Advanced Oxygen-Free Electrolyzer for Ultra-Low-Cost H_2 Storage for Fossil Plants

For

FECM Spring R&D Project Review Meeting

Prime Recipient: T2M Global LLC

Presenters: Pinakin Patel and Ludwig Lipp

Award Number: DE-FE0032023

Sub-Recipient & Host Site: Hawaii Gas, HI

Date: 04/19/2023

Dilute Syngas to Higher Value H_2

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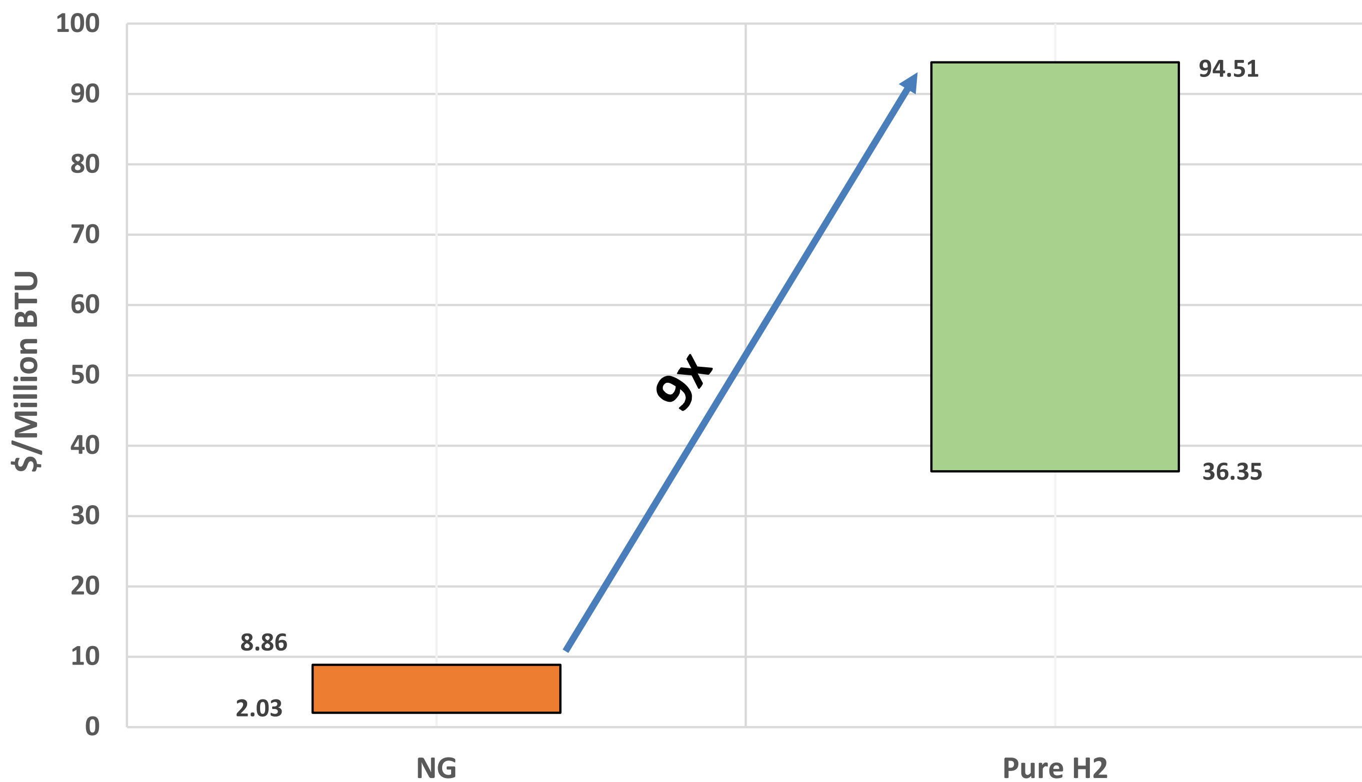

H_2 Price Premium is about 9X that of Natural Gas in USA

Hawaii Gas has ~10% H_2 in SNG pipeline – new opportunity

AES Project Overview: Key Components

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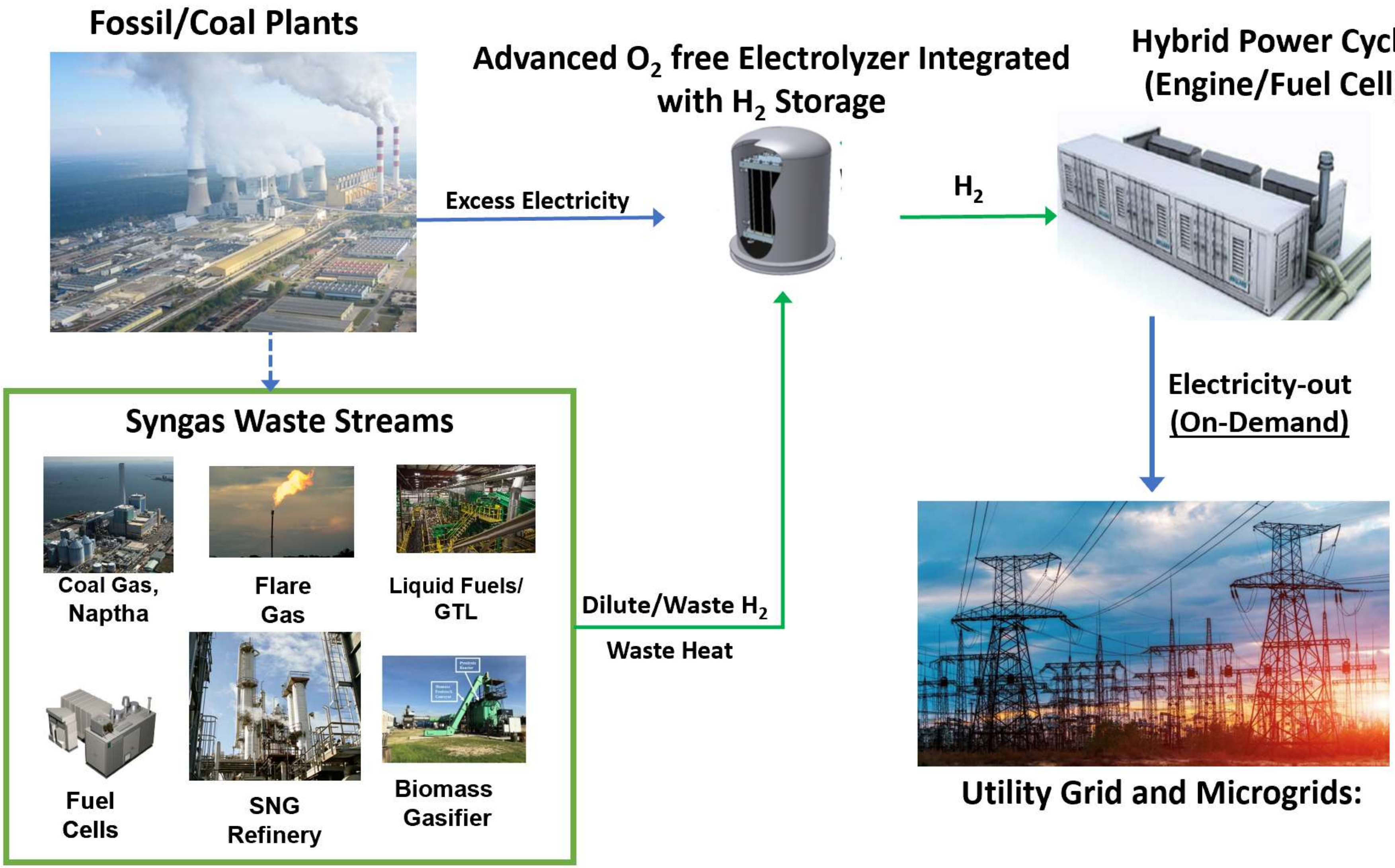

