HYDROGEN SUMMIT

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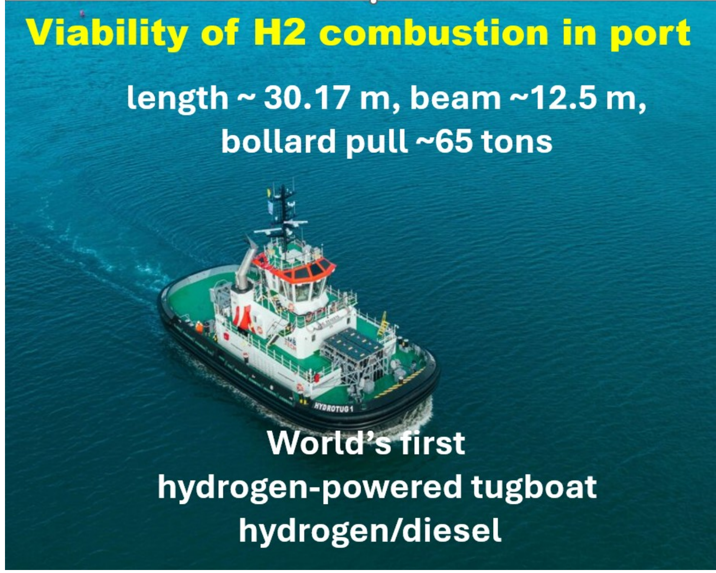
November 2025

"Pioneering Hydrogen Horizons: Transforming Greek Ports for a Sustainable Maritime Future"

Significance for the Port of Piraeus



Combustion Engine

Hydrogen propulsion using combustion engines, potentially more compatible with existing infrastructure.

Hull Design

Hull designs emphasize storage for alternative fuels like hydrogen.

Tug/Ferry Scale

Tug/ferry scale shows port-based hydrogen applications.

Retrofit Systems

Retrofit or novel drive systems for larger ships to use hydrogen.

Ship Design Adaptation

Ship design is adapting to the hydrogen era for efficient use.

Commercial Path

Clear path from demonstration to commercial series offers insight.

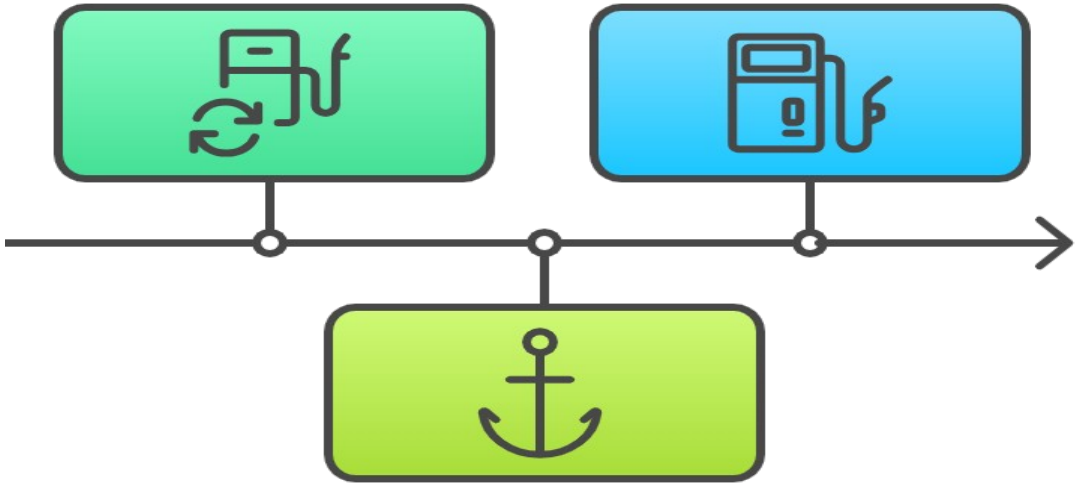
Port Infrastructure Roadmap

Initial Launch

Truck-to-ship e-MeOH bunkering, OPS connection, H_2 skid, and safety training at Piraeus Gate E8/E9

