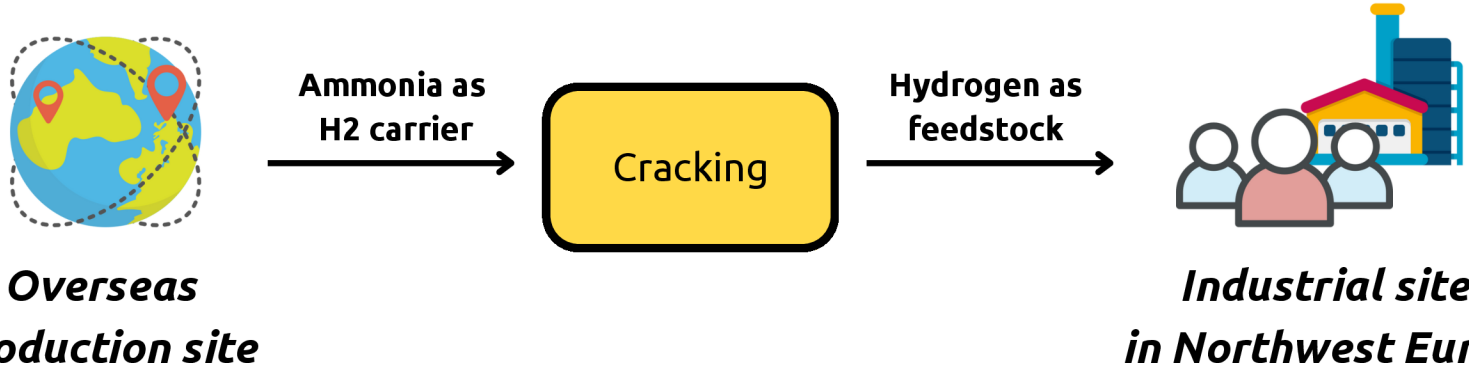
Cracking, the bridge between ammonia powerhouses and hydrogen consumers

October 23, 2024



- **Europe’s industries need at least 1.6 Mt of clean hydrogen to decarbonize their operations in 2030**
- **Imported ammonia needs to be cracked and delivered in the form of hydrogen at factory gate**
- **Ammonia-cracked hydrogen will likely to be cheaper than hydrogen produced at local sites**

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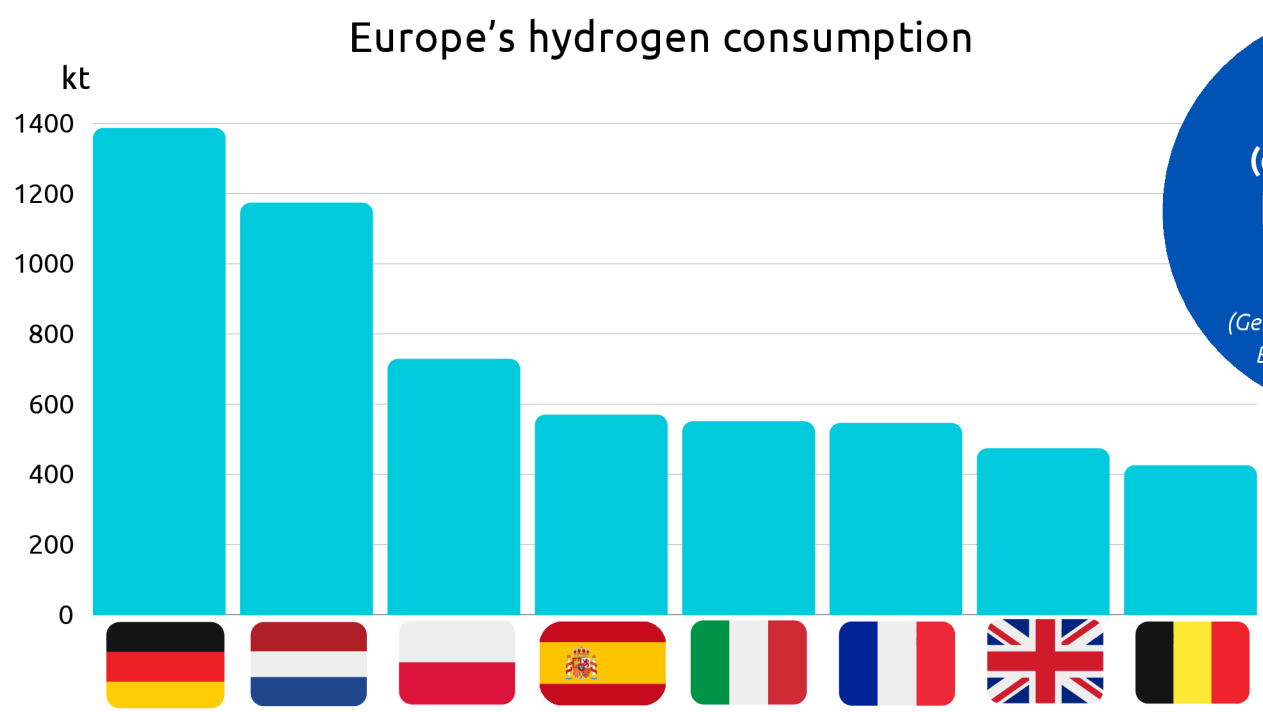
Under RED III, European industries require > 1.6 Mtpa of green H2 in 2030

