Carbon Reduction Through Efficient Use of Resources for a Gas Turbine Driven Generator Set

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LEADING THE WAY CampusEnergy2022 Feb 15-18 | Westin Boston Seaport District Hotel | Boston, MA

Solar Turbines A Caterpillar Company

Advanced Power & Energy Program University of California · Irvine

International District Energy Association

Problem Statement

- UCI operates a 19 MW CHP based on a 13MW Solar Turbines T130 Generator Set
- Carbon neutrality is a future goal of the UC system that CHP supports

Problem Statement

- Goal is to develop a 25MWh (returned energy) H2-based energy storage system to be integrated with the existing fossil fueled gas turbine.

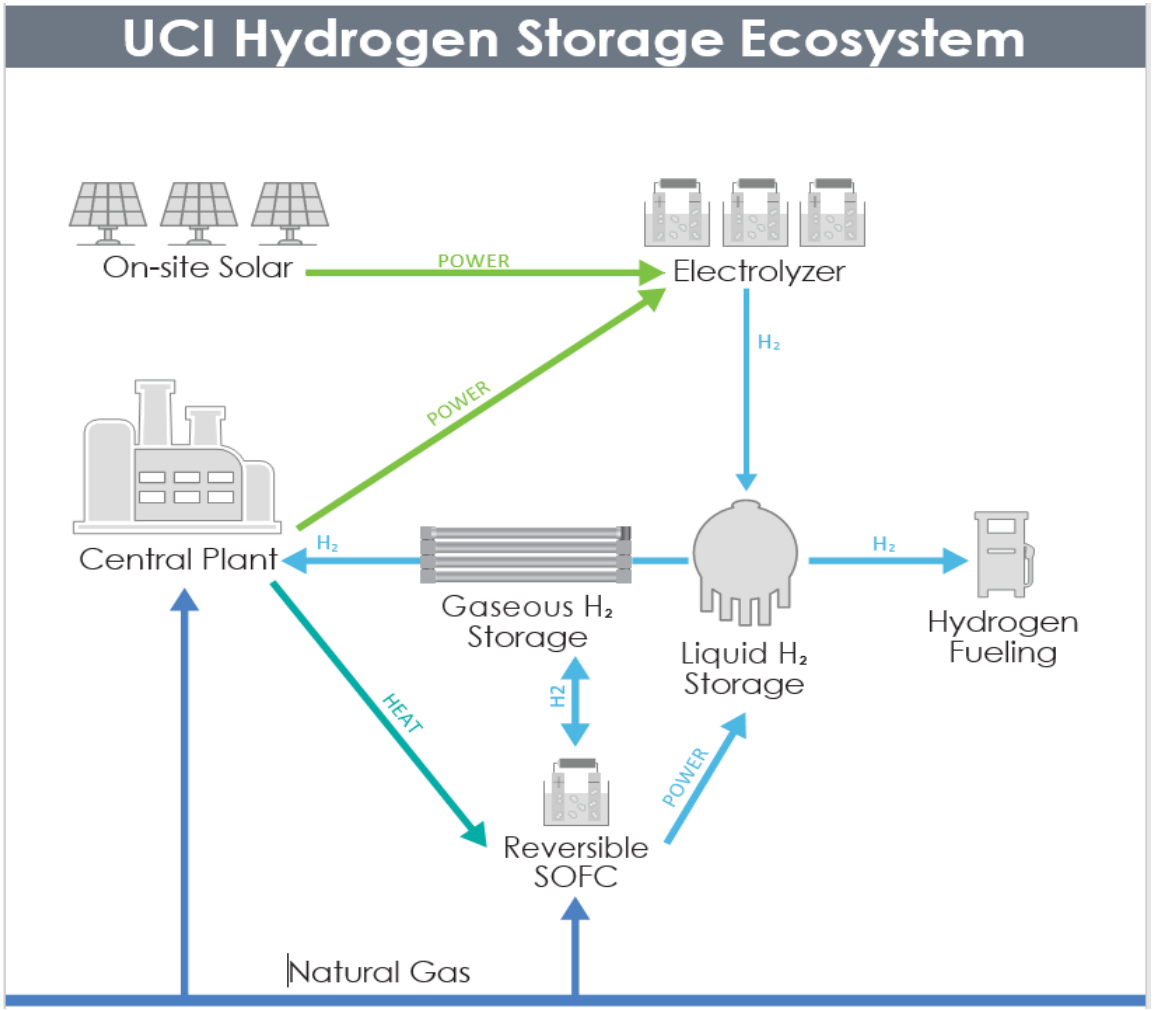
- Recently added 4MW of PV Panels
- Turbine has completed testing at 4% H2