Scale-Up

Modular bunkering barge and scaled H_2 supply for RoPax fuel cells

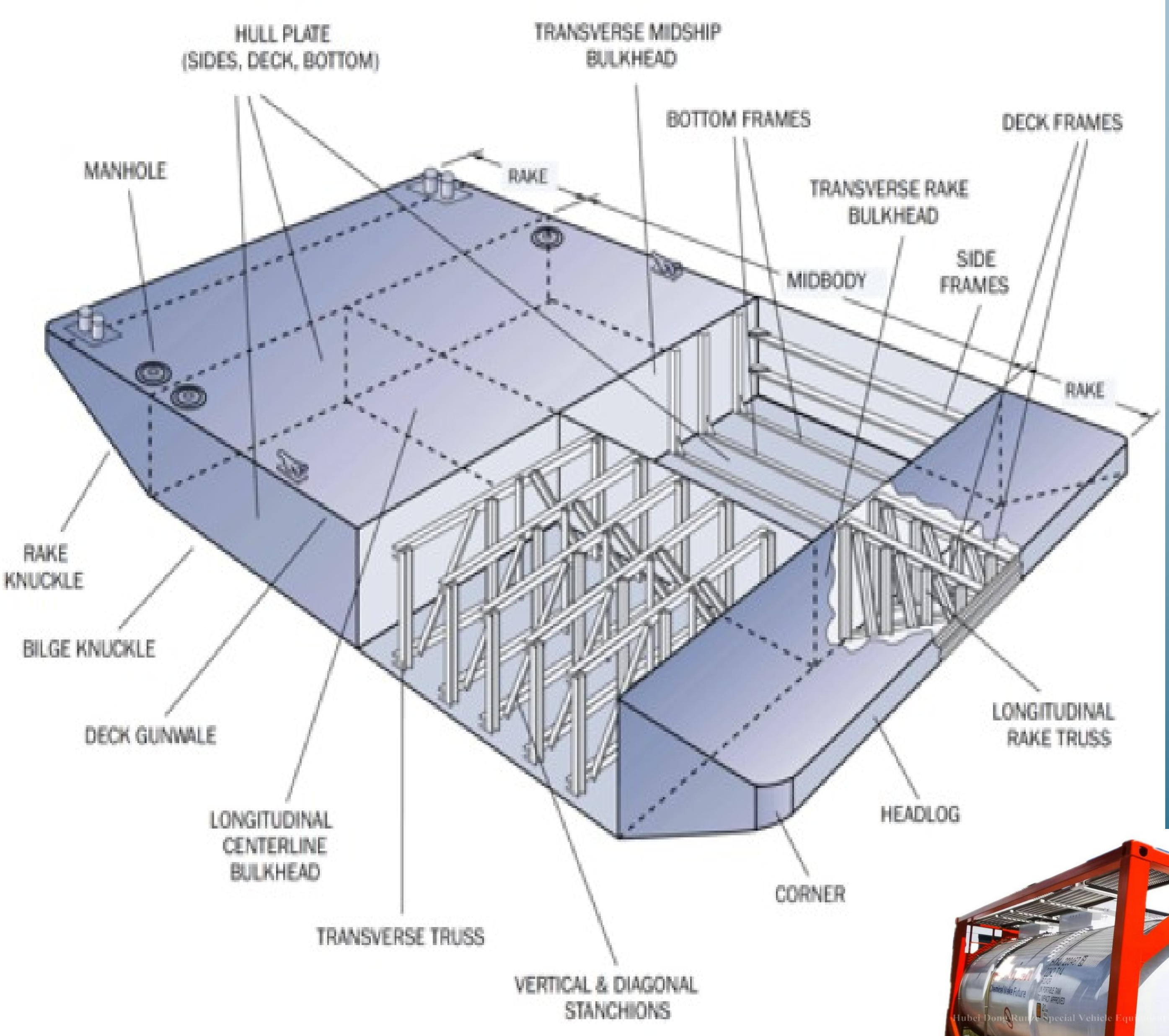


Expansion

Shore tank for e-MeOH and second bunker point at Aegina for redundancy

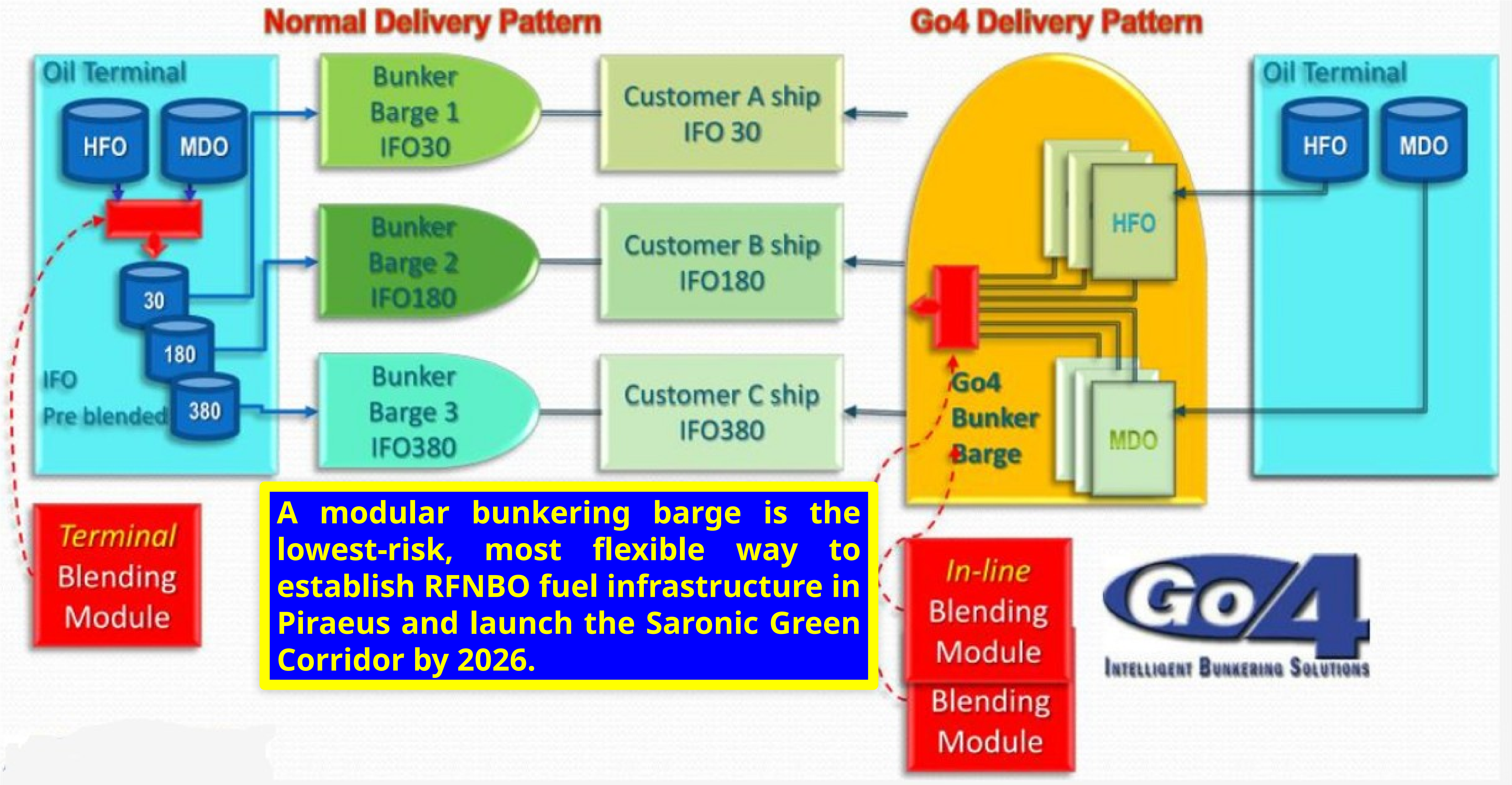
Modular vs Conventional Bunkering Barge

Feature	Conventional Bunker Barge	Modular Bunkering Barge
Construction	Fixed, integrated structure	Modular, transportable, scalable
Fuel Handling	Limited tank configuration and blending options	Supports multiple fuel types and blends simultaneously
Deployment	Longer build and modification times	Quick assembly & deployment
Maintenance	Complex maintenance, more downtime	Modular replacement, less downtime
Operational Flexibility	Low – fixed operational profile	High-adaptable to varying requirements
Cost Efficiency	Higher upgrade and maintenance costs	Potentially lower lifecycle costs



"Plug-and-play" = containers of fuel you can add, remove, or replace

The Go4 modular bunkering barge



A modular bunkering barge is the lowest-risk, most flexible way to establish RFNBO fuel infrastructure in Piraeus and launch the Saronic Green Corridor by 2026.

