TEAM

047

Green Ammonia Production and its Utilization as Sustainable Aviation Fuel

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CHE

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Introduction/Background

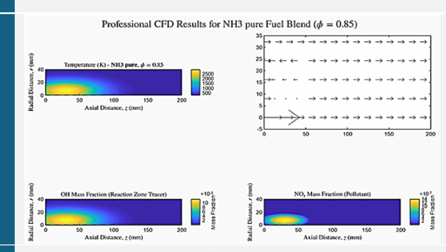
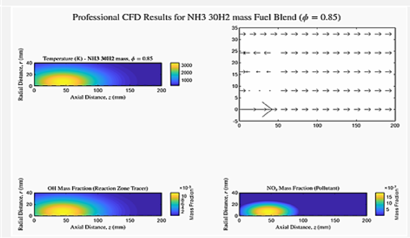
Aviation still relies on high-emission fossil fuels, and current alternatives cannot meet its energy and safety demands. This project develops a renewable-powered green ammonia production system and evaluates its feasibility as a sustainable aviation fuel, featuring a demonstration prototype and supporting Saudi Arabia's Vision 2030 clean-energy and innovation goals for future sustainable progress.

Constraint	Requirement
Budget	≤ **7,200 SAR**
Prototype Size	**1 × 1 × 1 m³** limit
Safety	No high-pressure or high-temperature use in prototype
Energy Source	Must operate on **renewable energy** (solar)
Environment	**Near-zero greenhouse gas** emissions
Time	Complete project within **one semester**

Specification	Target
Ammonia Purity	≥ **95%**
Production Rate	**200–300 MT/day** (simulation basis)
Reactor Conditions	**400–500 °C, ~150 kg/cm²**
Storage Conditions	**20–25 °C, 10 kg/cm²**
Renewable Fraction	> **90%** solar energy
Electrolyzer Efficiency	> **60%**

Prototype Design

Testing / Validation

Category	Pure NH3	NH3-H2 (70%:30%)	Key Advantages of the Blend
Energy Density LHV	18.6 MJ/kg	49.0 MJ/kg	2.63× more energy per kg → stronger combustion
AFR	1:12.2	1:14.52	H_2 is highly energetic
T_{flame} (Tad)	2000 – 2050 K	2350 – 2600 K	Higher temperature → more efficient burn
Fuel Mass Per 1 KWh	High	60 – 65 % lower	Huge weight reduction for aviation applications
Safety & Storage	Toxic, pungent, corrosive; stored as liquid ammonia	More complex (ammonia toxicity + hydrogen flammability)	Requires gas detection, high-integrity piping, and safety systems
Example of CFD Results			The CFD results clearly demonstrate improved flame stability and lower ammonia slip with the blended fuel, H_2 dramatically improves stability
NOx Emissions	Low	Higher	Due to higher Tad → can be reduced using lean burn
CO2 Emissions	0% (carbon-free)	0% (carbon-free)	Same climate benefit → 100% CO_2 reduction vs Jet-A

