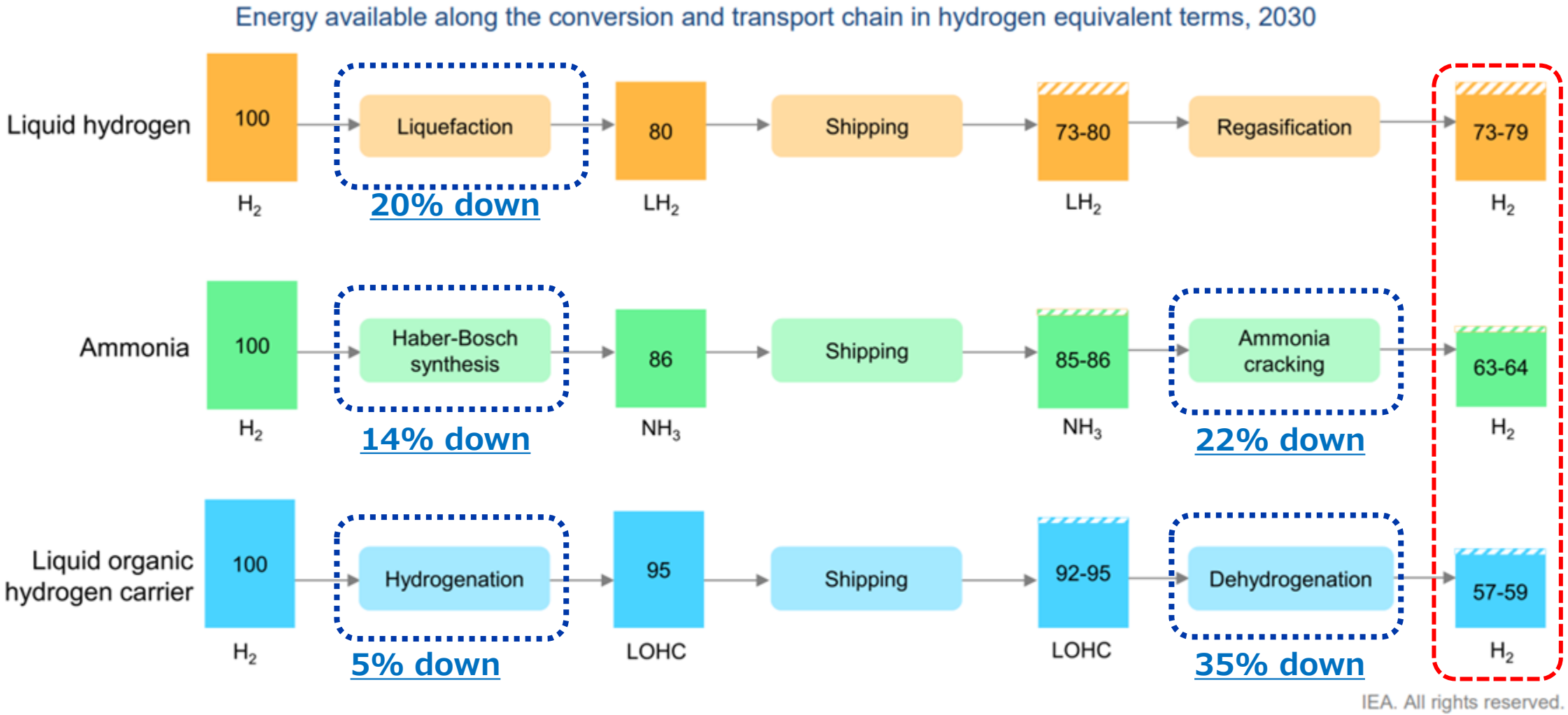
Why Kawasaki Heavy Industries chooses liquefied hydrogen?

Challenges

Safety Issues

	Overseas Source	Maritime transportation	Japan
Liquefied Hydrogen		Challenges in technology and cost Outer energy Liquefaction H_2O Liquefied hydrogen Carrier	Outer energy Vaporization Cooling Utilization No need for outer energy for purification H_2 Site Area
Ammonia		Outer energy Synthesis CO_2 Ammonia Carrier	Challenges in technology and cost Outer energy Cracking 90% H_2 Outer energy Purification H_2 Site Area Toxicity of ammonia
LOHC		Outer energy Hydrogenation CO_2 CO_2 MCH Carrier Toluene supply Toluene carrier	Challenges in technology and cost Outer energy Dehydrogena-tion 90% H_2 Outer energy Purification H_2 Site Area Toxicity of toluene

Hydrogen Carriers Energy Efficiency



Notes: LH_2 = liquefied hydrogen; NH_3 = ammonia; LOHC = liquid organic hydrogen carrier. Numbers show the remaining energy content of hydrogen along the supply chain relative to a starting value of 100, assuming that all energy needs of the steps would be covered by the hydrogen or hydrogen-derived fuel. The Haber-Bosch synthesis process includes energy consumption in the air separation unit. Boil-off losses from shipping are based on a distance of 8 000 km. For LH_2, dashed areas represent energy being recovered by using the boil-off gases as shipping fuel, corresponding to the upper range numbers. For NH_3 and LOHC, the dashed area represents the energy requirements for one-way shipping, which are included in the lower range numbers.

Resource: IEA Grobal Hydrogen Review 2022

Comparison of Hydrogen Carriers

	Ammonia (NH_3)	Organic Hydride (LOHC)	Liquefied Hydrogen
Volume (vs. gaseous form)	1/1300	1/500	1/800
Conditions for liquefaction	-33°C, atmospheric pressure	Atmospheric temperature and pressure	**-253°C**, atmospheric pressure
Toxicity	**Toxic, corrosive**	**Toxic with toluene**	None
Direct usage	Mixed combustion in coal-fired power generation, etc. (pure hydrogen must be separated)	Not possible (hydrogen separation is required)	Allow to evaporate, then use as-is
Transportation infrastructure	Can be transported using existing technology (chemical tankers etc.)	Can be transported using existing technology (chemical tankers etc.)	Domestic distribution is Widely spread on an industrial scale
Issues facing expanded usage	**Development of dehydrogenation equipment / direct use technology**	**Reduction of energy loss in hydrogen separation**	**Development of large-volume cryogenic transportation technology**

*Estimated by Kawasaki with reference to Agency for Natural Resources and Energy's "Direction of Hydrogen-Related Projects Research and Development as well as Full Implementation," April 2021 edition, etc.