Pilot Craft on Hydrogen

Asset	Role	Fueling	Hydrogen Use
Piraeus port tug	Escort / berthing	Trucked H_2	Showcase zero-emission port ops
Pilot boat	Piraeus harbor	Trucked H_2	Frequent operation = visibility

Fuel consumption: 50–150 kg H_2/day per craft → small but strategic proof of operations

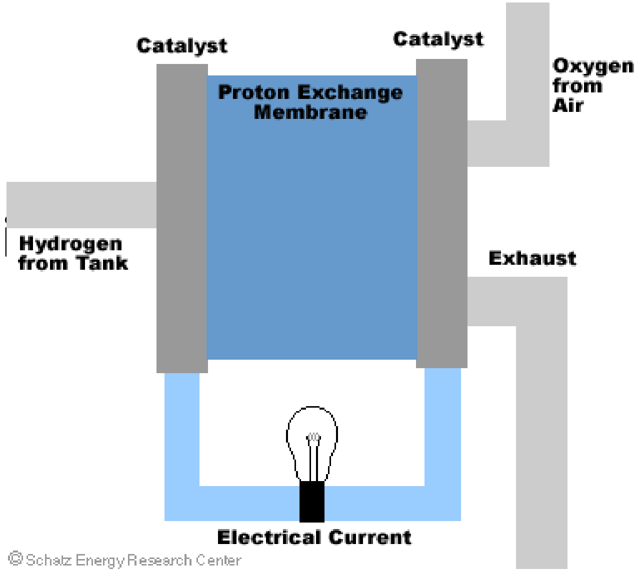
Why Saronic Works?

- **Frequent & short routes → fuel certainty**
- **Close to H_2 / e-fuel production → logistics efficienc**
- **High public visibility → strong political momentum**
- **Refinery-ports ecosystem → great delivery capabili**

Saronic can be Greece's showcase: "the world's first green RoPax corridor."

Fuel Cell Retrofit

- Add H_2 storage (compressed 350–700 bar or LH_2)
- Install fuel cell stacks (PEMFC for high power, SOFC for auxiliary/effici
- Power electronics (DC-AC conversion, energy management)
- Safety systems: ventilation, gas detection, double-walled piping
- Often battery hybrid to handle load transients
- Integration with existing propulsion (keep shaft motors or pods)



Where FC retrofits make most sense

Vessel Type	Feasibility	Why
Port craft (tugs, pilot boats, service vessels)	High	Short range, fixed base – easy fueling
Short-sea ferries / cats	Medium (pilot-ready)	Space constraints, but tech improving
Deep-sea ships	Low today	Range & volume penalties

For Piraeus: FC retrofit best starts with port craft — frequent returns to base, strong emissions visibility.

Fuel Cell Retrofit of a High-Speed Catamaran

Space is the #1 challenge on existing high-speed cats due to light-ship weight limits

- Relocation of tanks (deckhouse or below in protected area)
- Weight + stability assessment
- Battery room (often in sponsons)
- Fire protection zoning upgrades

Recommendations for Piraeus

Phase 1A: Hydrogen fuel cell retrofit for 1 tug + 1 pilot boat in Piraeus→ pioneer operational know-how, safety protocols

Phase 2 (2030+): FC-hybrid upgrade on selected catamarans→ when power density improves

Innovations for Piraeus & Saronic Corri

Traditional Approach	Modular Plug-and-Play Approach
Permanent shore tank	Floating mobile tank bank
Requires heavy permitting & civil works	**Fast deployment** (months, not years)
Fixed capacity	**Scalable** with tank count
Fuel-specific	**Fuel-agnostic** future ready
Locked to one terminal	Can **move to busiest berth**

A plug-and-play tank system means containerized fuel modules that can be easily loaded, connected, removed, and swapped on a bunkering barge — making the fuel infrastructure scalable, flexible, and future-proof

What infrastructure do ports need for H_2 bunkering?

Bunkering

- Truck-to-ship, shore-to-ship and ship-to-ship with dedicated bunker barge
- Hazard zoning, ESD interlocks, purging/venting, custody-transfer metering and gas detection
- Guidance now exists via IMO/IGF/CCC interim material and classes/ports (IMO CCC 11 H_2 fuel guidelines)

Safety envelope:

- QRA/HAZID/HAZOP
- Firefighting upgrades (foam/water spray
- Dry powder for cryogenic fires
- Emergency shutdown and break-away couplings

Storage in double-walled vacuum-insulated LH_2 tanks

Storage in tube-trailers/bundles for GH_2

Boil-off management

High-integrity vacuum pipe-in-pipe lines

Transfer: cryogenic hose/arm for LH_2 with inerting/purge

High-pressure connectors for GH_2

Greece's first dedicated hydrogen law- 5215/2025

National Hydrogen Law

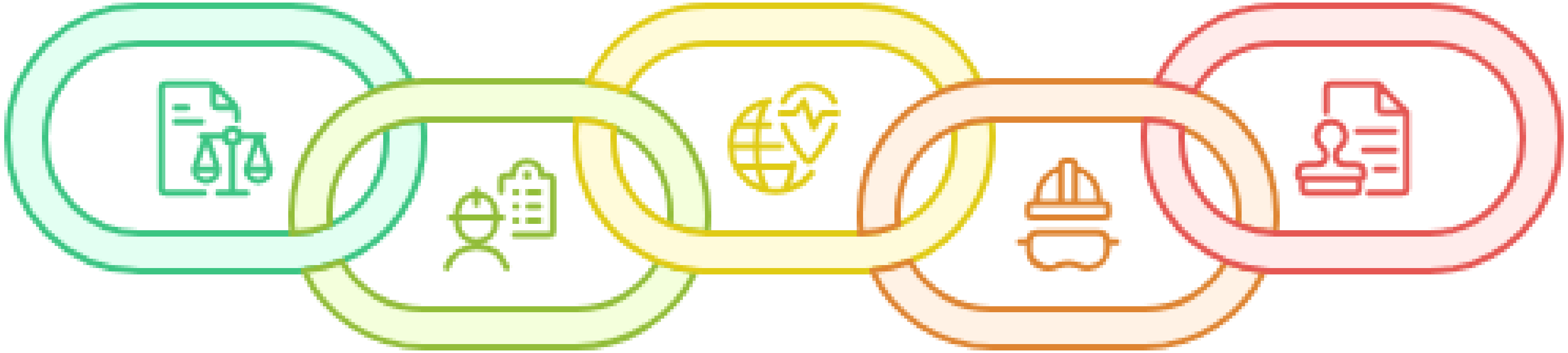
Greece's first law dedicated to hydrogen production and market organization.

