Ammonia Safety in End Use Applications

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Low-Carbon Resources Initiative

FOCUS

Multiple options and solutions to establish viable low-carbon pathways

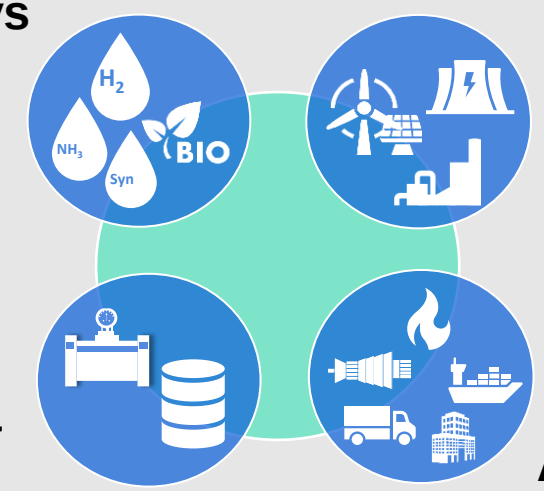
Technologies for hard-to-decarbonize areas of the energy economy

Affordable, reliable, and resilient integrated energy systems for the future

RESEARCH AREAS

Hydrogen **Ammonia** **Synthetic/ Derivative Fuels** **Biofuels**

Production Pathways



Integrated Energy Systems

Storage & Delivery

End Use Applications

VALUE

Independent, objective research leveraged by global engagement and collaboration

Comprehensive approach to low-carbon value chain and technology analyses

High-impact results from technology evaluations, and safety, environmental, and economic assessments

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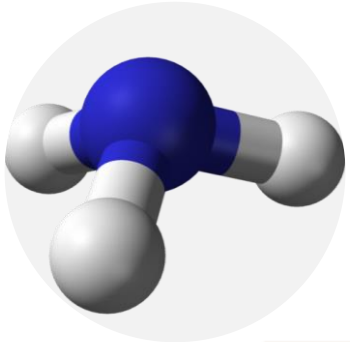
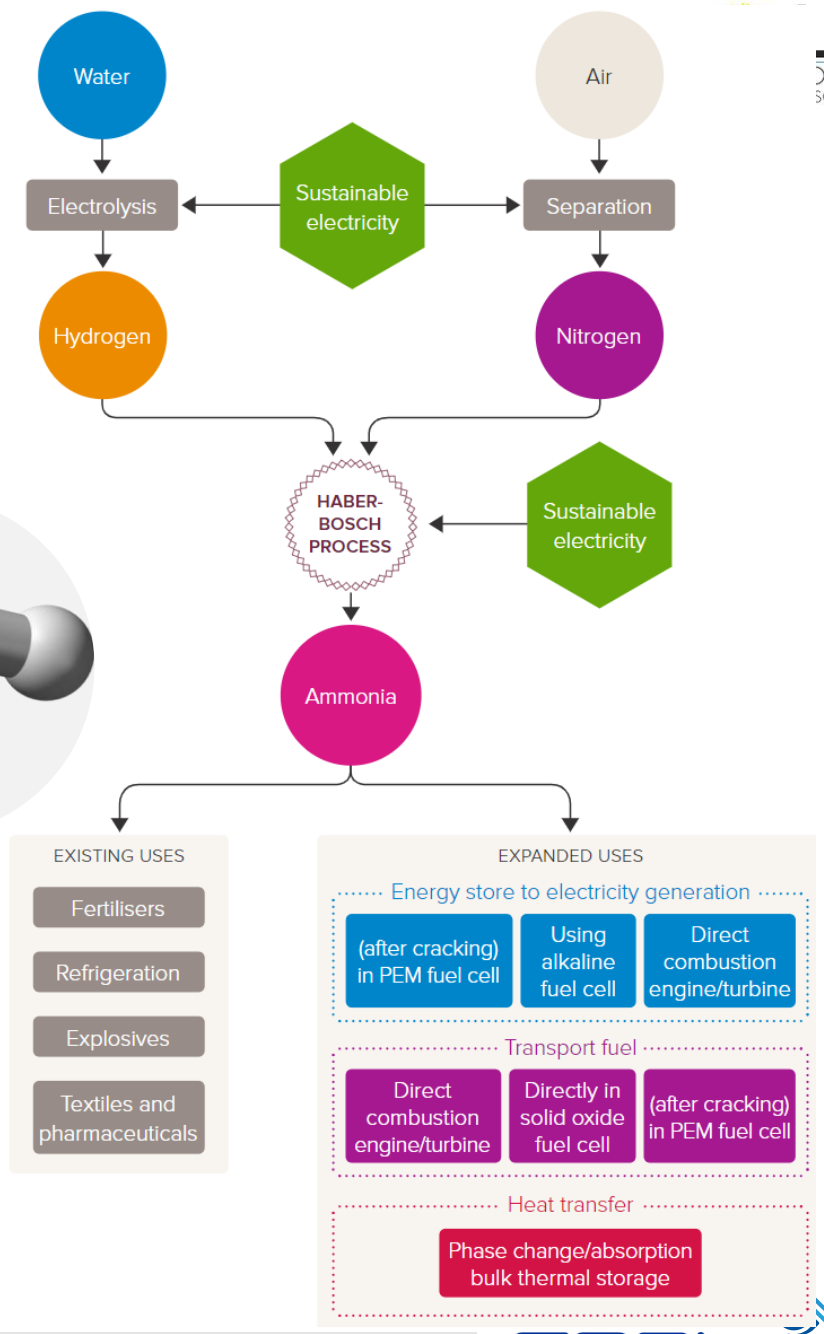
End Use Ammonia Applications