Produce Higher Value H_2 from Dilute Syngas Streams:

Extend the life of Fossil Plants – Support VRE

Milestone Status: On-track

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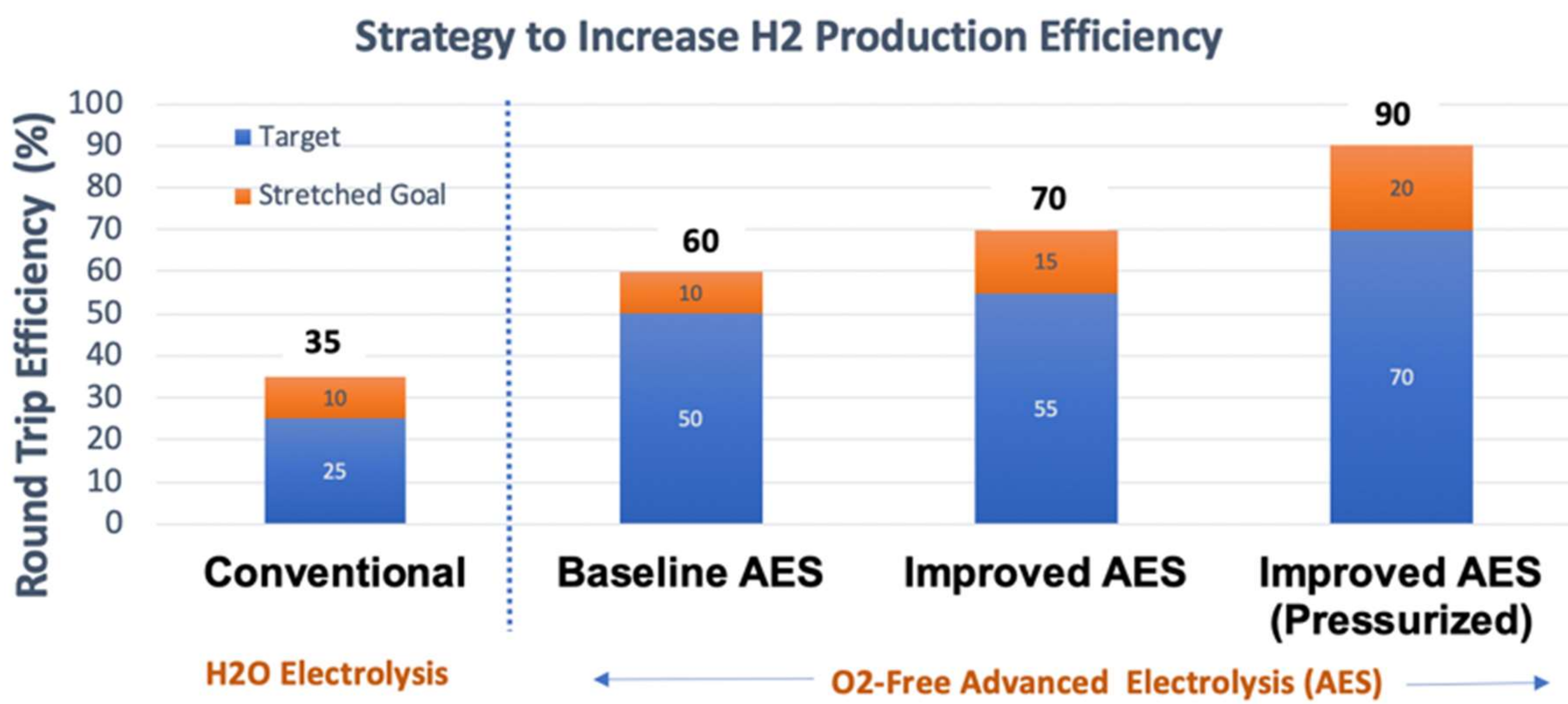
Milestone Description	Planned Completion Date	Actual Completion Date	Verification Method	Comments
Syngas streams available for AES integration at Hawaii Gas (Verify 1 ton/day recoverable H_2 is available)	07/30/2021	9/30/2021	Gas Chromatography	Completed
Stack Operation on Selected Syngas Streams (500 hr, <15 kWh/kg)	10/31/2021	11/30/2021	kWh/kg of H_2	Completed
HI Gas review of AES integration requirements and benefits for demonstration (Target: 1 ton/day H_2)	3/31/2022	4/15/2022	Strategy Document	Completed
Complete Baseline design for tall stack building block (Target: 100 kg/day, 2.4 MWh)	2/28/2023	2/28/2023	Stack Design Description	Completed
Prototype MW-class module design for Hawaii Gas (Target Capacity: 1 ton/day H_2, <1.5 MWh/ton H_2)	3/31/2023	3/30/2023	Module Design Description	Completed
Develop a Technology Maturation Plan for MW-class module (Target: 1 ton/day H_2)	6/28/2023		Strategy Document	In Progress

Advanced O_2 free Electrolyzer (AES)

- Oxygen-free AES technology offers a modular system with the safest hydrogen production and the lowest Pt-catalyst loading
- AES validated at short stack level at atmospheric pressure



AES Ideal for Fossil Plants: 2x Increase in Capacity and Efficiency for H_2 Production

Natural Gas Consumption in Hawaii: Source of Dilute H_2

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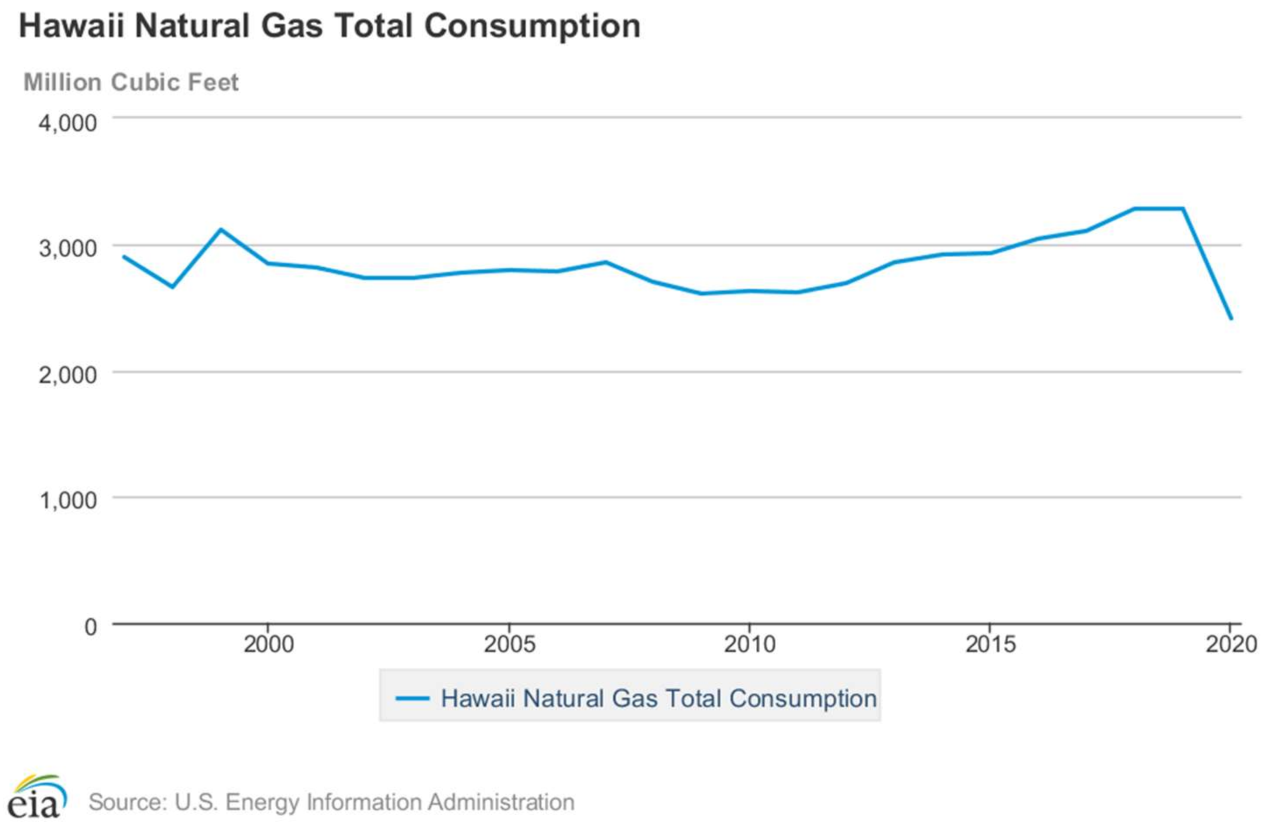

