the Energy to Lead

DE-FE0031615--Hydrogen to Power (H2P)

Official Title, "A Modular Heat engine for the Direct Conversion of Natural Gas to Hydrogen and Power Using Hydrogen Turbines"

UTSR
November 1, 2018
Daytona Beach, FL

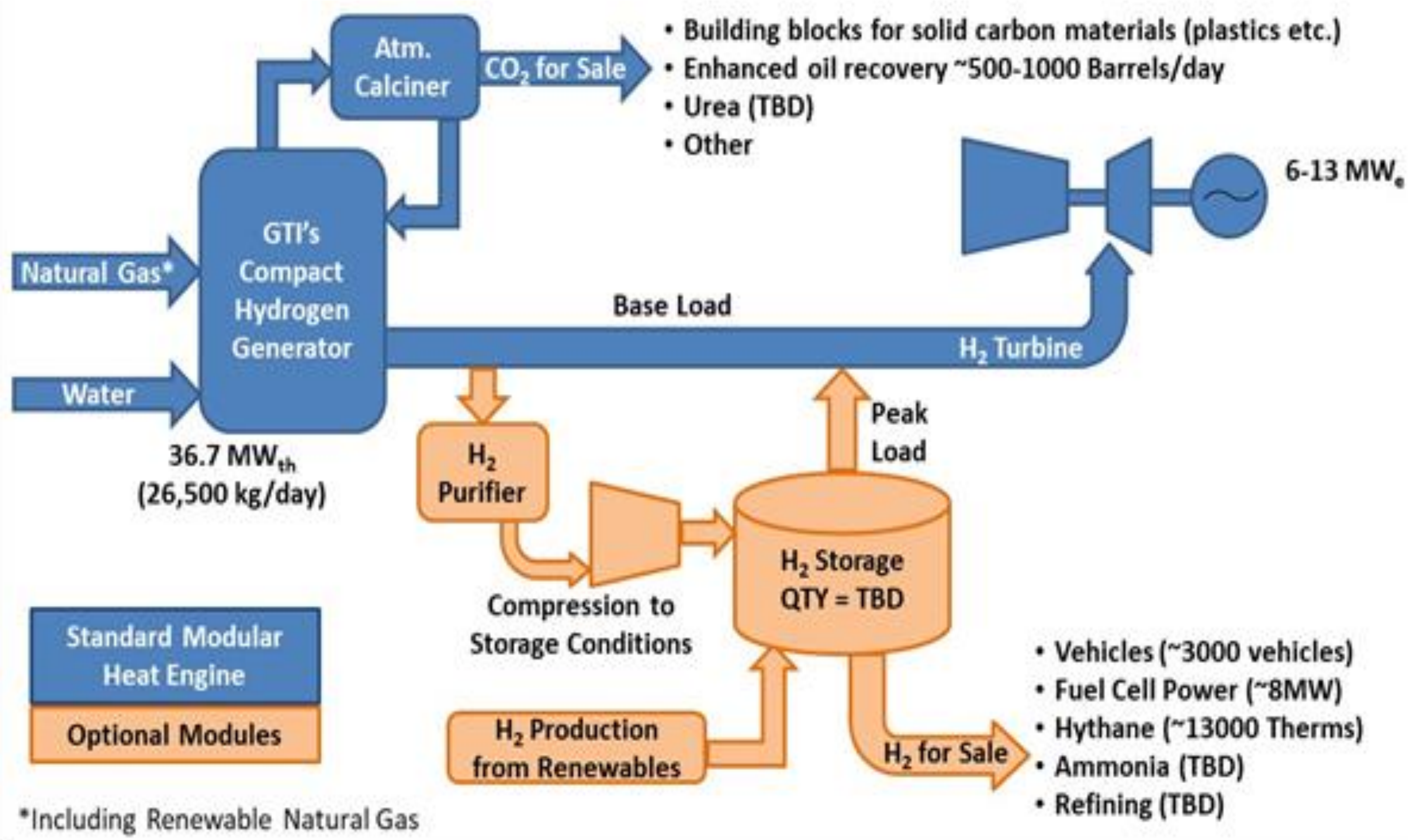
Contact:
G. (Subbu) Subbaraman
Institute Fellow, GTI
Ganesan.Subbaraman@gastechnology.org
(818) 519-3711 (Cell)