EU Infrastructure Mandates

EU regulations pushing for alternative-fuel infrastructure in ports.

Operational Permits

Permits required from local authorities for bunkering operations.



Port Authority Approvals

Case-by-case approvals for hydrogen bunkering operations by port authorities.

Safety Standards

Regulations ensuring safety in hydrogen storage and handling.

hubs?

Piraeus–Elefsina cluster: Greece's busiest hub with container/ro-ro/cruise demand and Elefsina/Aspropyrgos refinery, plus Revithoussa LNG nearby. PPA has already presented interest in H_2 bunkering and is involved in **TRIĒRĒS hydrogen valley** actions

Thessaloniki: Large multi-purpose port with Northern Balkan hinterland and industrial base; active on emissions monitoring and appears in H_2 narratives. Refining/biogenic feedstocks in region; rail connectivity

Igoumenitsa: Ro-pax gateway to the Adriatic—early OPS/renewables/energy-upgrade studies funded by EU, so a pragmatic pilot location for truck-to-ship H_2 bunkering (as ferry demand emerges)

Corinth: Industrial proximity and transit flows. Canal constraints limit scale; plausible for niche/short-sea pilots, less so for large-scale import/re-export

Investment & business case

- Hydrogen (LH_2): cryogenic tanks/pipe-in-pipe dominate CAPEX
- An LH_2 export terminal estimated ~€206 m total CAPEX (storage-heavy).
- Studies show large LH_2 tanks (10–180 k m^3) are technically feasible but costly
- Deloitte/Clean Hydrogen study uses terminal cost of about €90 per ton H_2
- LH_2 is the cost outlier: a basic terminal will be €100–250 m depending on tankage

How ready are Greek shipowners for H_2 / fuel cells?

Momentum is real but selective. Newbuilds still skew **LNG-ready.** Pure **H_2 or fuel-cell main propulsion** remains **pilot/early-demo** (good fit for port craft and auxiliaries).

Domestic ferries: Attica Group is renewing with alt-fuel designs (methanol-capable RoPax), reflecting a practical near-term path (methanol/OPS/batteries first; H_2 later as hybrid/aux).

Deep-sea dry bulk: Almi Marine (with **RINA**) unveiled an **Ultramax design** that integrates **LNG + on-board hydrogen reforming** to avoid liquid-H_2 storage — Credible H_2-derived solutions

H_2 fuel-cell retrofit: feasible for tugs/pilot boats now; for ferries it's heavier CAPEX and space trade-offs (H_2 tanks + batteries). Owners tend to stage FC as aux/hybrid

Concepts like Almi's LNG→H_2 reforming optimize arrangement, safety zones, and weight from day one, cutting lifecycle cost/complexity vs deep retrofits — but require long lead times and funding

First-mover infrastructure in Greece: hydrogen bunkering in Piraeus / Attica / Corinth.

Partnering upstream (renewables + electrolysis) with downstream (fuel off-take, shipping, bunkering).

Commercial agreements for shipowners to take hydrogen or equip vessels accordingly.

Regulatory risk: ensure that Greek hydrogen legislation, EU RFNBO regimes and maritime fuel regulations are aligned.

Technology & cost risk: hydrogen storage, bunkering, vessel fuel systems are still emerging

Greece must mitigate via pilots.

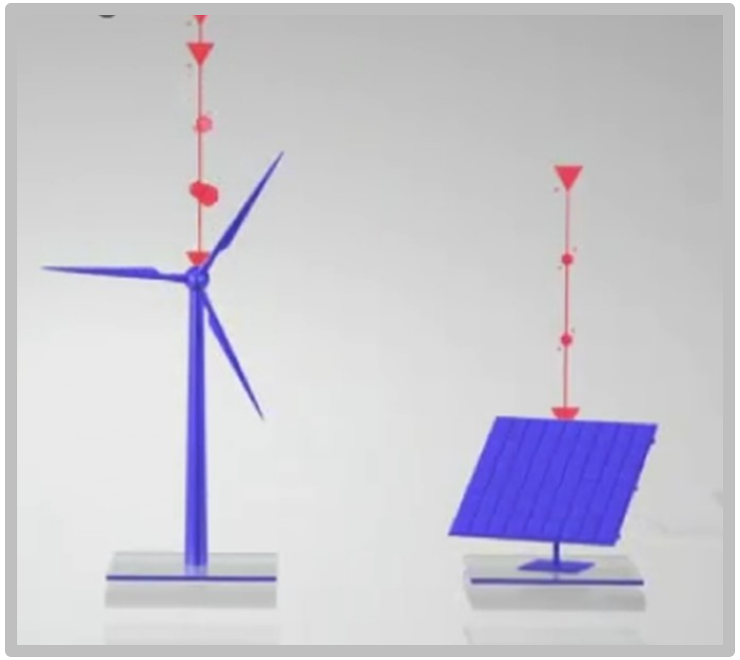
Value chain risk: green hydrogen only ₹ competitive if the whole chain (renewables → electrolyser → storage → fuel) is optimized.

Funding/leverage: EU programs (CEF, Innovation Fund) give a competitive advantage.

