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On Point

Analyzing shipping cost of hydrogen as per end use application and distinct terrains

Part -7 (Hydrogen cost benchmarks, demand built-up, transport infra & market size evaluation for India)

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Shipping cost analysis as per distance, terrain and end use

For short and medium range distances, retrofitted pipelines can achieve very low H2 transportation costs (less than or equal to USD 0.1/kg for up to 500km). However, these costs are realizable only if existing pipeline networks are available and suitable for retrofitting (e.g., ensuring leakage prevention), and high volumes of H2 are transported, guaranteeing high utilization rates. For lower or highly fluctuating demand, or to bridge the development to a full pipeline network roll-out, trucking hydrogen – in gaseous or liquid form – is the most attractive option. It can achieve costs of around USD 1.2/kg per 300km. End applications as well as demand size are decisive for choosing between liquid or gaseous hydrogen trucking options.

For longer distances, both new and retrofitted subsea transmission pipelines provide cheaper at scale transportation than shipping, but are not relevant for all regions. Where pipelines are not available, the transportation choice involves a range of different carriers. The three modelled here – LH2, LOHC and NH3 – are the most discussed. Since all three carriers fall into a comparable cost range, the optimal choice depends on the targeted end-use and requirements concerning hydrogen purification and pressure levels.

Hydrogen distribution & transmission through pipelines

Cost	<0.1 USD/kg	<0.1 USD/kg
Distribution	0-50 km	51-100km
Retrofitted	City grid	Regional distribution
New	City grid	Regional distribution

Cost	<0.1 USD/kg	<0.1 - 1 USD/kg
Transmission	101-500 km	> 1000 km
Retrofitted	Onshore transmission pipelines	Onshore/subsea transmission pipelines
New **For new the cost Shall be <0.1 - 1 USD/kg**	Onshore transmission pipelines	Onshore/subsea transmission pipelines

Source: Eninrac research, Hydrogen Council, IEA, Channel Checks

Hydrogen distribution through shipping and trucking

Hydrogen transmission through shipping

Cost	1-2 USD/kg	>2 USD/kg
Transmission	> 1000 km	> 5000 km
LH2	LH2 Ship	LH2 Ship
NH3	NH3 Ship	NH3 Ship

Hydrogen pipelines are cheaper than electricity transmission lines Hydrogen pipelines can effectively transport renewable hydrogen across long distances. They can transport 10 times the energy at one-eighth the cost associated with electricity transmission lines. Furthermore, hydrogen pipelines have a longer lifespan than electricity transmission lines and offer dual functionality, serving as both a transmission and storage medium for green energy.

Hydrogen distribution through trucking

Cost for LH2 trucking	**1-2 USD/kg**	**1-2 USD/kg**
Distribution	0-50 km	51-100 km
LH2 trucking	Distribution truck LH2	Distribution truck LH2
Gaseous trucking	Distribution truck CH2	Distribution truck CH2
Cost for gaseous trucking	**0.1-1 USD/kg**	**0.1-1 USD/kg**

Hydrogen transmission through trucking

Transmission	101-500 km	**Cost**
LH2 trucking	Distribution truck LH2	**1-2 USD/kg**
Gaseous trucking	Distribution truck CH2	**1-2 USD/kg**

Source: Eninrac research, Hydrogen Council, IEA, Channel Checks

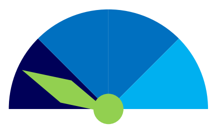
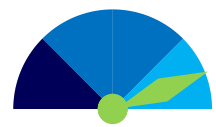
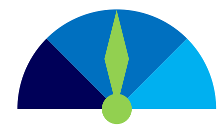
Pipelines enable both international and regional /last-mile transport , moving H2 upto 5000 km at low cost but not all are equal