Looking Toward a Decarbonized Economy

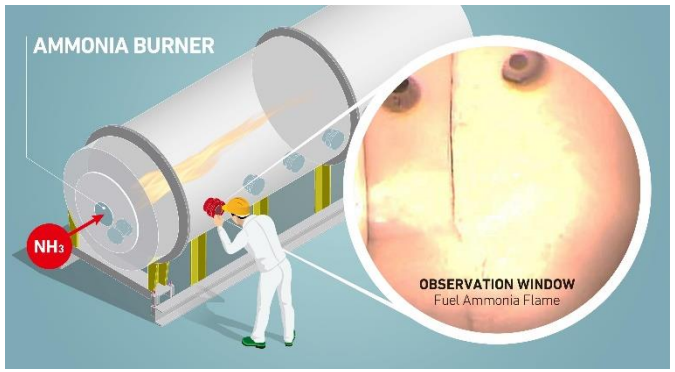
Due to ammonia's unique properties, a high level of safety is needed to responsibly establish new applications.





LCRI End Use Focus Areas

Combustion for Process Heat



Maritime Transport Fuel

General Ammonia Safety

		Ammonia Summary Table
		• Low flammability • Toxic • Low pressure transport and storage
	Maturity/Analogues	Fully mature value chain for incumbent uses.
Safety and Health	Fire	Low flammability: flammable between 15 and 28% by volume in air, auto-ignition occurs at 651.1°C (1204°F).
	Explosion	Can explode if ignited; pressurized containers of ammonia can explode under high heat.
	Leak Propensity	Not difficult to contain; leaks can be readily detected with sensors and/or by odor (150 ppm).
	Detection	Colorless gas at room temperature, strong pungent odor; detection before injury is dependent upon exposure concentration, rate of release (in case of leak), and availability of detection equipment.
	Temperature and Pressure	Transported and stored at room temperature and moderate pressure.
	Reactivity	Strongly reacts with hypochlorites, halogens, acids, and reducing agents.
	Toxicity	Toxic
	Asphyxiation	In enclosed areas, 2500 to 4500 ppm fatal in 30 minutes.
	Long-term Exposure	Not an issue at concentrations below 100 ppm; some evidence that long-term exposure to higher concentrations can result in chronic respiratory irritation.
Environment	Water and Land	Might contaminate ground water; toxic to aquatic ecosystems.
	Climate Impact	No global warming potential; however, N_2O is formed in the combustion of ammonia and ammonia uptake by secondary organic aerosols in the atmosphere can form brown carbon.
	Criteria Pollutants	Might generate incremental NOx when combusted.

Ammonia Release Incident, Millard Refrigerated Services, Theodore, Alabama, USA

Engineering Controls:
- Interlocked ammonia detectors in high-risk areas
- Ventilation systems and emergency wash stations
- Appropriate/compatible materials & equipment

Administrative Controls:
- Educate workers on ammonia risks & safe practices
- Limit time in ammonia areas; trained operators ONLY
- Procedures: operations, maintenance, and emergency response
- Regulatory requirements, e.g., OSHA PSM

Personal Protective Equipment:
- Gloves, clothing, goggles/face shields, NIOSH respirators

Safety knowledge from existing industries can be leveraged for new applications.

Conclusions

Key Findings

Ammonia spills: toxic, fire risks, weather-dependent, water management impact.

Ammonia exposure: symptoms vary by concentration, from mild to severe.

Controls: air monitoring, emergency response, respiratory protection.

Ammonia storage safeguards: prevent corrosion, stress, overheating, incompatible materials.

Ammonia incidents: often from uncontrolled releases, human error, equipment failure.

Knowledge Gaps

Ammonia combustion in process heat systems lacks formal risk assessments and mitigation strategies, despite insights from established applications.

Maritime transport safety guidance is more developed, but limited real-world experience with ammonia-fueled vessels limits its applicability.

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