Among 7.9 Mt of hydrogen consumed in Europe in 2023 (including UK and EEA), the majority was used in industrial countries in Northwest Europe



~50%
(or 3.8 Mt) from Northwest Europe
(Germany, the Netherlands, Belgium, France, etc.)

Source: European Hydrogen Observatory (2023)

Under RED III, current hydrogen consumption needs to be massively decarbonized

RED III Industry

42.5% in 2030

60% in 2035

RFNBO H2 demand in 2030

> 1.6 Mtpa

(without considering new end-use cases)

RFNBO: renewable fuel of non-biological origin

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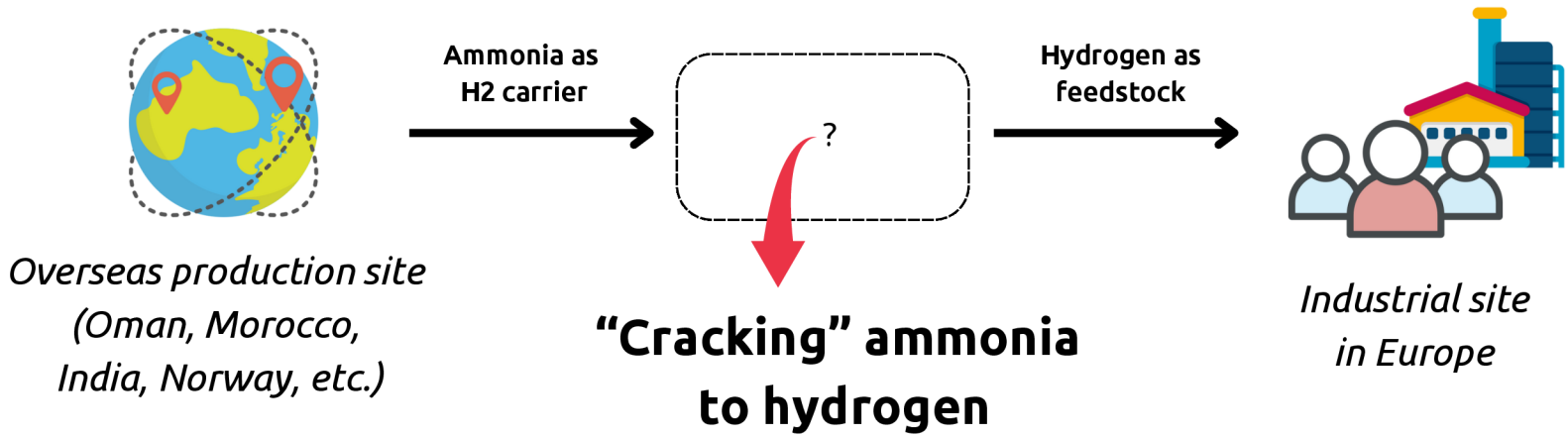
Current momentum for hydrogen demand at factory gate