- Current consumption: 2.4 Billion cu ft/yr
- At 10% injection of H_2 in the pipeline: 240 Million cu ft H_2/yr
- At 80% recovery of H_2 from pipeline: 192 Million cu ft of H_2/yr
- Potential recoverable H_2 from pipeline storage: 506.6 ton/yr

At $5000/ton of H_2: $2.5 Million/yr of potential revenue from pipeline storage

Source: https://www.eia.gov/dnav/ng/hist/na1490_shi_2a.htm, Internal management, subject matter expert discussion and data

AES for SNG Plant at Hawaii Gas

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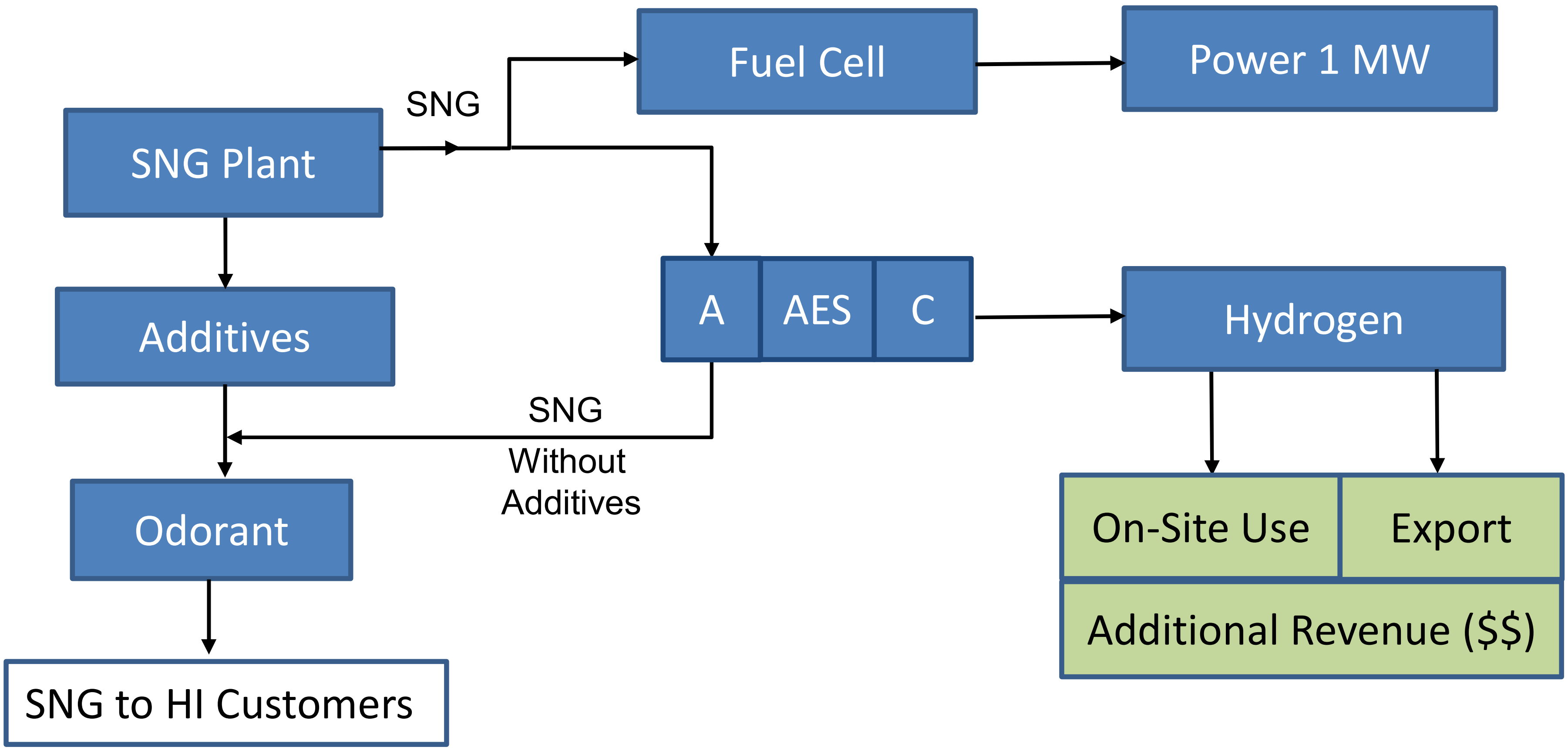

Recovered hydrogen for on-site power production:
Export hydrogen for additional revenue – Toyota, Plug Power

AES Integration with HI Gas Plant

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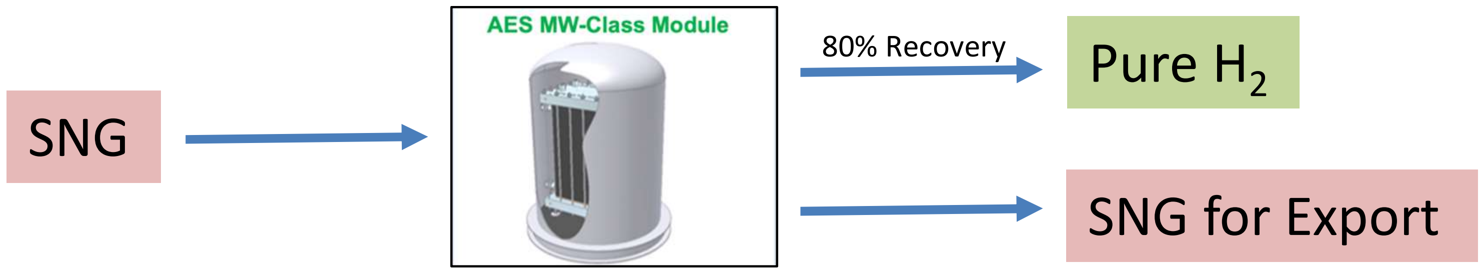