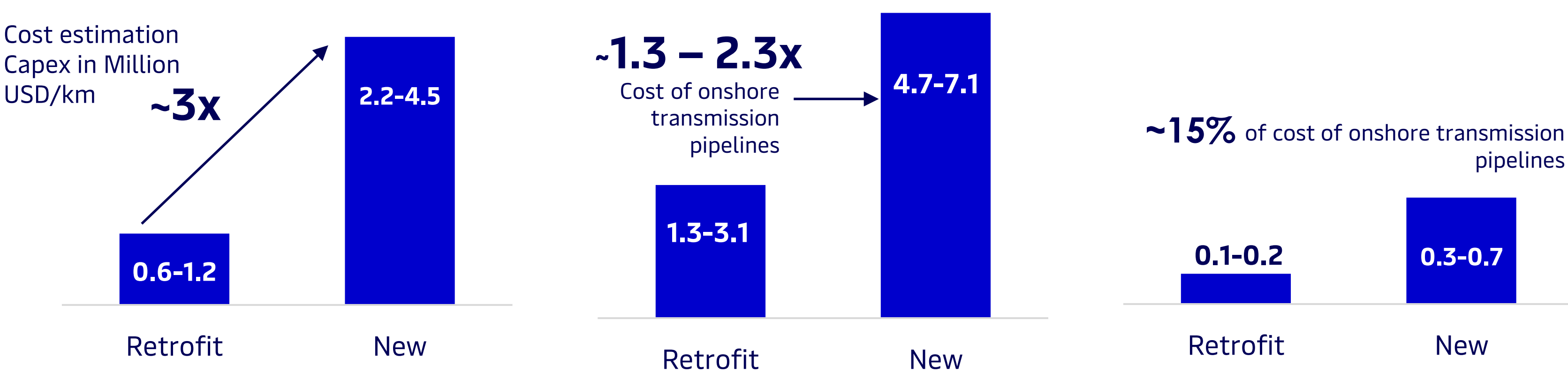
While distribution networks cover regional and last-mile transport, onshore and subsea transmission pipelines could move hydrogen across distances that range from 500 to 5,000 or more kilometers. Pipelines can achieve extremely low-cost H2 transport compared with alternative transportation modes, especially where retrofits of existing infrastructure are possible. For example, retrofitting pipelines can save 60-90% of the cost of greenfield pipeline development. While hydrogen pipelines provide cheaper transportation compared with many alternatives, the actual costs of hydrogen networks vary by type, length of network, and the condition of the retrofitted pipeline itself. Typical capex costs for onshore transmission networks including compression will range between USD 0.6 and 1.2 million per km for retrofit and USD 2.2 and 4.5 million per km for newly built H2 pipelines, resulting in H2 transport costs of USD 0.13-0.23/kg/1000km

For longer distances, both new and retrofitted subsea transmission pipelines provide cheaper at scale transportation than shipping, but are not relevant for all regions. Where pipelines are not available, the transportation choice involves a range of different carriers. The three modelled here – LH2, LOHC and NH3 – are the most discussed. Since all three carriers fall into a comparable cost range, the optimal choice depends on the targeted end-use and requirements concerning hydrogen purification and pressure levels.

For offshore/subsea transmission pipelines, costs are a factor 1.3 to 2.3 higher, given the specific challenges and conditions of subsea pipeline construction and operation for both new projects and retrofits. Distribution pipelines are substantially cheaper than transmission pipelines (roughly 15% of transmission pipeline costs), given their smaller diameter and lower pressures. However, distribution pipelines will likely become relevant only in the runup to 2040, when demand for hydrogen in residential and commercial buildings exceeds the threshold that the blending of up to 20% hydrogen into the natural gas grid can supply.

Comparing hydrogen pipelines

	Onshore transmission pipelines	Subsea transmission pipelines	Distribution pipelines
Description	Large, high pressure transmission pipelines transporting gas on land	Large, high pressure transmission pipelines transporting gas through oceans	Smaller, lower pressure pipelines for last-mile gas delivery to end users
Ease of retrofitting	 **High** Potential availability constraints due to long-term natural gas commitments and capacity contracts	 **Low** High compression requirements and subsea transmission network may be challenging	 **Medium** Distribution network location in densely populated areas could be problematic



Source: Eninrac research, Hydrogen Council, IEA, Channel Checks

Beyond pipelines, three carbon neutral H2 carriers are competitive for long distance hydrogen transportation

The costs of retrofitting versus building new pipelines depend on a variety of factors including diameter and pressure, the quality of the materials used, the pipeline's overall condition, the existence of cracks, the social costs of construction, and other considerations. Many of these factors are location-specific and thus give some regions and countries an advantage for retrofitting the natural gas grid. For example, in the Netherlands, parallel natural gas grid infrastructure allows companies to retrofit for hydrogen usage while gradually phasing out natural gas. The costs of retrofitting can change based on pipeline upgrades and the presence of connected equipment such as metering stations, valves, and compressor stations.

Beyond pipelines, three carbon neutral H2 carriers are competitive for long distance hydrogen transportation. As gaseous hydrogen is not suitable for long-distance shipping, suppliers can liquefy hydrogen, convert it to ammonia, or bind it to a liquid organic hydrogen carrier.