gti

Presentation Outline

- **Hydrogen-to-Power System Demonstration Concept**
- **Program vision**
- **Key Subsystems description**
  - **Compact Hydrogen Generator**
  - **Hydrogen Turbine**
- **Value proposition/Preliminary Techno-economics**
- **Phase I Objectives**
- **Applicable Markets**
- **Summary**

Hydrogen-to-Power System Concept and Options



Vision: DOE Program on Modular Heat Engines

Phase I – System Definition

Create Team: End-Users
OEM's
NG Distributors
Industrial Gas Co's

Define System: Requirements
Architecture
Modularity

Assess: Technology Readiness
Technology Gaps
Techno-Economics (Lvl 5)
Phase II Test Planning

18 Months

Phase II – Preliminary Design

Perform:
Tech. Gap Reduction Testing
- Components & System

Assess:
Updated Techno-Economics
Technology Maturation Plan

Design:
System Design
Front-End Engr. Design
Plant Cost Estimate (Level 4)

Up to 48 Months

System Concept Demonstrator

Planning:
Site planning
End-user agreements
Funding Sources

Engineering & Construction:
Detailed Design
Site Engineering
Plant Installation

Operations:
Start-up & Commissioning
1 year+ operations

36+ Months

Vision: Design, build and operate a modular heat engine system for efficient co-production of clean power, CO_2 and H_2

CHG Process Schematic

Sorption Enhanced
Steam Methane Reforming

$CH_4 + 2H_2O + Heat(a) \rightarrow 4H_2 + CO_2$

$CaO + CO_2 \rightarrow CaCO_3 + Heat(b)$

$CH_4 + 2H_2O + CaO \rightarrow 4H_2 + CaCO_3$

Heat(b) ~ 95% Heat(a)

700°C, 20-35 psig

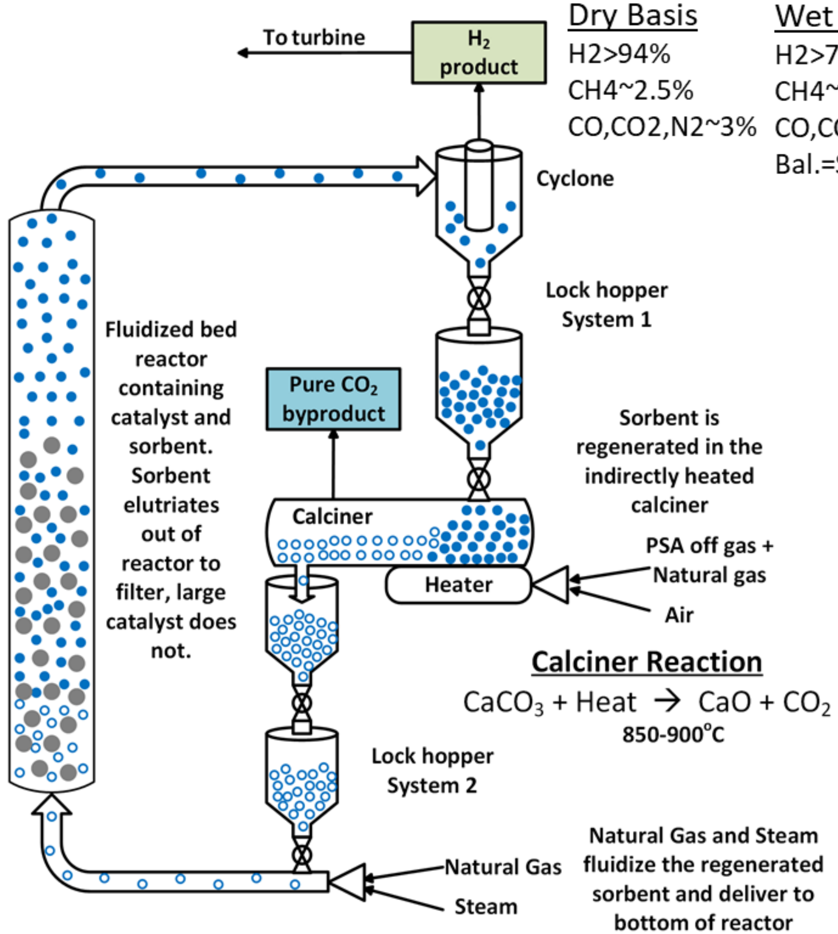
Catalyst:
Commercially Available
Ni on Alumina
2mm diameter