Several large European industrials have launched call for tenders to meet their clean hydrogen demand to decarbonize their operations

	Sector	Location	Demand	Timeline	Delivery
SALZGITTER AG	Steel	🇩🇪	150 ktpa	by 2027	**H2 at factory-gate**
thyssenkrupp	Steel	🇩🇪	143 ktpa	by 2028	
TotalEnergies	Refinery	🇩🇪 🇧🇪 🇫🇷	500 ktpa	by 2030	

**Non-exhaustive, based on public announcements*

While some hydrogen demand can be met through local onsite production, imports from major overseas locations will be essential to meet the full volume



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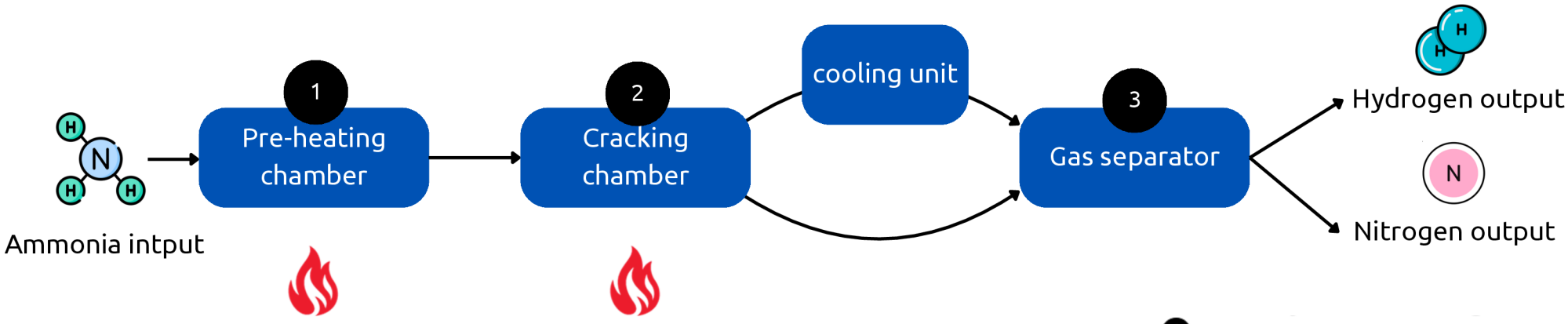
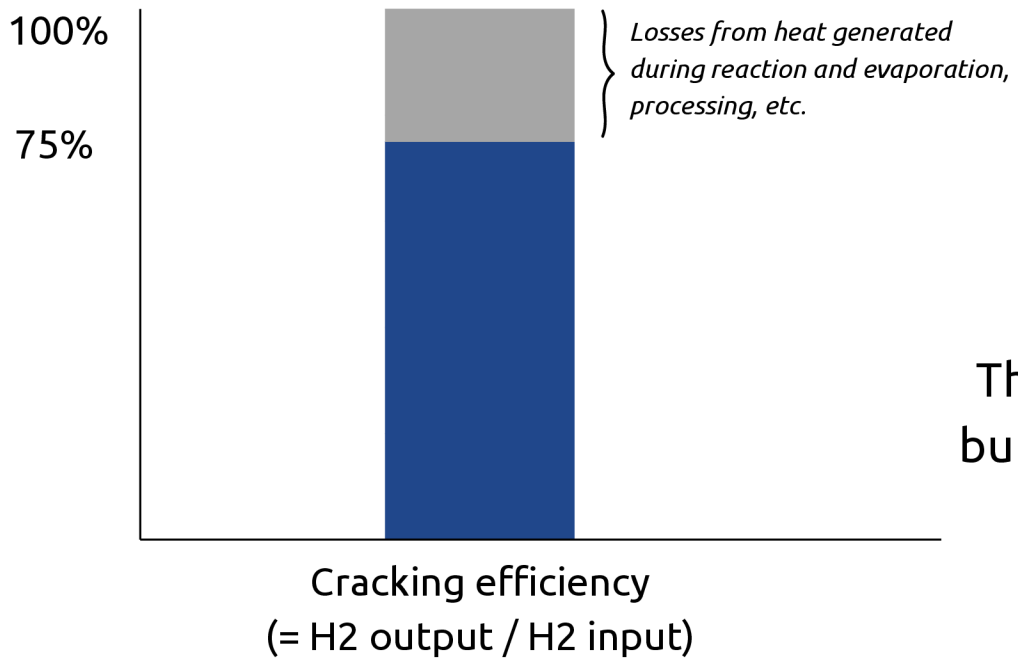
Ammonia cracking is a mature technology, yet to prove large-scale operations

