



Industrial Applications for Hydrogen

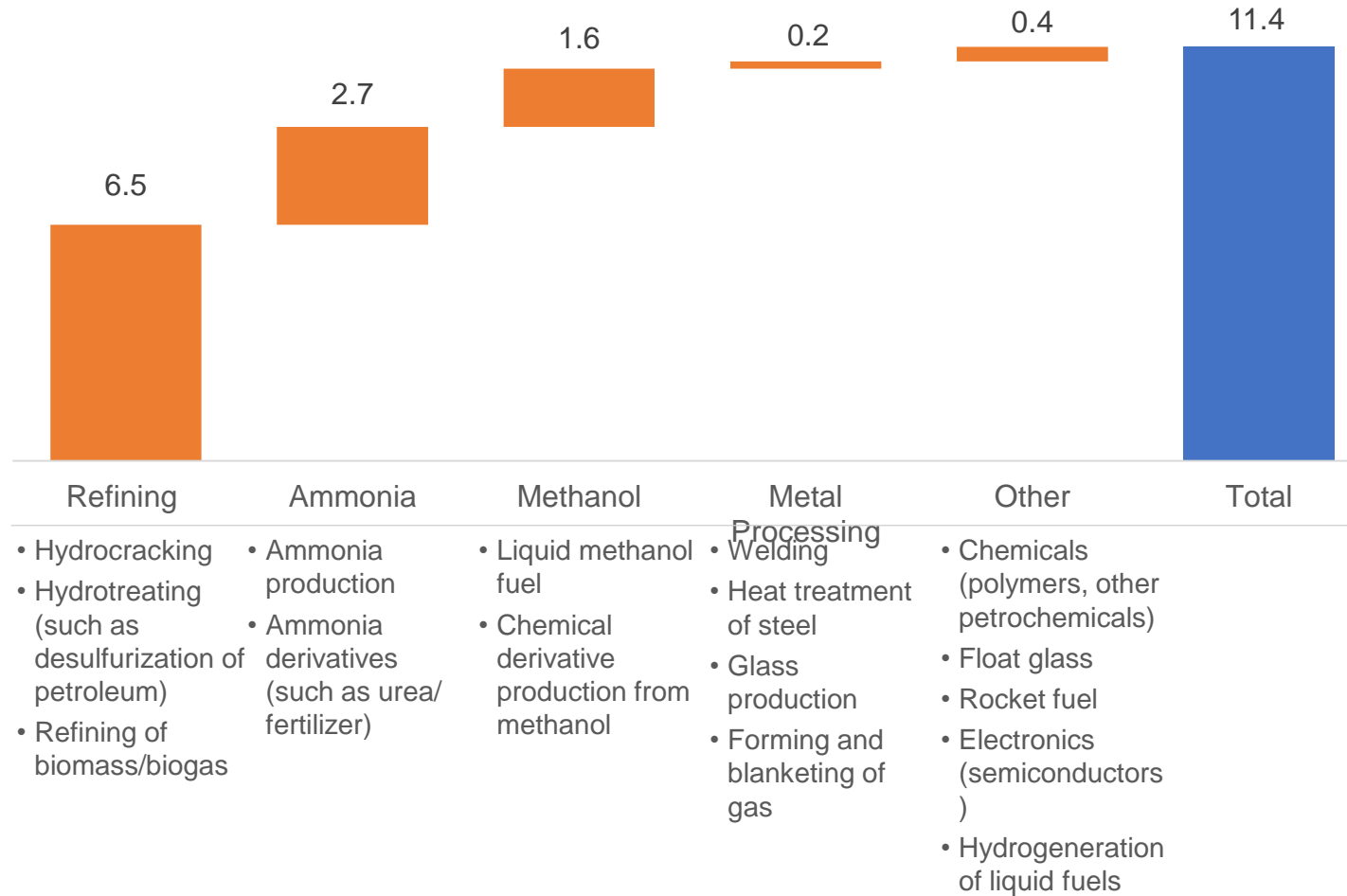
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Industrial Applications for Hydrogen – Key Conclusions

- **Substantial Industrial Applications Market Opportunity for Hydrogen:** Potential available industrial market for hydrogen is over 4x the current industrial market and will likely exceed the potential available market for energy storage, renewable natural gas and transportation
- **From Feedstocks to Fuels and New Integrated Processes:** While hydrogen is used primarily today as a feedstock in oil refining and chemicals manufacturing, it is likely to have applications in the future as a zero or low carbon industrial fuel or as an input into integrated manufacturing processes (such as steel manufacturing).
- **New Applications Considered “Hard to Abate”:** While hydrogen can be a drop-in fuel replacement for coal or natural gas in some applications (like aluminum or glass), larger opportunities in cement and steel will require an entire manufacturing process re-design.
- **Gulf Coast Well Positioned as an Industrial “Hydrogen Hub”:** Given the presence of industrial manufacturing facilities and hydrogen production, the Gulf Coast is well positioned to become a hydrogen hub. It could even attract new industries, such as a decarbonized steel industry.