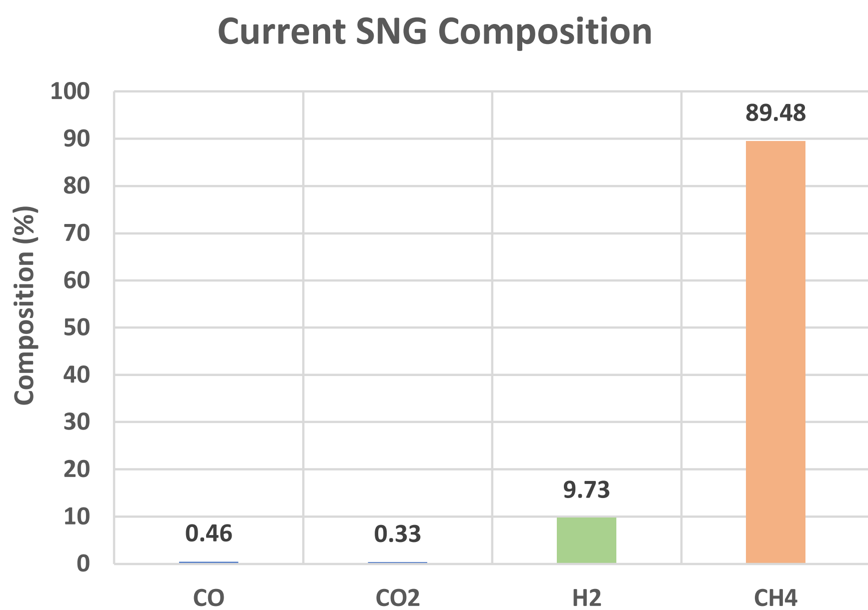

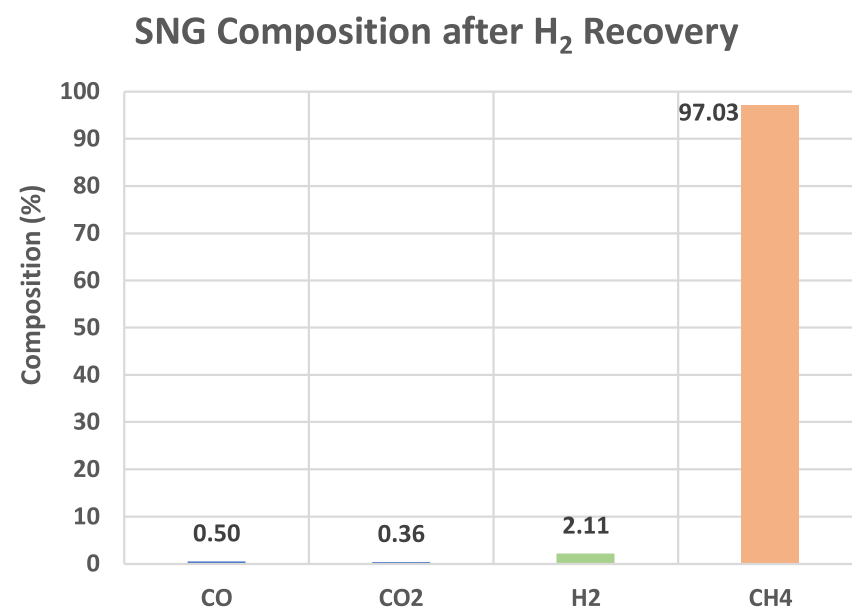

Better quality SNG for export: Eliminates expensive additives
Higher value H_2 for additional benefits

Benefits to Fossil Plant: >$5M/yr

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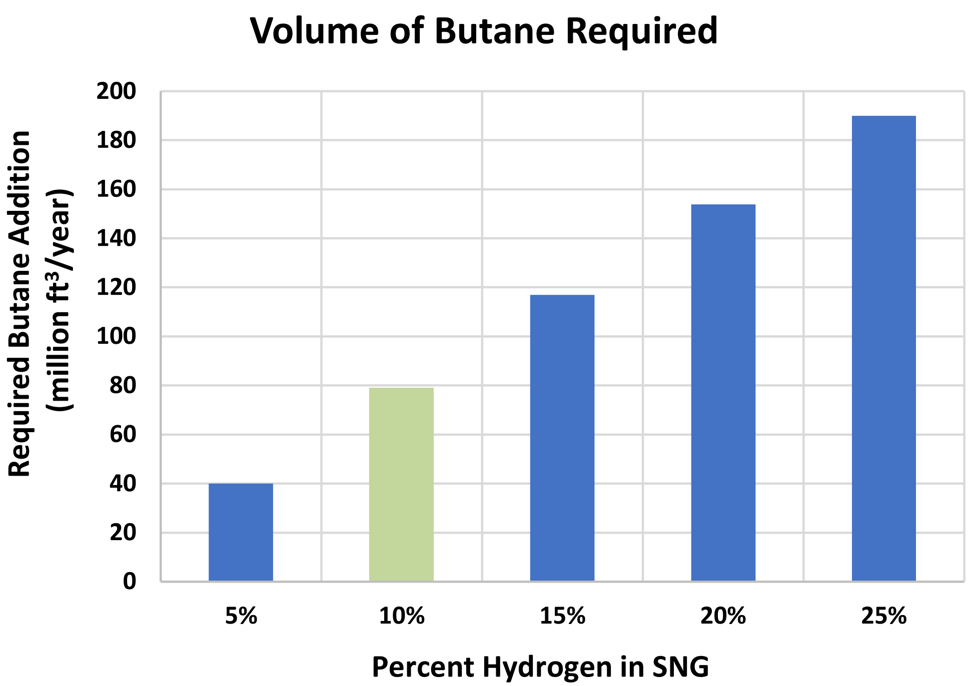
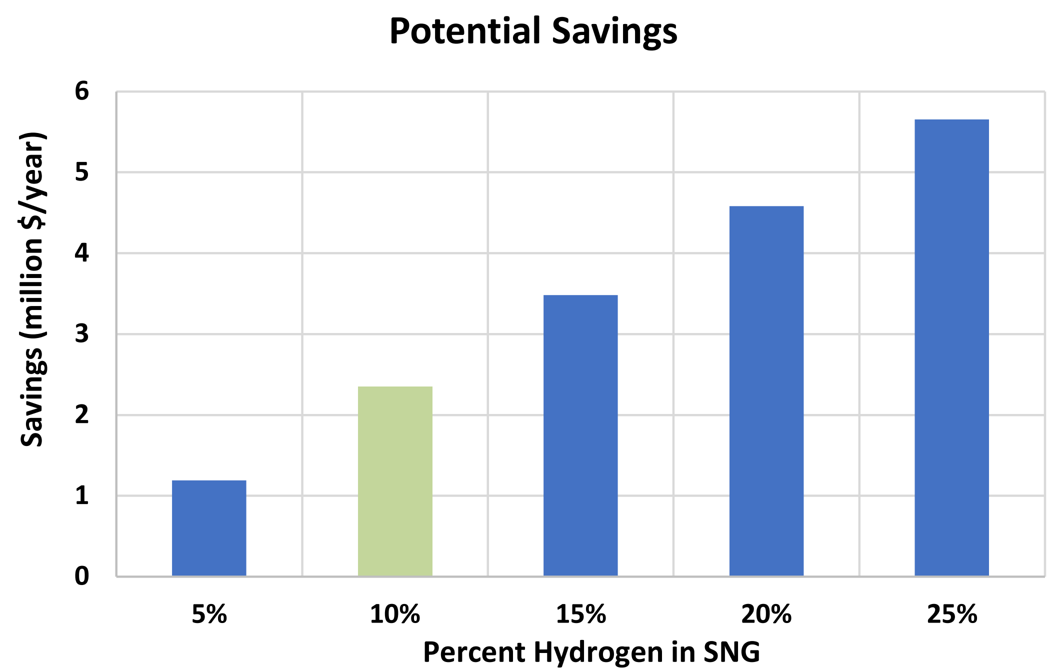
SNG Production: 3 billion ft³/yr