Sorbent:
Natural Solid Sorbent:
Limestone or Dolomite
<0.2mm diameter

- Catalyst
- Sorbent
- Sorbent with CO_2

H2 Product Composition

Dry Basis	Wet Basis
H2>94%	H2>75%
CH4~2.5%	CH4~2%
CO,CO2,N2~3%	CO,CO2,N2~2.8%
	Bal.=Steam for NOx Control



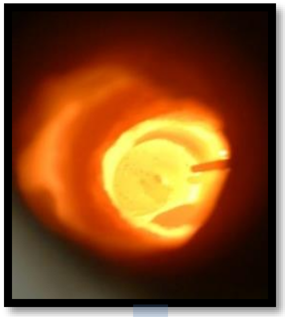
CHG Process Development

> GTI has performed a systematic development of the CHG process, demonstrating each of the key system elements. This has culminated in a pilot plant which is operational and currently being tested.

Fixed Bed Tests
Demonstrated chemistry with commercial catalyst for wide range of operating conditions.

Cold Flow Tests
Defined component designs, demonstrated solids handling under wide range of operating conditions.

Flash Calciner Tests
Validated calcination rate models. Demonstrated operation of short-residence-time calciner.

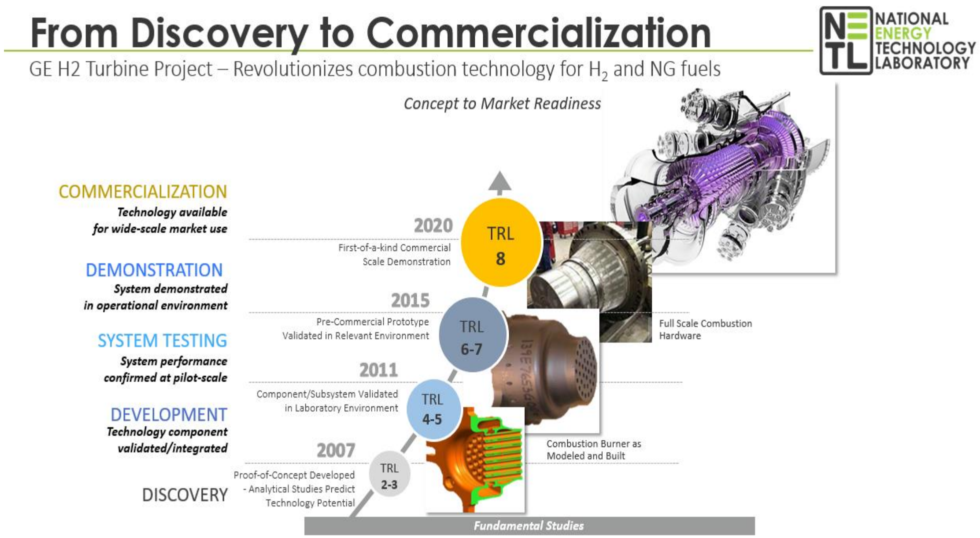


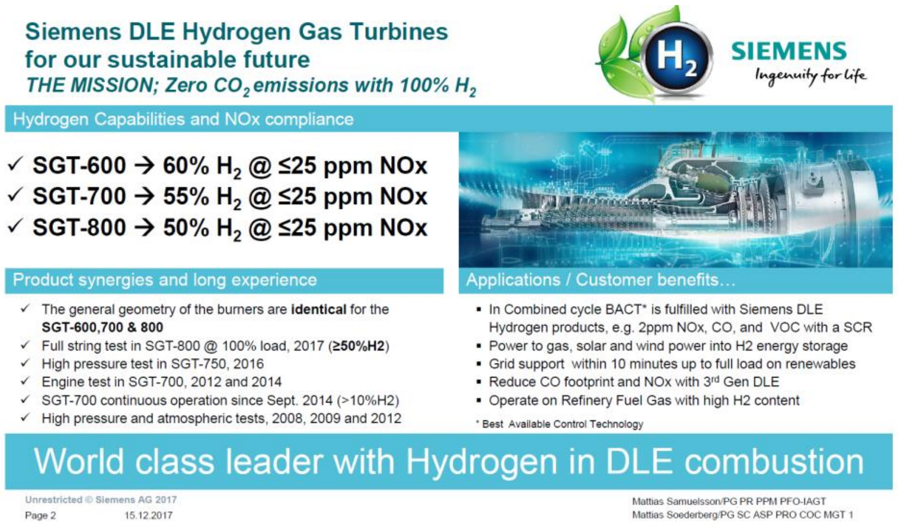
20 MSCFD Pilot
Demonstrated SER operations (92% H_2 purity) and solids handling. Catalyst evaluation in process. Current TRL=4.

Design Data and Operating Experience

DOE/Industry H_2 Turbine Development

- Significant H_2-fired turbine development was performed in the last 15 years