Current Industrial Applications for Hydrogen

Total hydrogen use in U.S.
Million metric tons per year



Source: Roadmap to a U.S. Hydrogen Economy, Fuel Cell and Hydrogen Energy Association



Hydrogen's Role in Industrial Decarbonization Strategies

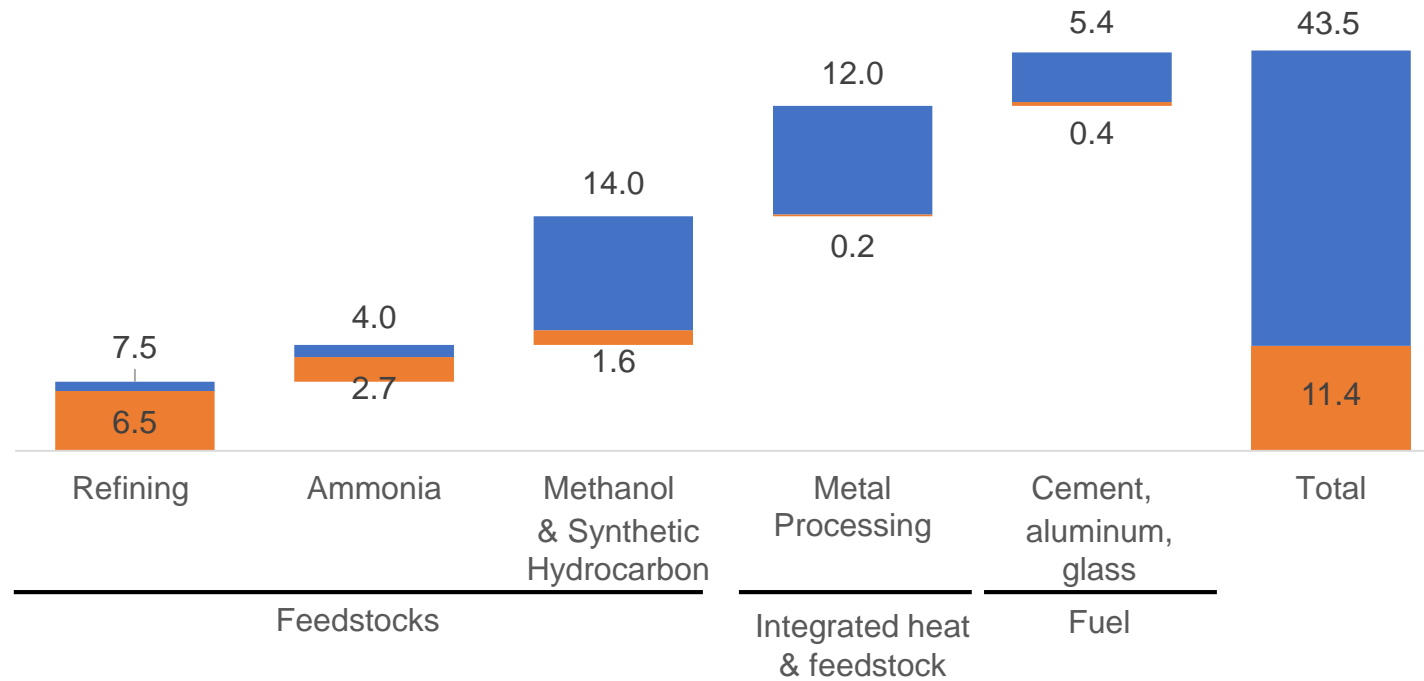
Target	Type	Decarbonation Strategies	Rationale
Fuel (e.g. industrial high temperature heat application)	Cement	Hydrogen or CCUS	<ul style="list-style-type: none"> Hydrogen could substitute for fossil fuels to reduce heat emissions CCUS could capture post combustion emissions
	Aluminum	Use hydrogen for aluminum recycling	<ul style="list-style-type: none"> Substitute hydrogen for natural gas on recycling operations
	Glass	Use hydrogen as a fuel for glassmaking	<ul style="list-style-type: none"> Substitute hydrogen for natural gas on recycling operations
Integrated Heat and Feedstocks (e.g. Steel and Iron Production)	Blast Furnace – Basic Oxygen Furnace	Hydrogen inappropriate given the role of coal in the process	<ul style="list-style-type: none"> N/A
	Direct Reduction/Arc Furnace	Green or Blue Hydrogen	<ul style="list-style-type: none"> Decarbonized hydrogen can reduce emissions from natural gas or coal
Feedstocks: Oil and Chemical Production	Oil Refining	Blue (SMR + CCUS) or Green	<ul style="list-style-type: none"> Decarbonize existing oil refining processes
	Ammonia Production	Blue (SMR + CCUS) or Green	<ul style="list-style-type: none"> Substitute low carbon hydrogen for gray hydrogen
	Methanol Production	Low benefit	<ul style="list-style-type: none"> Emissions are retained during the production process
	Synthetic Hydrogen	Hydrocarbon methanol to gasoline	<ul style="list-style-type: none"> React hydrogen & CO2