What to watch

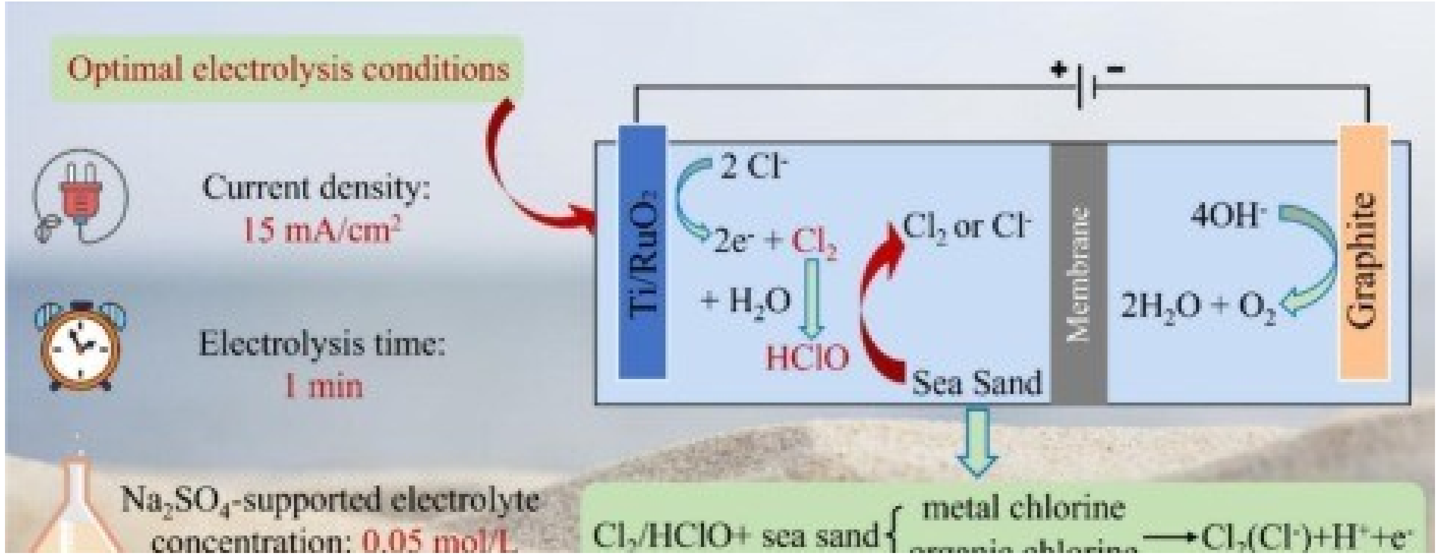
Seawater electrolysis for H_2 production

Captain



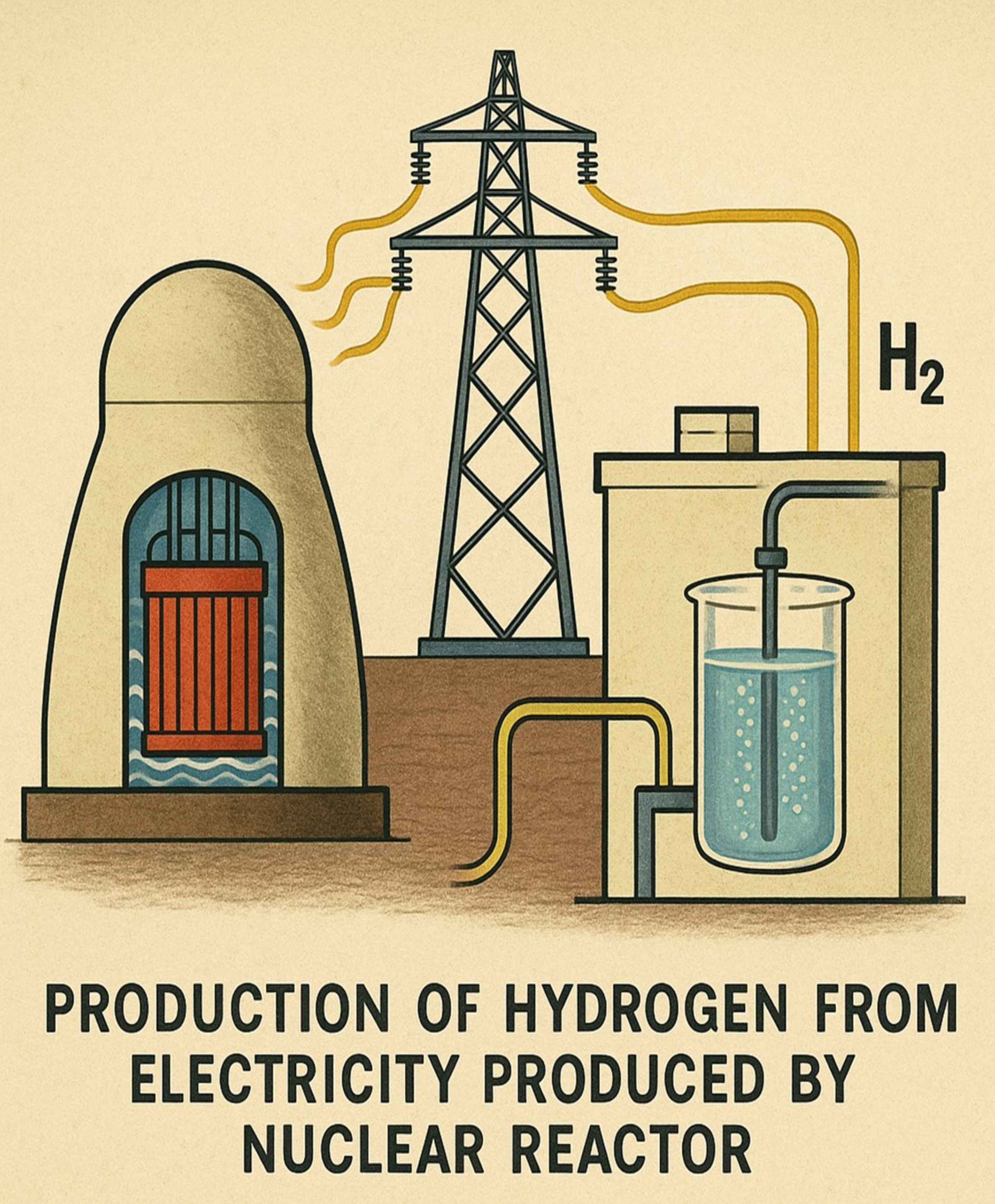
Renewable Energy Sources → Surplus Energy is created → Surplus Energy must be stored → Best storage is as Hydrogen