Ammonia cracking requires high temperature and pressure conditions



Potential source for heat inputs:

- Natural gas
- Renewable electricity
- **Ammonia** or hydrogen



Using ammonia as a heat input would achieve

efficiency around 75-80%

This would be the most efficient pathway, but is yet to be proven at an industrial scale

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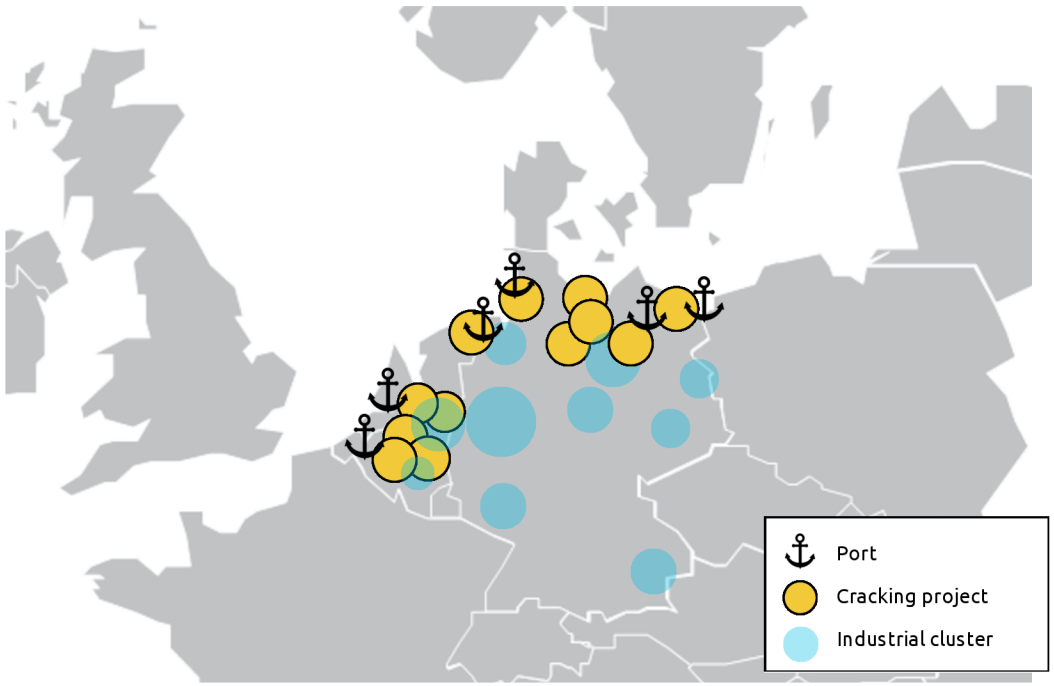
Crackers are likely to locate at large terminals in NW Europe

Most of the announced cracking projects are concentrated in Northwest Europe (Germany, Netherlands, and Belgium) developed by oil & gas majors, trading houses and gas TSOs



Why Northwest Europe?

Existing port infrastructure

Large industrial clusters (refineries, steel plants, etc.)

