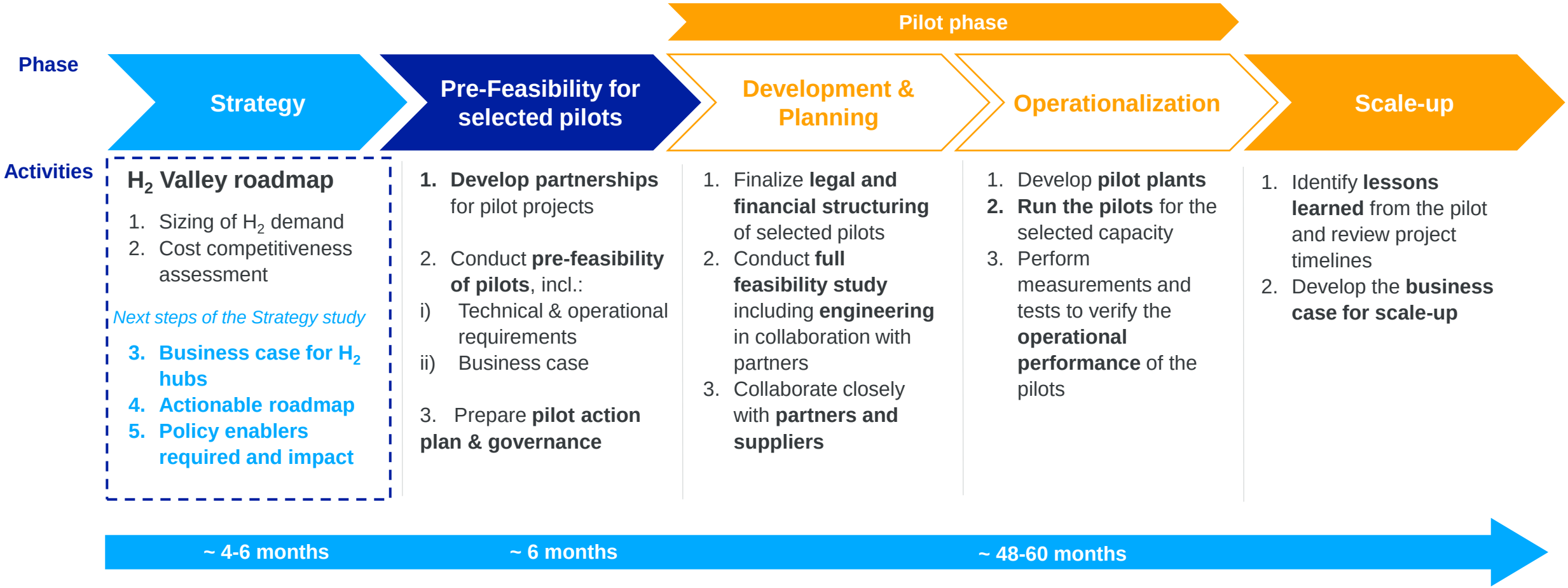
Due to its low grid prices and good RE potential, Piauí is expected to have a competitive LCOH globally



1. This benchmark includes H_2 Valleys (Perú and South Africa) and other H_2 studies (Netherlands and Germany) previously developed by ENGIE Impact
2. LCOH for South Africa and Ceara/Pernambuco was not calculated for 2050

Next steps

Next steps will ensure Piauí's transition from strategy phase to the scale-up of a H_2 economy in the State



Thank you

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