Reduction in additive cost: >2 million $/yr
Revenue from H_2: >3 million $/yr

Flexible H_2 Extraction

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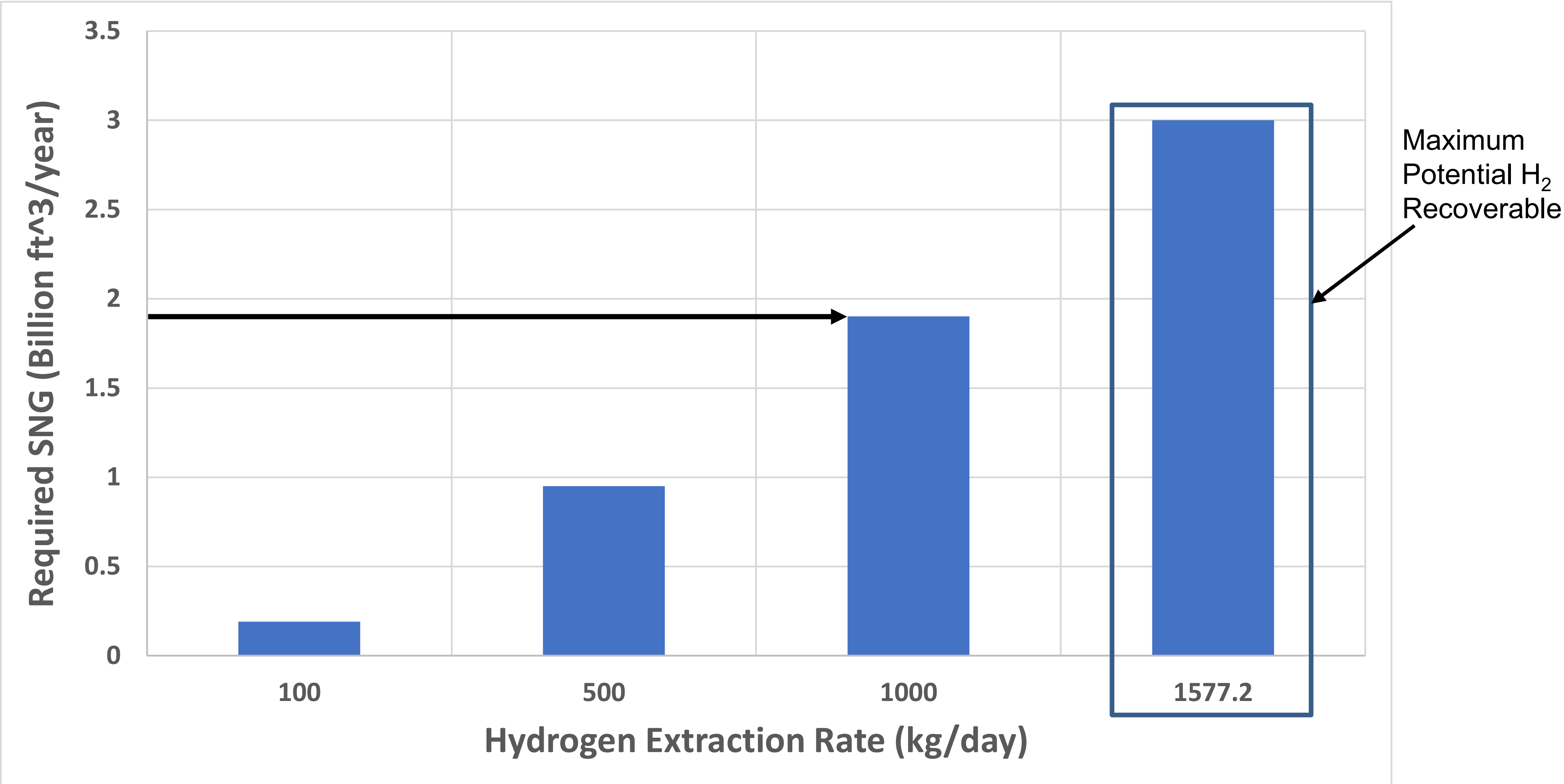

~1.9 Billion ft^3/yr of SNG is required for 1 ton/day H_2 Recovery
Reduction in >60% of additives purchased → Cost Savings, $$

H_2 from Pipeline Storage: Opportunity

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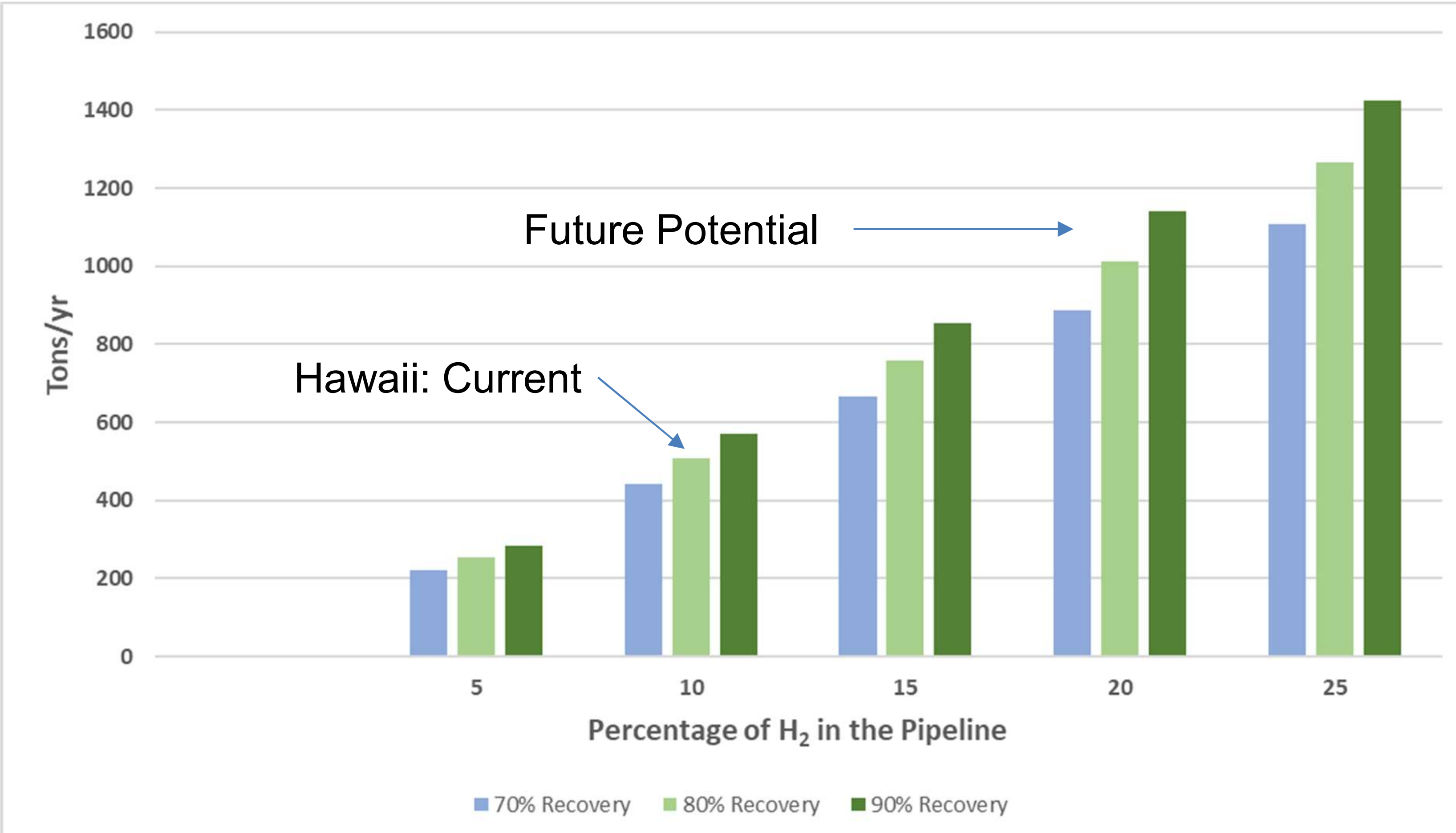