Technical Challenges in Seawater Electrolysis



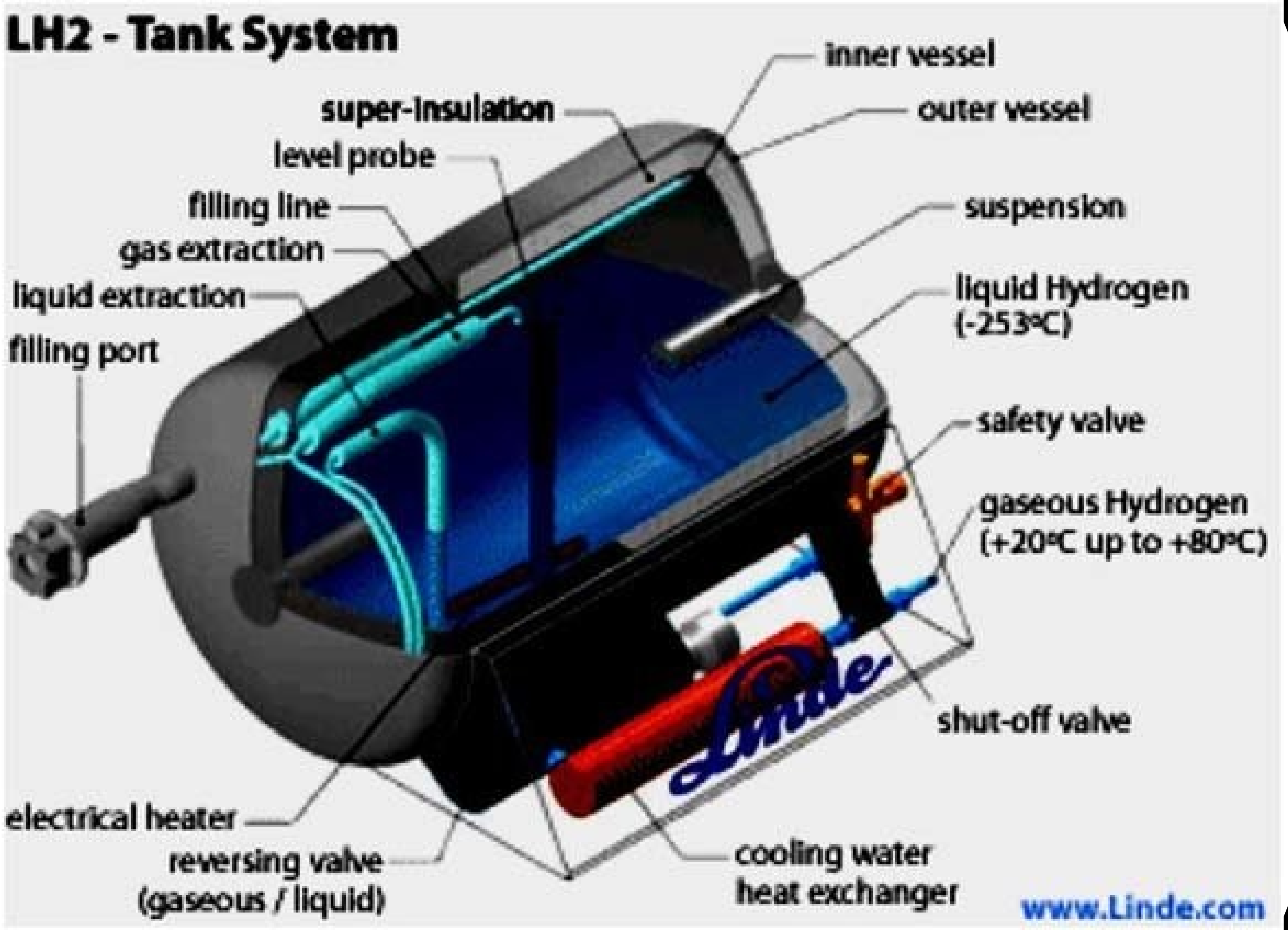
- **Chlorine evolution → toxicity & corrosion**
- **Biofouling degrades membranes**
- **Salt scaling blocks electrodes**
- **Catalyst poisoning by seawater impurities**