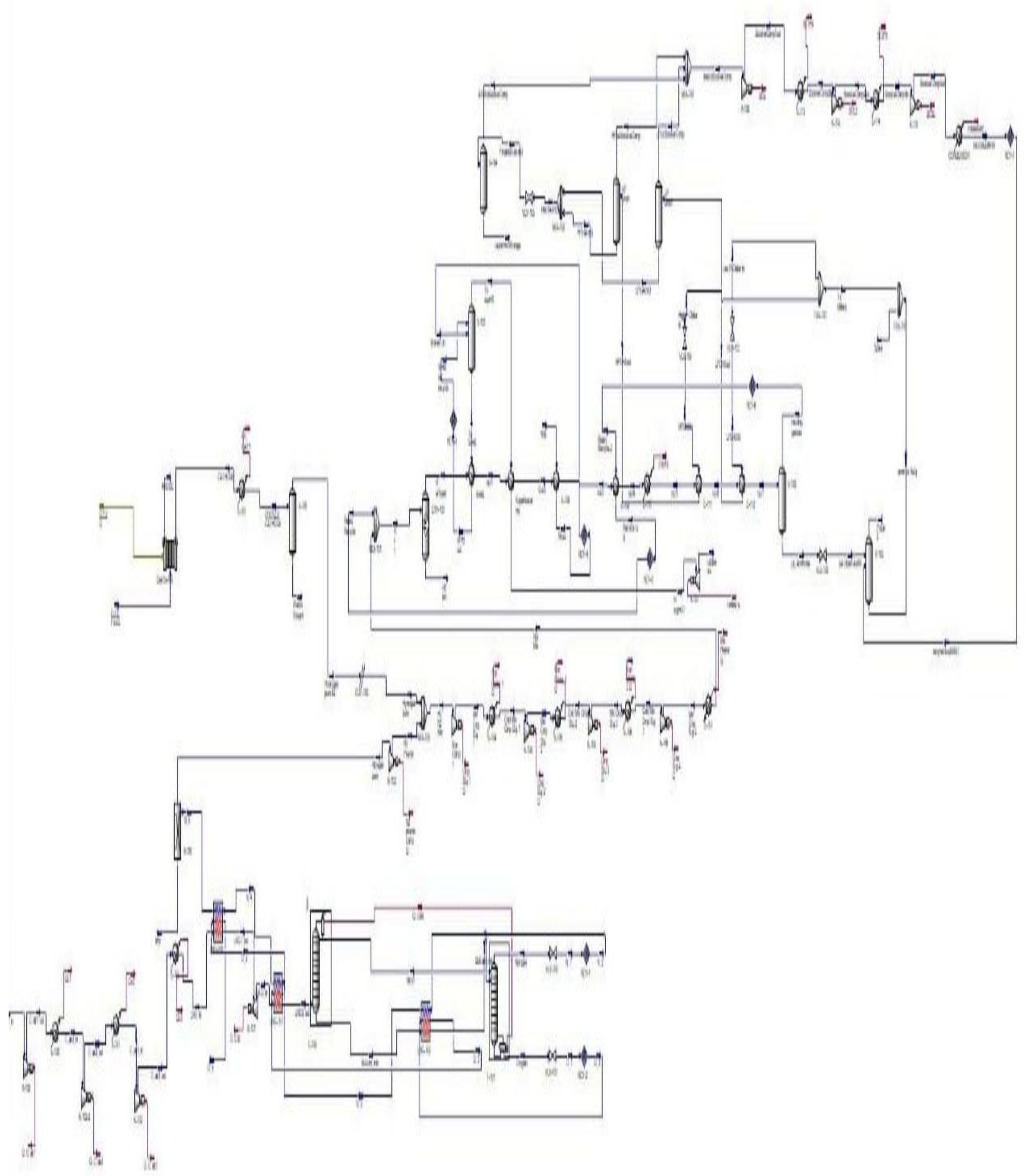
Risk Assessment

Assessment method	5×5 risk matrix (Severity × Likelihood) applied to main process units.
Risk response	High risks require engineered mitigation, Medium risks require control and monitoring, and Low risks basic monitoring.

Procecss unit	Hazard	Score	Key Controls
Electrolyzer (H2)	H_2 leak	≈ 15 (High)	Leak detection, forced ventilation, electrical grounding
Reactor (High-T)	Loss of cooling	≈ 12 (High)	Temperature monitoring, shutdown interlocks
Synthesis Loop (High-Pressure NH_3)	Pressurized NH_3 release	≈ 10 (High)	Rated components, double isolation, PSV venting
Storage & Handling (NH_3)	Tank over-pressure, valve/line failure during storage or transfer	≈ 12 (High)	PSV, level alarms, controlled filling %, periodic inspection, emergency isolation valves, ventilation strategy

Techno-Economic Analysis & Comparison

Category	Green Ammonia (Designed System)	Typical Fossil Ammonia
Production Capacity	~250,000 kg/day NH_3	Comparable industrial scale
Energy Demand	~82 MW continuous	27–30 MW typical (no electrolysis)
Electricity Source	100% Solar (RE)	Fossil fuels / Natural gas
CAPEX	~166 M$	Lower due to mature infrastructure
Operating Cost	~0.148 $/kg (electricity + water)	Lower (fuel cost advantage)
Levelized Cost	~0.36 $/kg NH_3	~0.20–0.25 $/kg NH_3
CO2 Emissions	Zero-carbon production	Large CO_2 footprint



Conclusion

This project shows that green ammonia can be sustainably produced with renewable energy and has strong potential as a low-carbon aviation fuel. Simulations confirmed high purity and stable operation, while the prototype demonstrated process flow and safety concepts, supporting ammonia's viability for future aviation applications.