- Operational experience with H_2-fired turbines (based on current technology)





gti

Value Proposition/Techno-Economics (Preliminary)

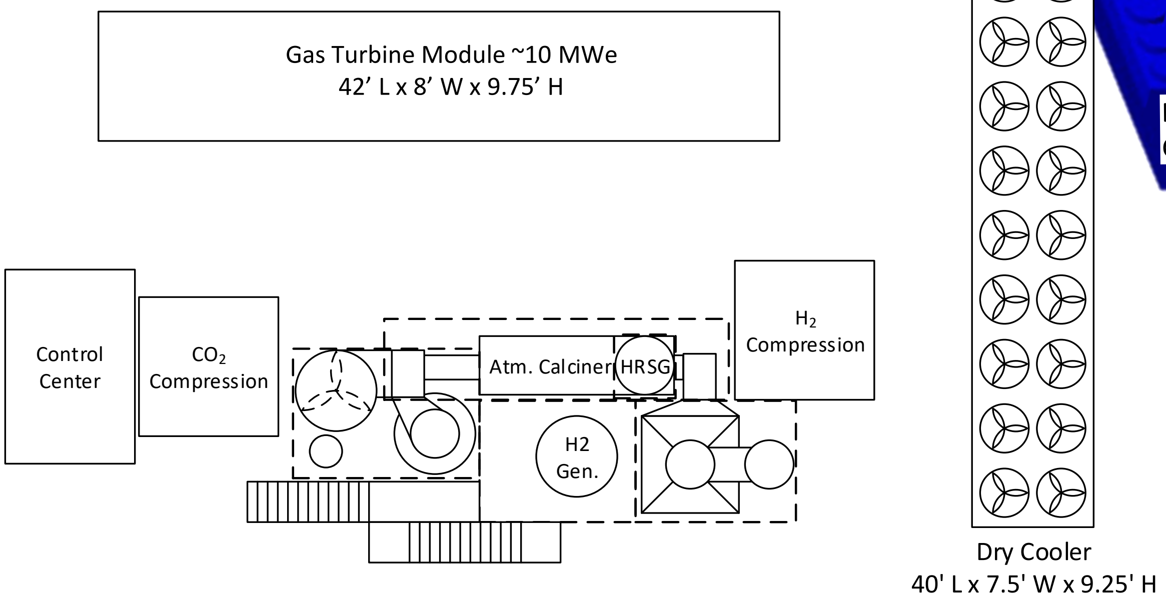
	NGCC Standard Case	NGCC w/ Post-combustion CO_2 separation	SOTA Heat Engine H_2 Via SMR and Natural Gas Turbine modified for hydrogen use (0. 399 Utility)	GTI's Modular Heat Engine with Natural Gas Turbine modified for hydrogen use (0. 335 Utility)	GTI's Modular Heat Engine Advanced Hydrogen Turbine (0. 335 Utility)
Total Plant Power (MW)	630	559	596	604	761
Percent of CO_2 Recovered	0%	90%	90%	90%	90%
Total Plant Cost, Capital Costs ($MM)	$431	$828	$952	$548	$771
Total Overnight Cost ($MM)	$525	$1,008	$1,160	$669	$939
Total As-Spent Cost ($MM)	$567	$1,087	$1,250	$721	$1012
Annual Costs (excluding T&S) ($MM)	$270	$347	$436	$331	$384
COE (including T&S) ($/MWh)	$58	$87	$102	$77	$73
System Efficiency (%)	56. 9	50. 5	39	51. 1	56. 4
CO_2 T&S ($/MWH)	0	$4. 00	$3. 75	$3. 70	$3. 04
Cost of CO_2 Separation ($/MT)	0	$66	$81	$42	$29
Total CO_2 Recovered (MT/day)	0	4,432	5,498	4,478	4,801
Total CO_2 Not Recovered (MT/day)	5,394	492	611	498	533
BBL of Oil Recovered per Day	0	12,000	17,000	13,000	13,000