Potential for >1000 ton/yr of H_2 → >$10 million/yr revenue

Feedstocks Validated: Dilute Syngas

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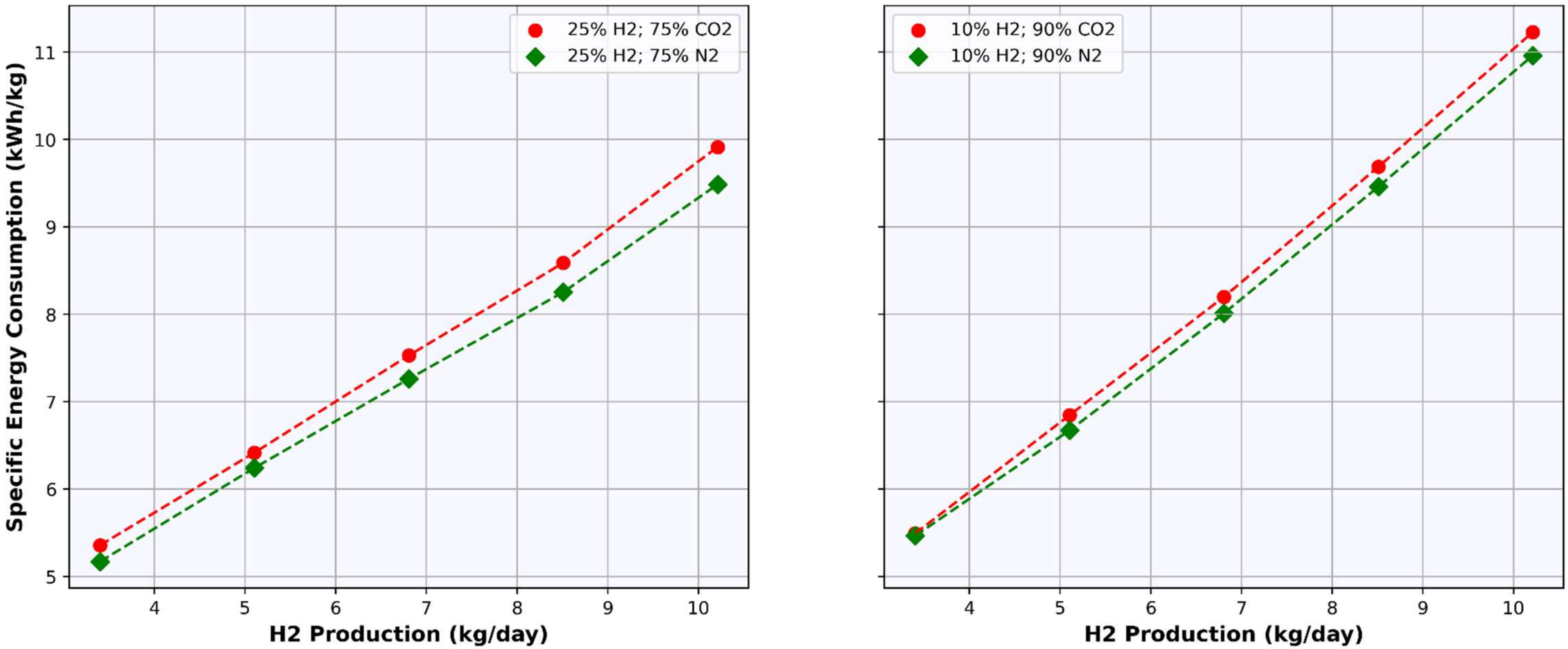

DOE Target Met: <15 kWh/kg to purify H_2
Very dilute syngas: 25% → 10% H_2 in CO_2 or N_2
TEA shows feasibility of <$4/kg in the near term

Power Consumption: Effect of Pressure

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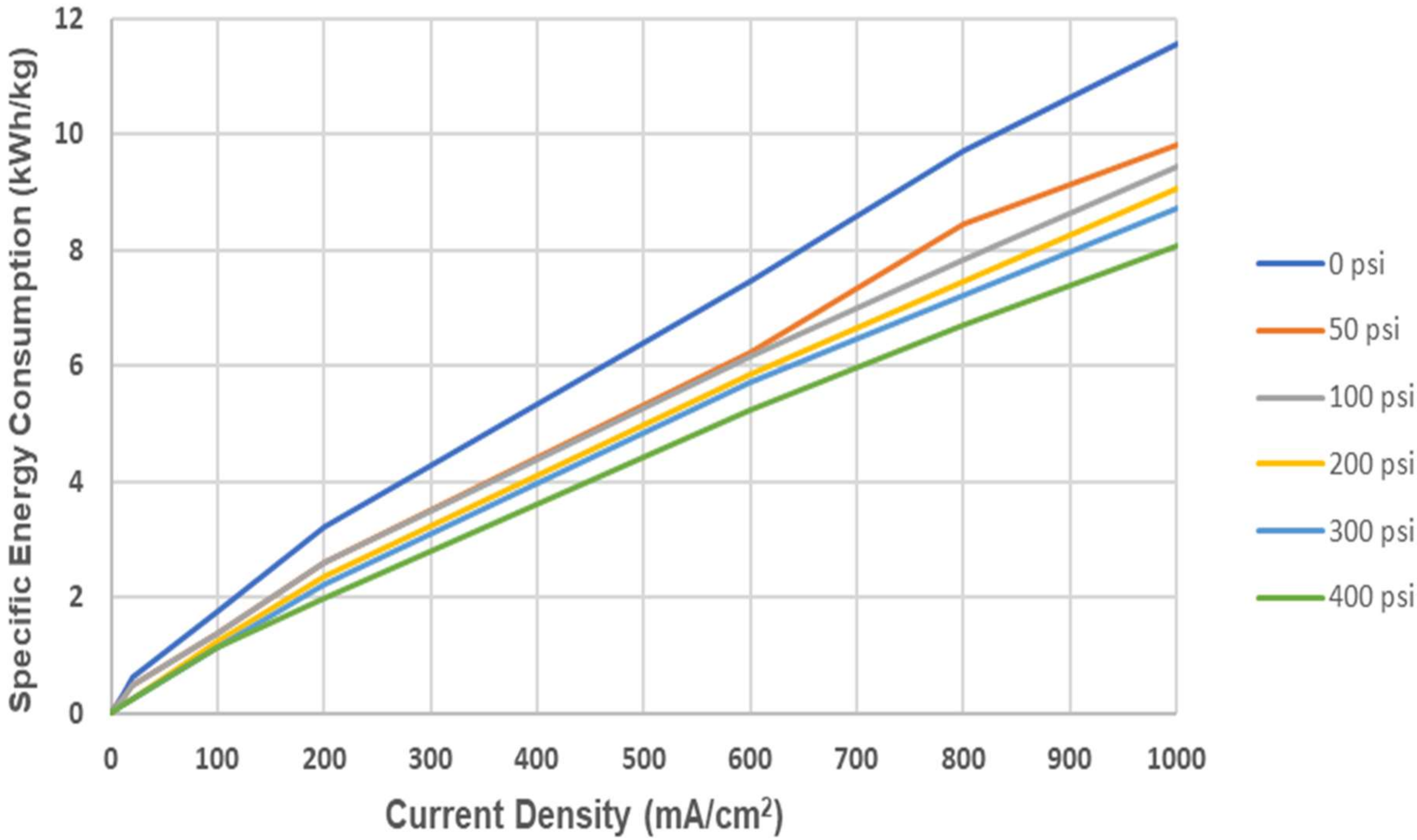

Power Consumption Decreases at Elevated Pressures:
Power requirement for SNG plant: <5 MWh/ton H_2