Industry players with existing operations and expertise

We expect large-scale cracking to happen in locations where:

Existing terminal with high commercial activity

Proximity to large offtakers (industrial clusters)

Connection to hydrogen backbone pipeline

Timeline of cracking projects needs to be aligned with the construction of European hydrogen backbone pipelines to ensure smooth delivery to end-users

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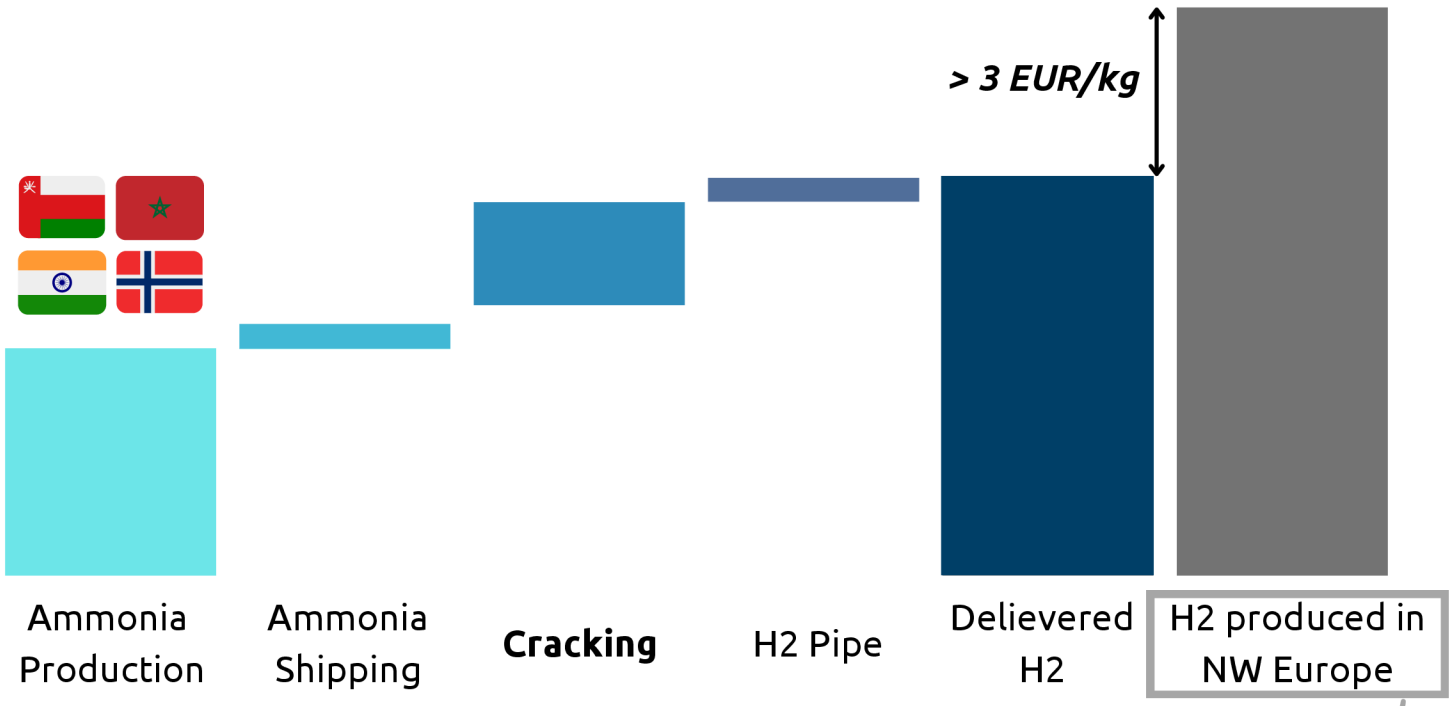
Ammonia cracking can be cheaper than local production under the right conditions

Ammonia, when imported from the right locations (e.g., Oman, Morocco), can provide cheaper solution for sourcing green hydrogen than producing at local sites in Europe



Average levelized cost of renewable hydrogen in NW Europe

Netherlands
9.80 EUR/kg

Belgium
11 EUR/kg

Germany
11.62 EUR/kg

Source: Pilot auction result of European Renewable Hydrogen Auction (2024)

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