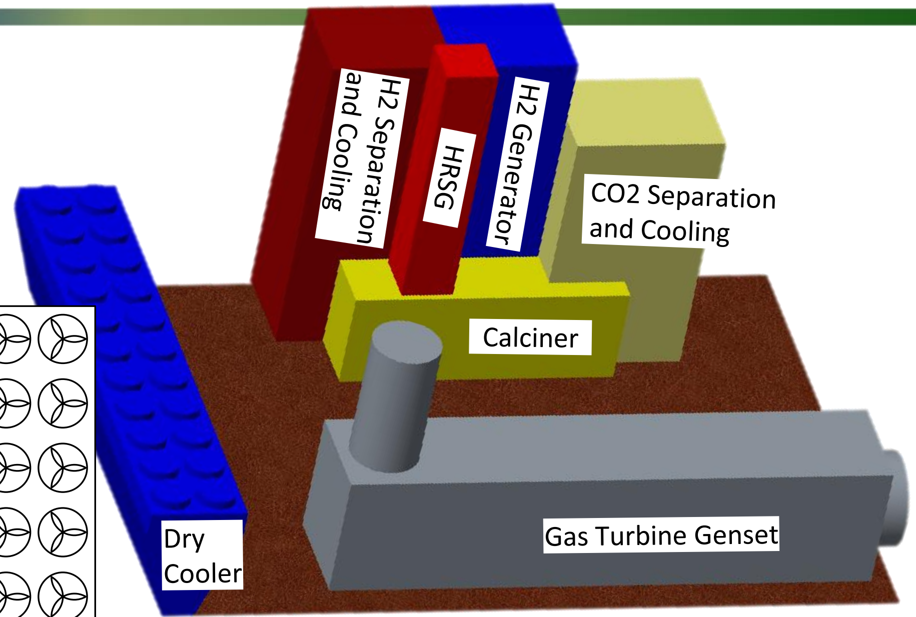
Phase I Objectives

1. Define overall system and component parameters via interactions with technology development, turbine OEM's, and end-user organizations, thus creating a viable system and team
2. Perform detailed thermodynamic cycle and performance analysis of the system
3. Optimizing the size(s) and overall specifications for the key subsystems and components
4. Establish performance baseline for integrated system along with levelized costs
5. Design a modular system concept to take advantage of factory built modules
6. Identify technology gaps and recommend a test plan to close gaps