Electricity Requirement: Conservative

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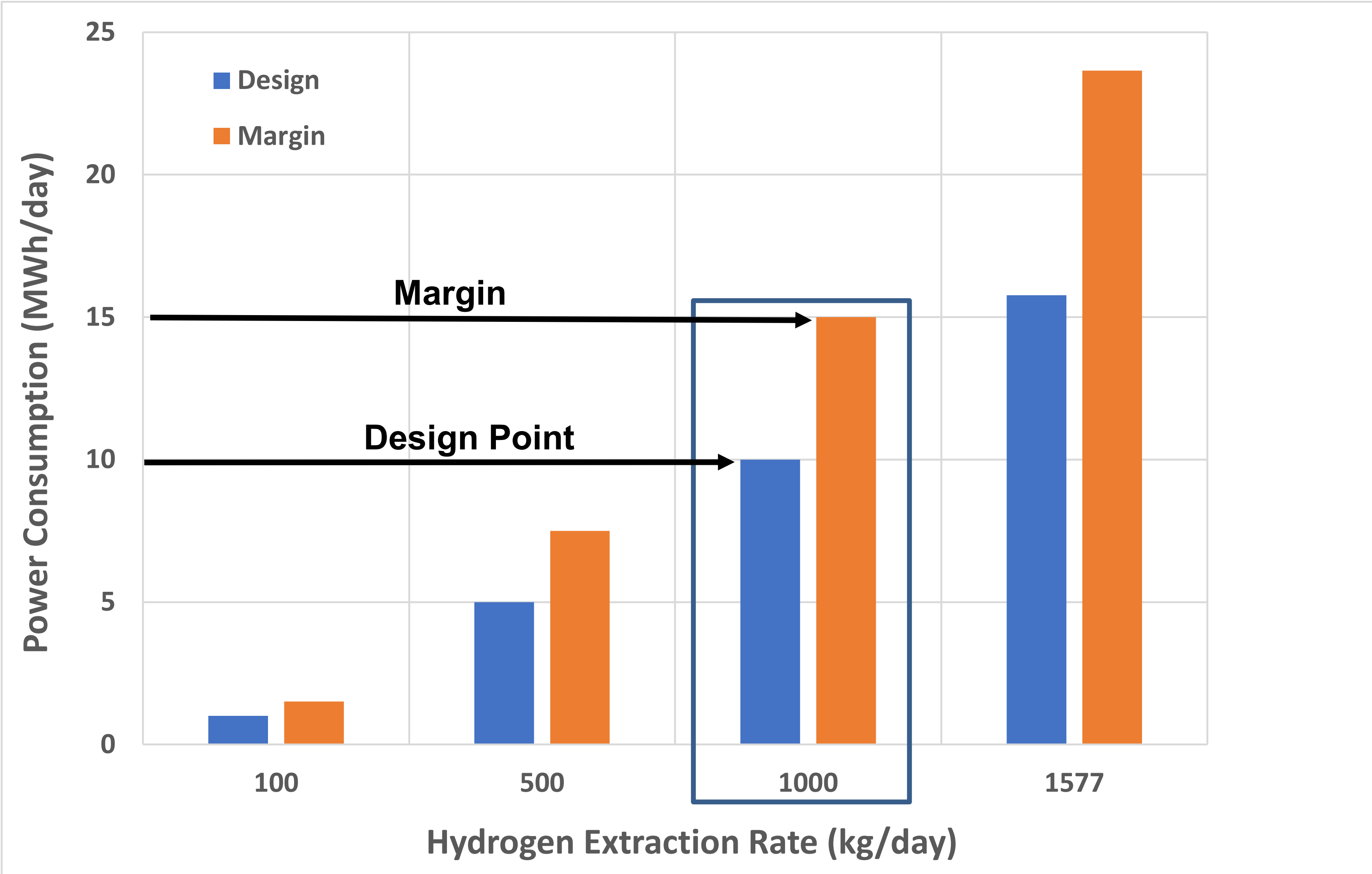
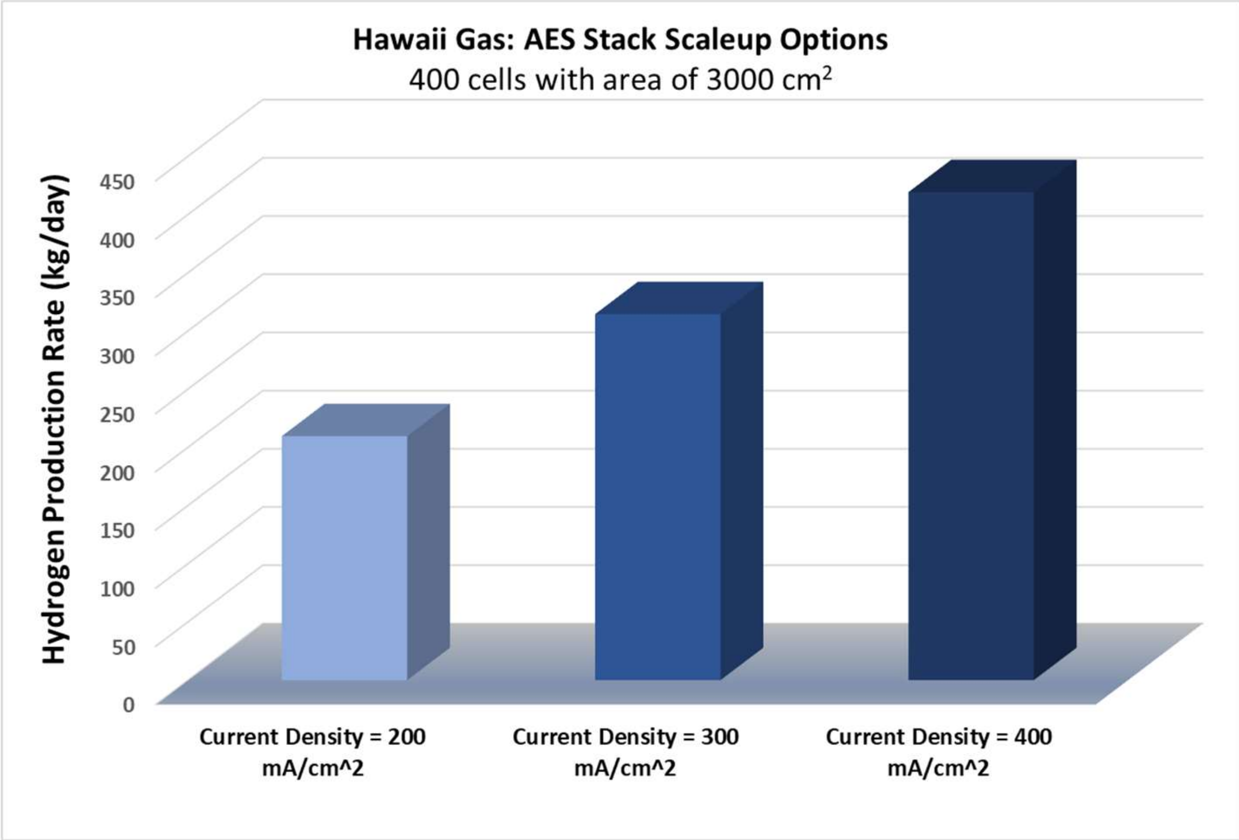


Conservative Estimate: 10 MWh/ton → Expected to Reduce at 400 psi
Energy content per ton of recovered hydrogen: 33 MWh

H_2 Capacity Scaleup: Current Density

Design consideration for increasing the current density:

- **Increased stack heat generation**
  - Requires additional cooling
  - Increases challenge of thermal management to distribute heat uniformly across each cell
  - Adds constraints to material selections
- **Tolerance Management Risks:**
  - With increase in current density, tolerance management becomes more important and complex



Higher Current Density → Beneficial → Higher Risk
Higher current density reduces CapEx, increases cooling requirements

Fuel Cell Plant in Danbury, CT

Modular plant for rapid field installation
Good example for AES design for deployment

H_2 Capacity Scaleup: Stack → Module

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Supply Chain is Critical in Capacity Scale-up
Near-term 1000 cm^2 area → Mid-term 3000 cm^2