Source: Roadmap to a U.S. Hydrogen Economy, Fuel Cell and Hydrogen Energy Association, NREC, Technical & Economic Potential, H2@Scale; RFF Decarbonized Hydrogen in the US Power & Industrial Sectors



Serviceable Consumption Potential for Industrial Applications for Hydrogen

Million metric tons per year

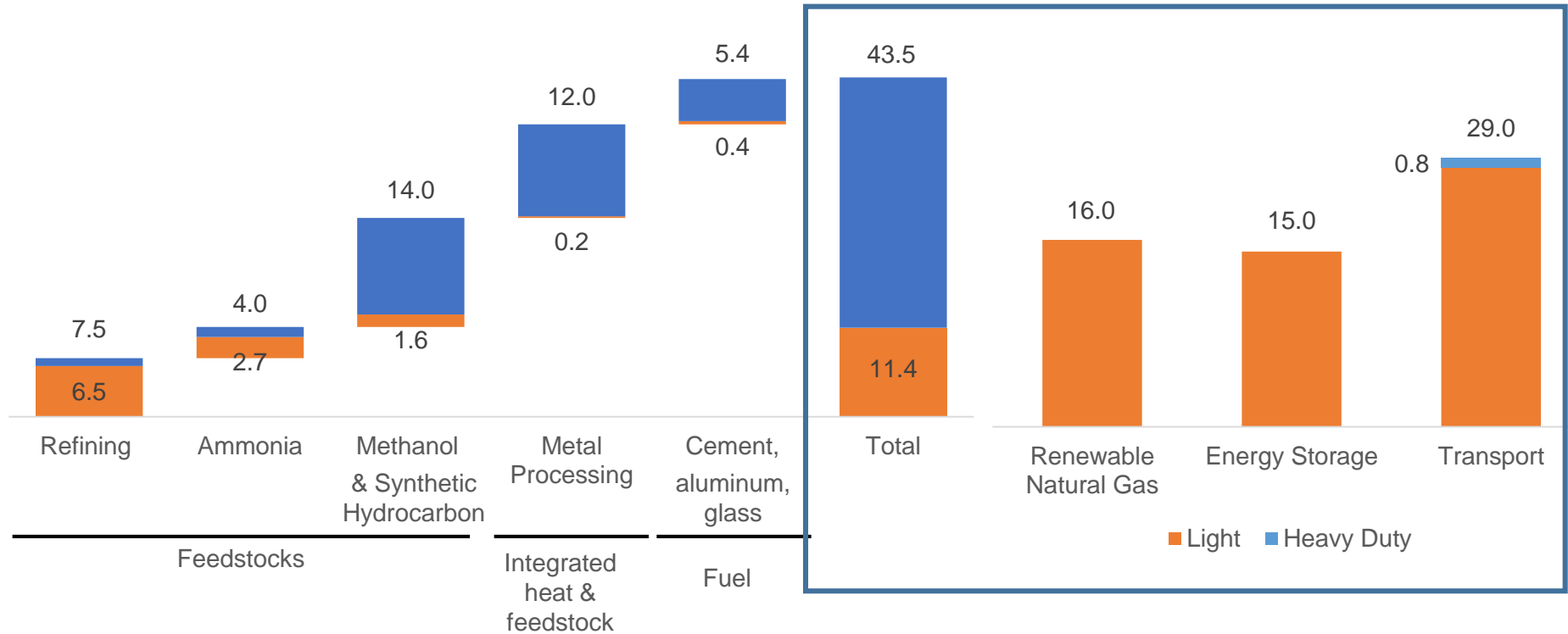


Source: Roadmap to a U.S. Hydrogen Economy, Fuel Cell and Hydrogen Energy Association, NREC, Technical & Economic Potential, H2@Scale; RFF Decarbonized Hydrogen in the US Power & Industrial Sectors