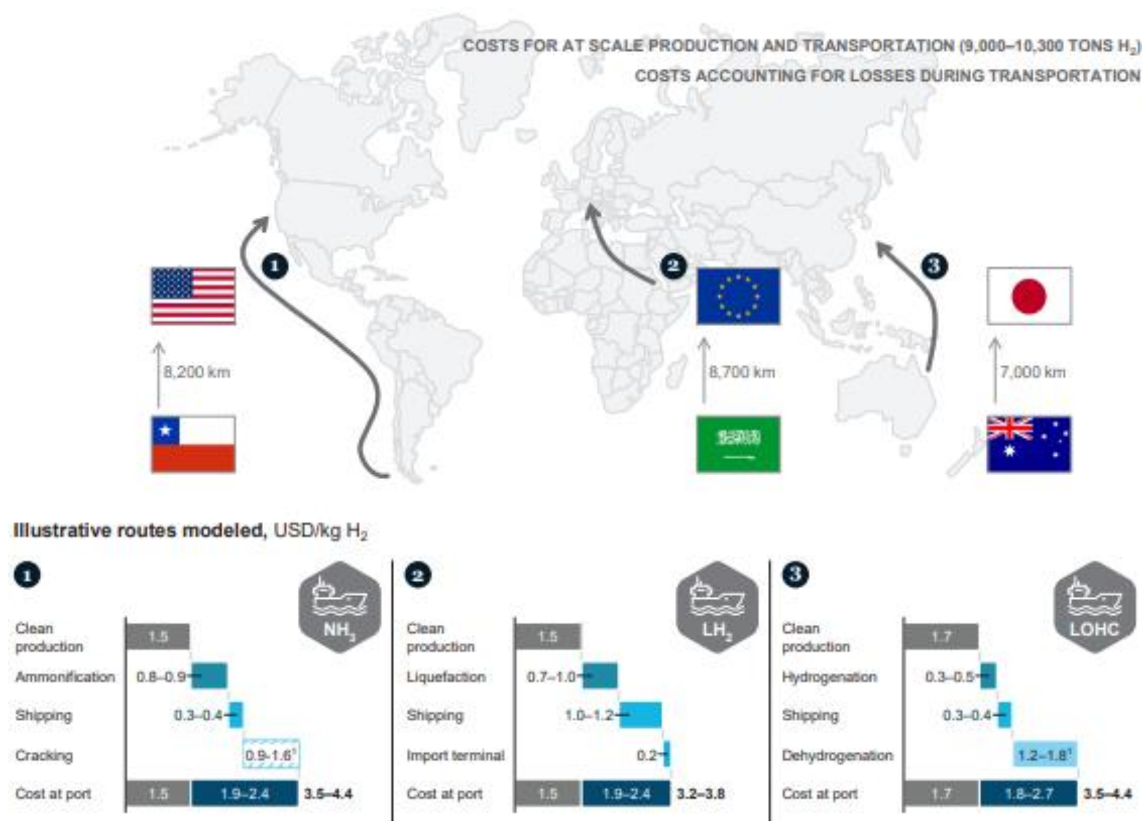
If every step of the value chain uses green energy (fuel and/or electricity) and the hydrogen is produced from low-carbon sources, all three carriers can be considered low carbon. The optimal carrier depends on the intended end-use, purity requirements and the need for long-term storage. The long-term optimal choice of carrier depends on a range of factors. LH2 is most efficient if the destination requires liquid or high-purity hydrogen, and has benefits if hydrogen needs to be distributed with trucks after landing at port. This is typically the case for hydrogen refuelling stations for cars or trucks, for example. In contrast to NH3 and LOHC, LH2 does not require dehydrogenation or cracking to convert into gaseous hydrogen, which not only saves costs but also avoids purity challenges caused by carrier residues. LH2's main drawback is its relatively low volumetric energy density compared with ammonia, which limits the amount of hydrogen per ship, and the boil-off losses that occur with every day of storage. While liquefaction is a proven and commercialized technology, liquid hydrogen shipping and large-scale storage – which requires suppliers to manage the boil-off losses – remain in the early stages of deployment. Ammonia is the straightforward answer for end-uses that need ammonia as a feedstock and can therefore avoid the need to crack NH3 back into hydrogen (such as for fertilizer, shipping fuel, co-firing or ammonia combustion for power generation). However, suppliers are also considering this approach for other hydrogen use cases. Ammonia benefits from a higher volumetric energy density than does liquid hydrogen and thus suppliers can ship it more cost effectively than LH2 using commercially available ammonia ships. However, the two drawbacks of using ammonia as a hydrogen carrier are the high costs of cracking it back into hydrogen and the achievable purity levels. Furthermore, because ammonia is toxic, it may face handling and storing restrictions in residential areas as well as limited options for in-land distribution.

Cost comparison for pipelines and benchmarks globally

Hydrogen global transport can cost less than USD 2-3/kg

By 2030, assuming at-scale production and transportation infrastructure, hydrogen could be shipped from locations such as Australia, Chile or Middle East to projected demand centers at costs of USD 2-3/kg of hydrogen. This cost, coupled with very low hydrogen production costs, unlocks demand in many key sectors (e.g., in transportation, industry, feedstock and others) at the point of usage

Landed cost of hydrogen at port for selected global transport routes



Source: Eninrac research, Hydrogen Council, IEA, Channel Checks

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