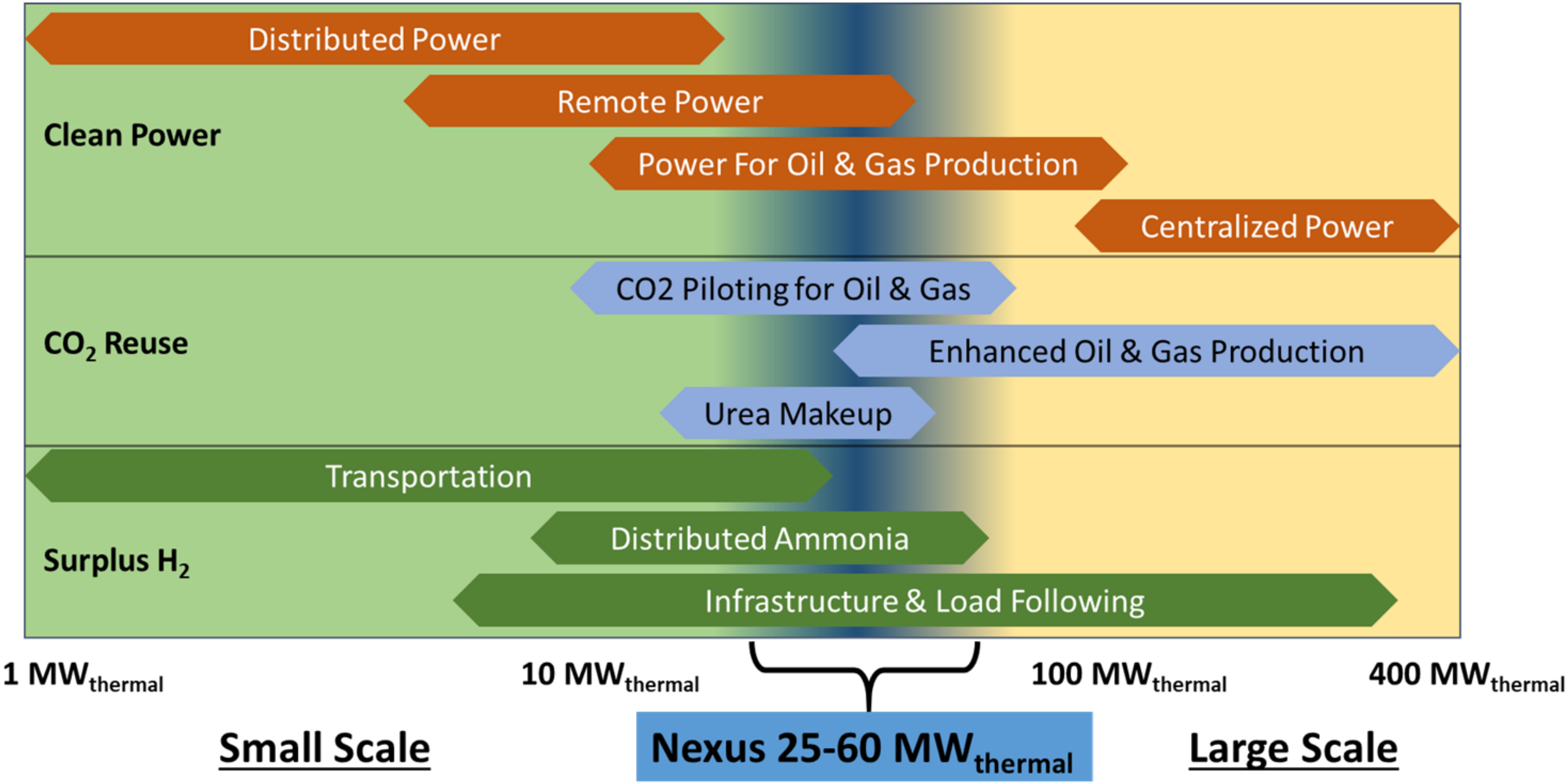
Hydrogen-to-Power Demonstration System Layout