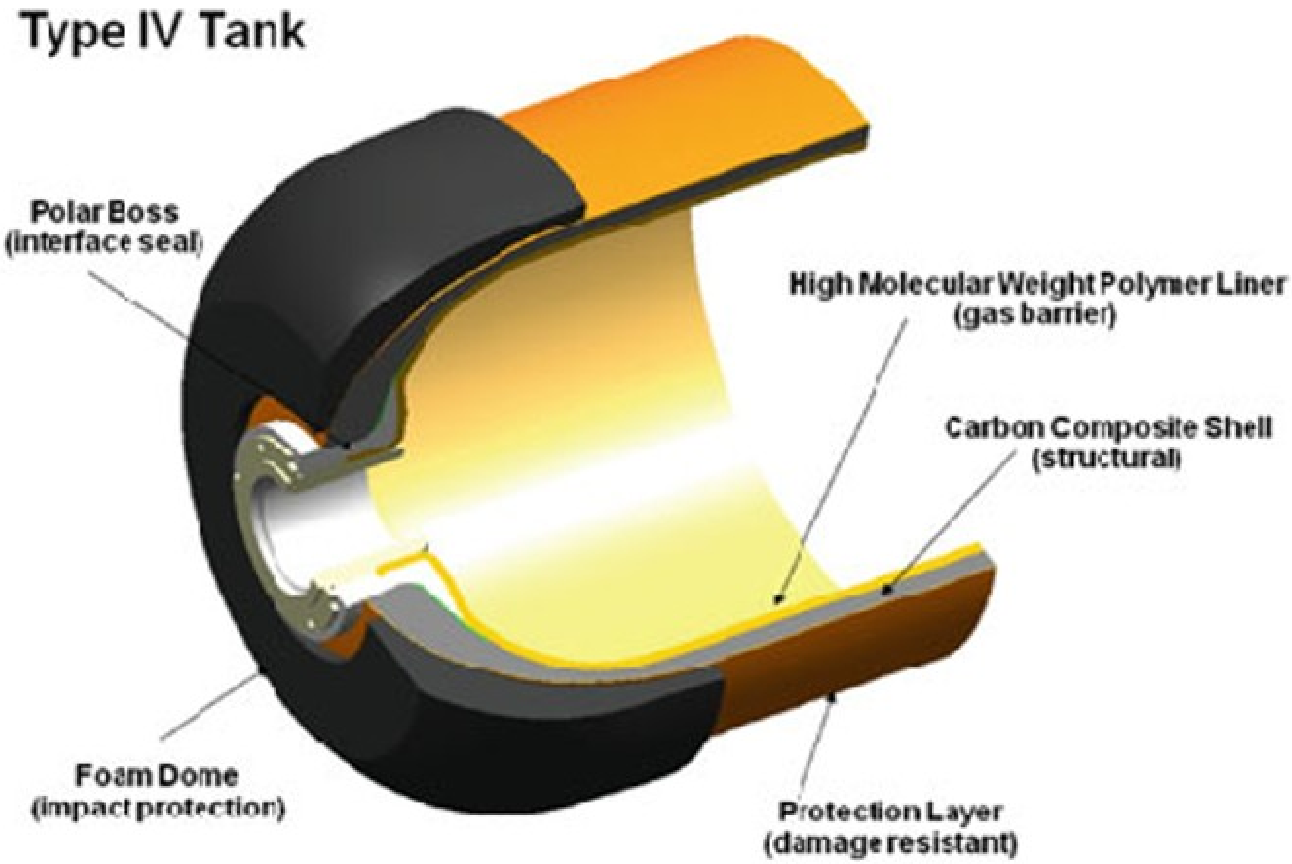

H2


H2
PRODUCTION OF HYDROGEN FROM
ELECTRICITY PRODUCED BY
NUCLEAR REACTOR

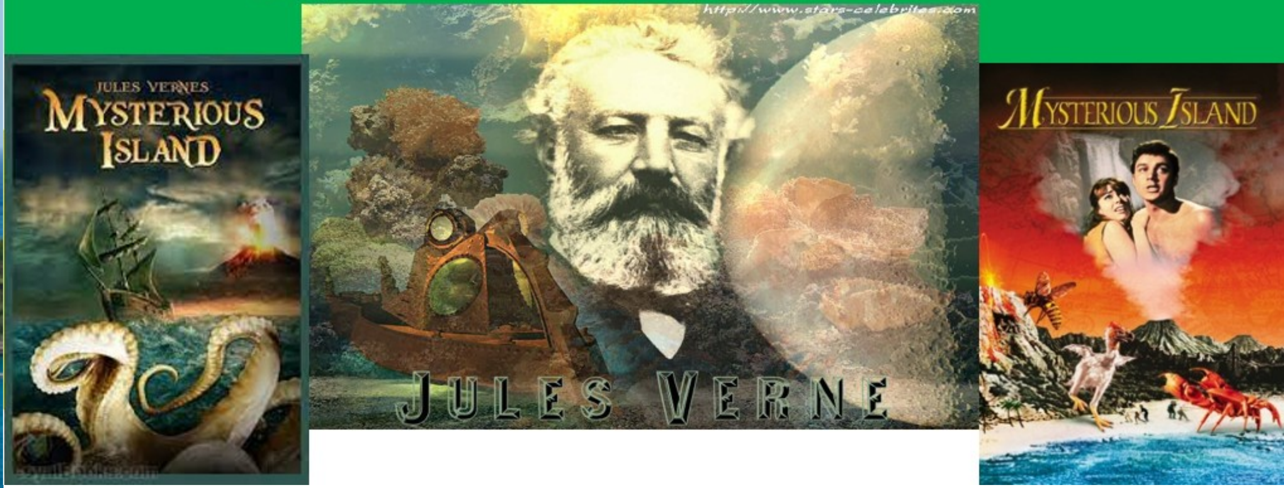
H_2 ⇨ Ammonia NH_3	Liquid Hydrogen LH_2	Compressed Hydrogen Gas
✅ Pros: • Established global shipping infrastructure • High volumetric energy density • Easier storage than liquid H_2 ❌ Cons: • Energy-intensive synthesis and cracking • Toxic and corrosive handling • Requires cracking units at destination	✅ Pros: • High purity hydrogen • Compact for transport compared to compressed H_2 ❌ Cons: • Very high liquefaction energy cost (~30–40%) • Boil-off losses during transport • Expensive cryogenic infrastructure	✅ Pros: • Lowest energy loss (10–20%) • Simple compression/decompression • Lower cost per kg delivered ❌ Cons: • Low volumetric energy density • Heavy tanks, impractical for long-distance • Infrastructure still growing

Pros & Cons of Hydrogen Delivery Options


LH2 - Tank System
inner vessel
super-insulation
outer vessel
level probe
filling line
suspension
gas extraction
liquid extraction
liquid Hydrogen
(-253°C)
filling port
safety valve
gaseous Hydrogen
(+20°C up to +80°C)
shut-off valve
electrical heater
reversing valve
(gaseous / liquid)
cooling water
heat exchanger
www.Linde.com


Type IV Tank
Polar Boss
(interface seal)
High Molecular Weight Polymer Liner
(gas barrier)
Carbon Composite Shell
(structural)
Foam Dome
(impact protection)
Protection Layer
(damage resistant)