Industrial Markets vs. Other Markets for Hydrogen

Million metric tons per year



Source: Roadmap to a U.S. Hydrogen Economy, Fuel Cell and Hydrogen Energy Association, NREC, Technical & Economic Potential, H2@Scale; RFF Decarbonized Hydrogen in the US Power & Industrial Sectors



Locations for Serviceable Consumption for Industrial Hydrogen Applications

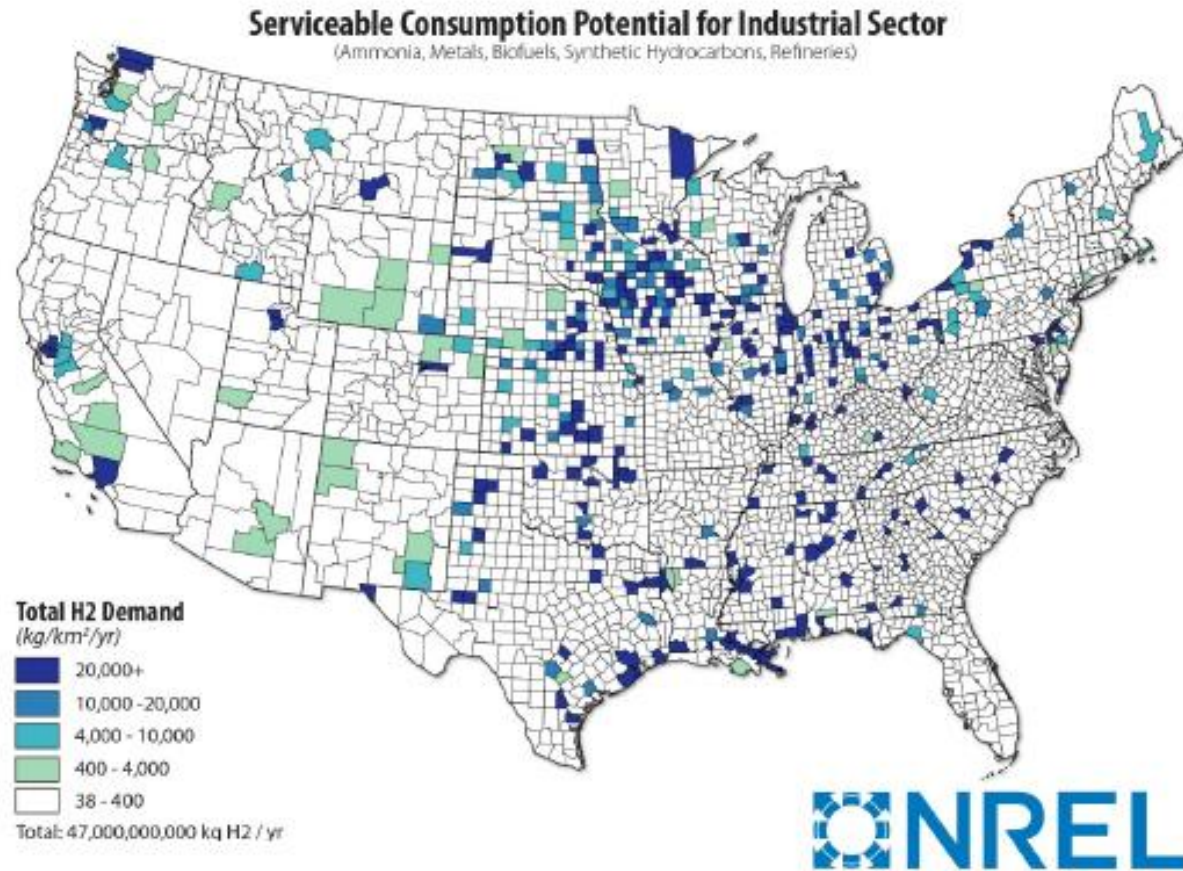


Figure 18. Locations of aggregated serviceable consumption potentials for industrial hydrogen applications

Industrial applications include oil refining, metals refining, ammonia, biofuels, and synthetic HC.