- 10 modules total



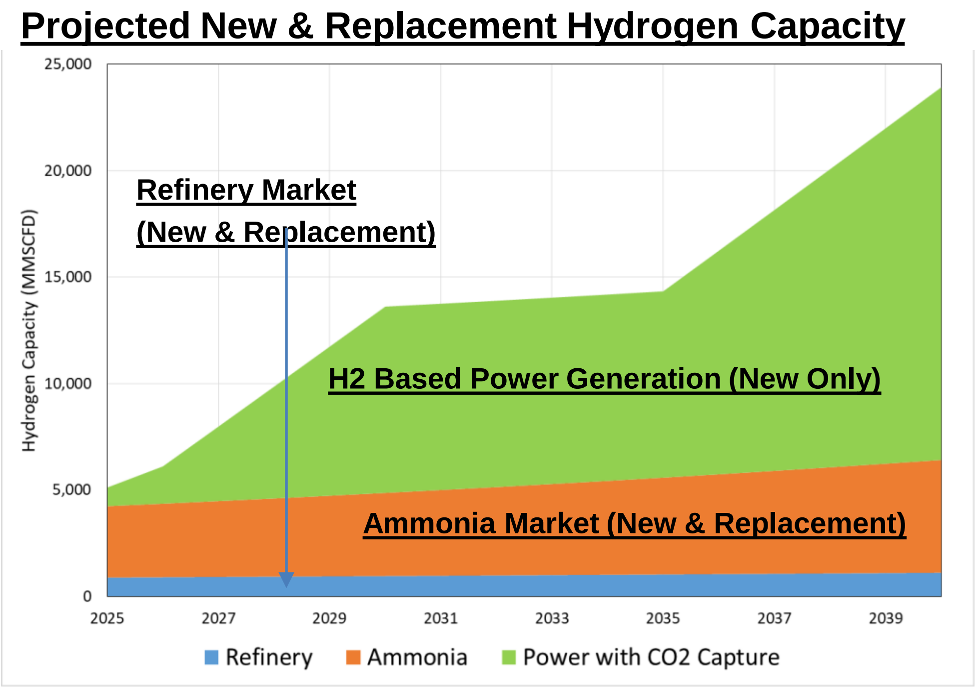


Overlapping Markets



Hydrogen Demand Market Expansion

- GTI utilized a recent assessment for CO_2-EOR needs and determined corresponding H_2 demand for power generation using the CHG



Reference: https://clearpath.org/wp-content/uploads/2018/07/Making-Carbon-a-Commodity-.pdf, Scenario #4b

Power market assumes U.S. and Europe only following Clearpath scenario #4b based on respective annual power generation

Summary

- Program combines GTI's Compact Hydrogen Generator (CHG) with a H_2 turbine thus leveraging (a) CHG's capability to affordably decarbonize natural gas and (b) prior DOE investment in H_2 turbine technology
    - Lowest cost of electricity, 11.5% to 16% better than post-combustion capture

- Enabling technology is GTI's Compact Hydrogen Generator (CHG), which is currently under development (TRL=5), and offers:
    - One-step conversion of natural gas to H_2
    - Lower product cost vs. current technology
    - Lower CO_2 capture cost vs. current technology

- A phased program has been initiated to advance power generation with hydrogen turbines utilizing CHG

- GTI is evaluating candidate applications and teaming
    - Demonstrate distributed electrical power, use of H_2 for transportation, etc., and low-cost CO_2 for EOR etc.

Thank You!

Turning Raw Technology into Practical Solutions

www.gastechnology.org | ganesan.subbaraman@gastechnology.org

gti