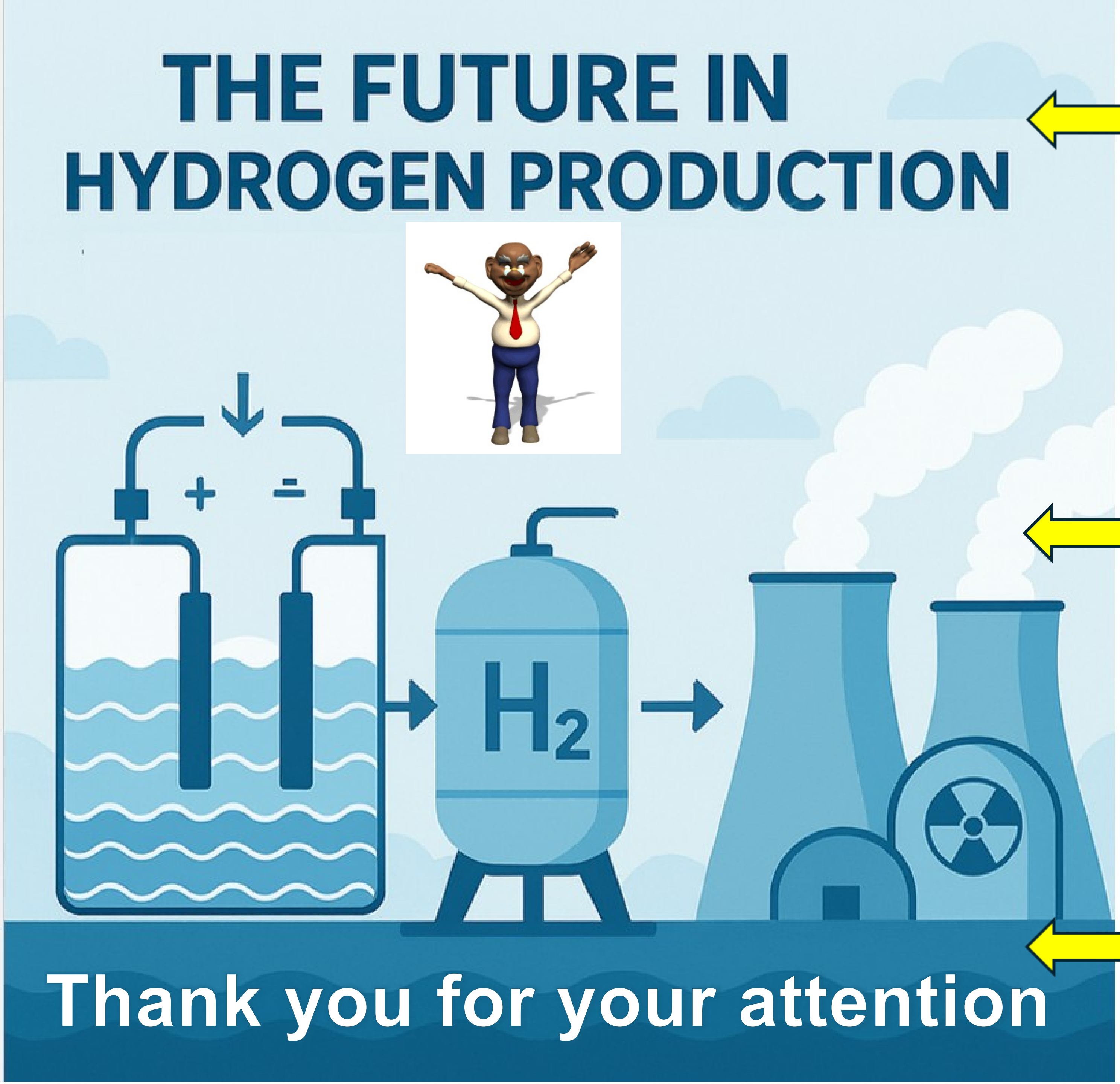
Hydrogen & Shipping
GREEN YACHTING

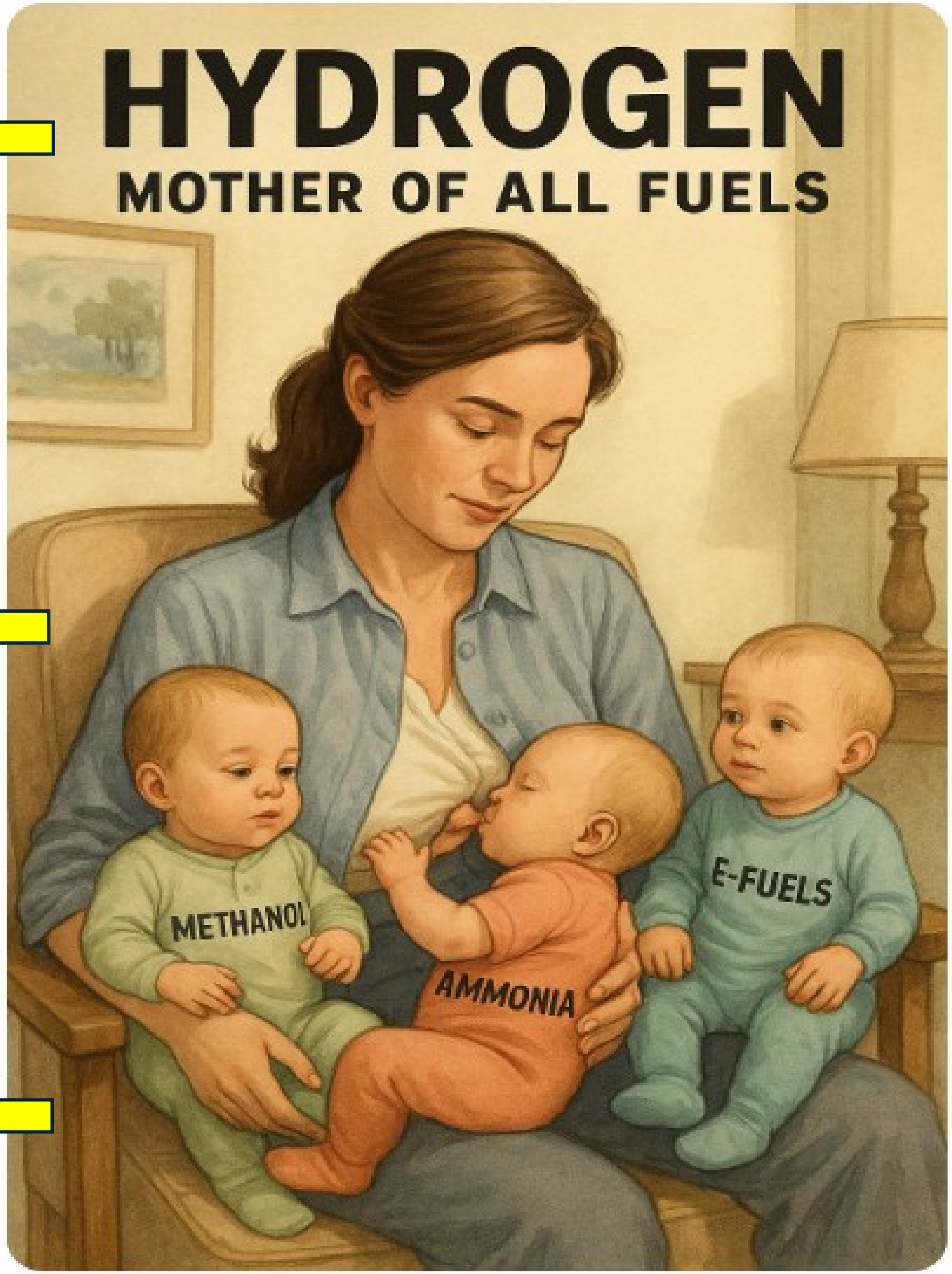


Hydrogen-Powered Yachts

will be the new "Norm"

High speed vessels are responsible for 55% of greenhouse gas emissions


THE FUTURE IN
HYDROGEN PRODUCTION
+
-
H_2
Thank you for your attention


HYDROGEN
MOTHER OF ALL FUELS
METHANOL
AMMONIA
E-FUELS