H_2 Production with Storage

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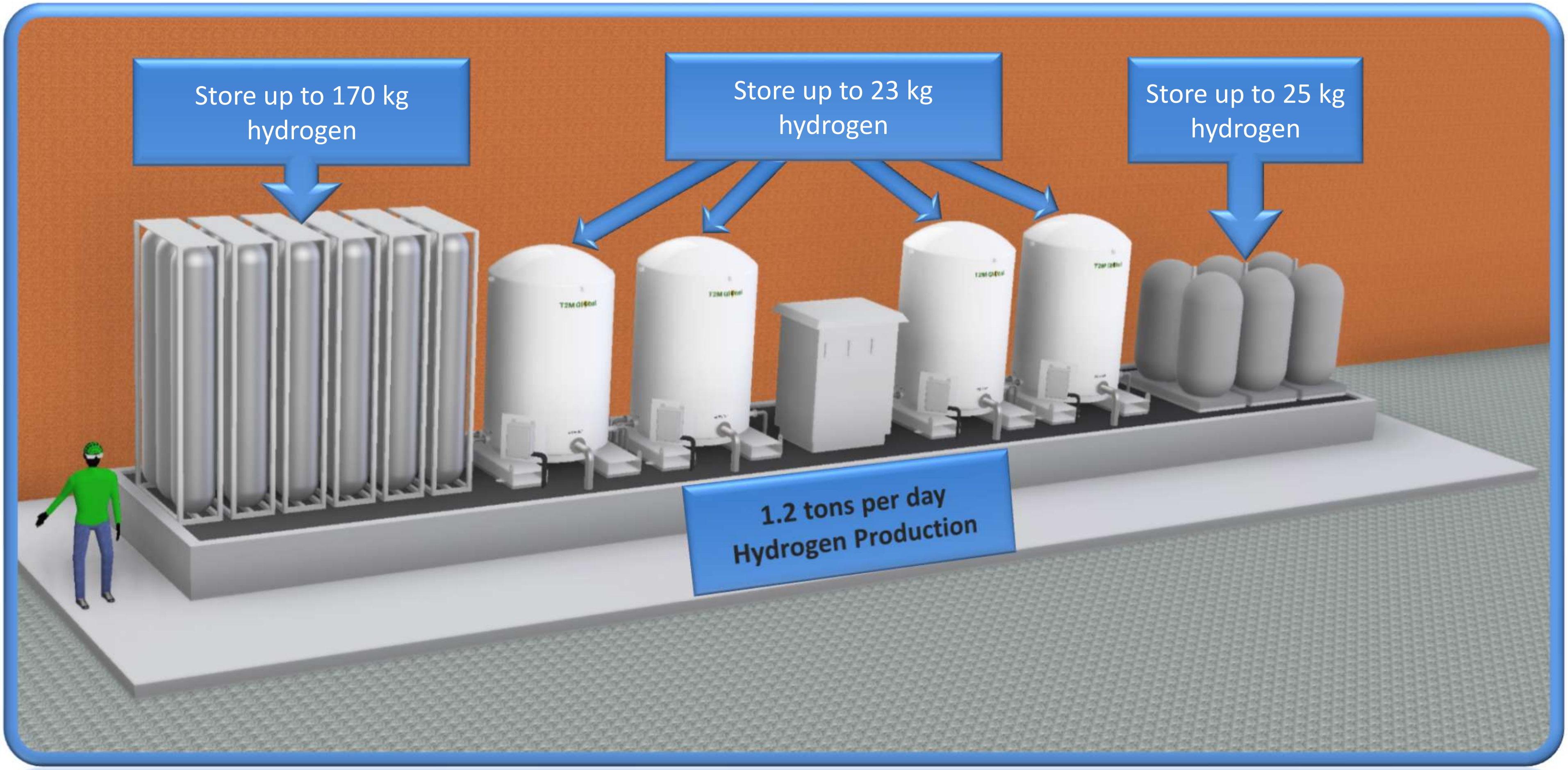

Low, Medium and High-Pressure Storage Provides Flexibility
Modularity provides easy capacity expansion

Fossil Plants: Fueling the H_2 Economy

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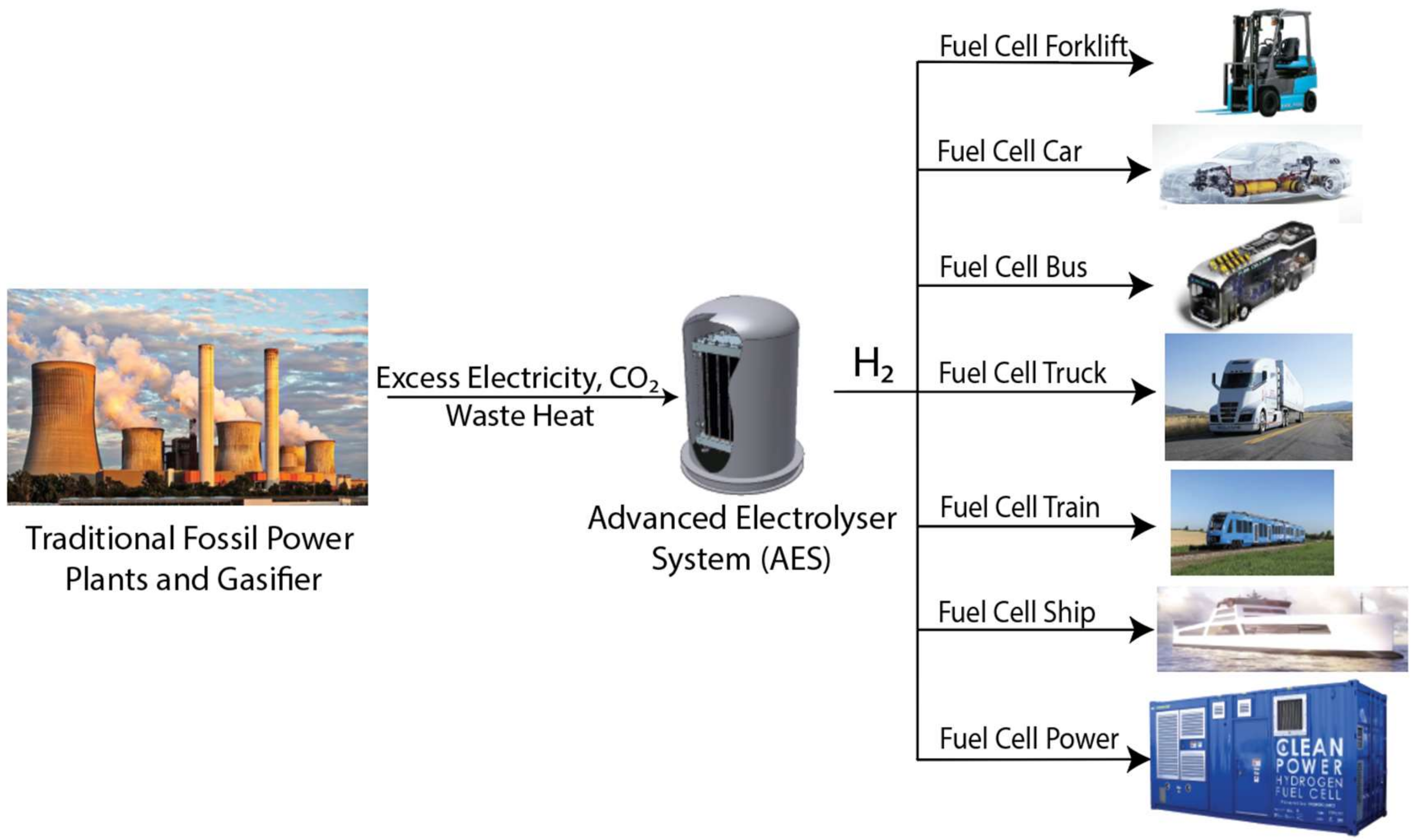
H_2 fuel cells are emerging as a multi-billion-dollar industry



Opportunity for HI Gas: Increase Value of SNG
Reduce operating cost, increase revenue from higher value

H_2 Storage: Impacts and Next Steps

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- Fossil Plants cannot load follow: H_2 is a solution → grid support market
- Application Flexibility: Higher value H_2 from different syngas streams, e.g. coal gasifiers, GTL plants, Naphtha crackers, Pet-coke, SMRs, etc.
- H_2 production without any incremental GHG emissions
- Convert excess electricity and waste heat to higher value hydrogen
- Modular and water independent system: Easier to deploy

- **Next Step: Demonstration at Hawaii Gas (1 ton/day class)**

Opportunity for FECM → $10 Billion/yr US Market
Opens pathway to DOE target for H_2: 1-1-1

Thank you!

Open for Questions

Converting Wasted Resources to Clean Energy

Pinakin Patel
www.t2mglobal.com
ppatel@t2mglobal.com