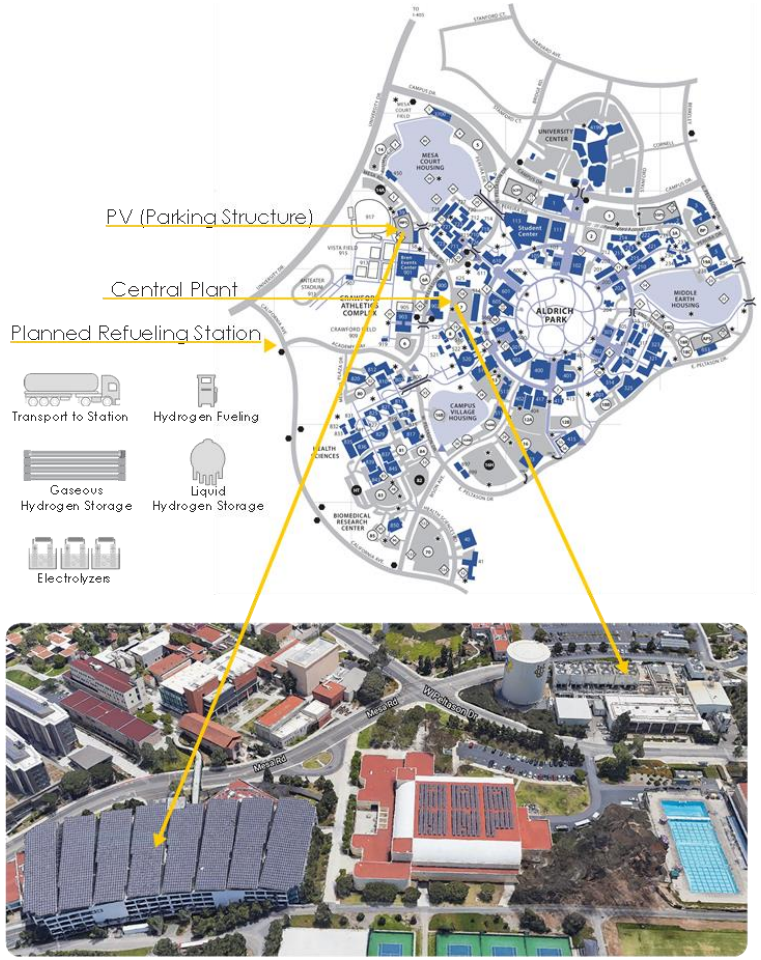
- How to approach the development of the H2 infrastructure, cost and optimize the system?

Goals

- Establishing and Operating the GT with a blend of H2/NG greater than 30%
- Integration of H2 generation technology with compression, storage and dispensing to the GT
- Evaluate the physical interconnection of the gas and electric subsystem with possible extension to the campus H2 refueling station
- Develop an integrated control systems to allow dynamic dispatching of ecosystem components

Overview





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Hydrogen Generation

- Reversible SOEC (Solid Oxyde Electrolyzer Cell)
- Alkaline
- PEM

Hydrogen Storage/Recompression consideration

- Gaseous
- Liquid

- Considerations:
  - Space
  - Cost/Size of storage
  - Pressure requirements/ Recompression cost

Optimization - Input

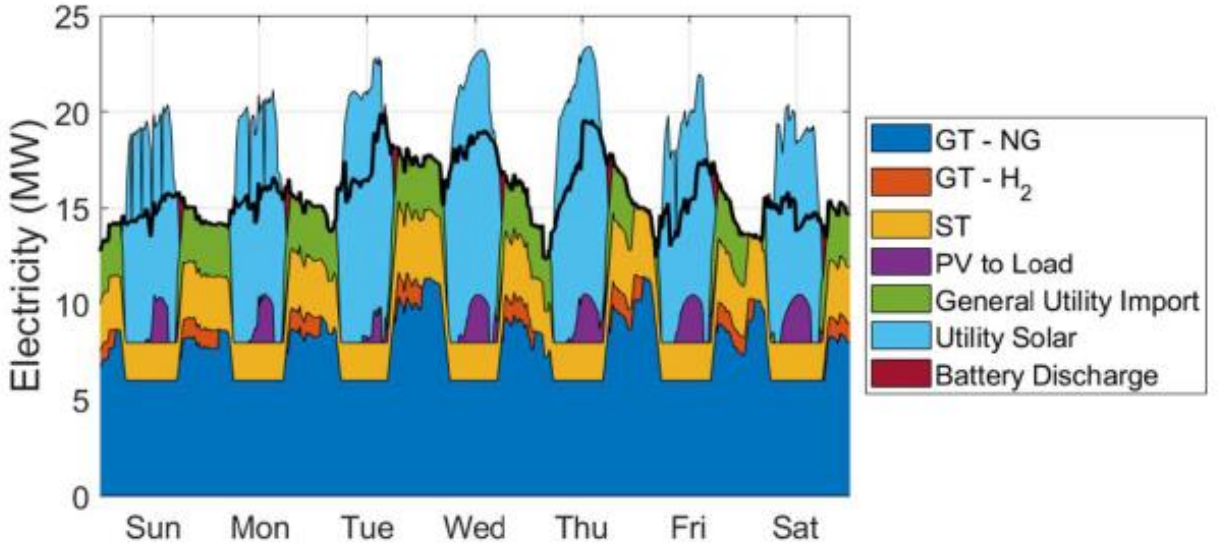
- Initial cost estimate for the system under consideration
- Initial performance estimate:
  - Carbon and pollutant emission
  - Cost of operation targets
  - Payback analysis

- Tools to be used:
  - DEROpt
  - NETL Tools /Models
  - Scenarios from DEROpt

DEROpt (UC Irvine)

- Mixed Integer Linear Program
- Techno-Economic Optimization and Analysis

- Inputs:
  - Site energy demand
  - Technology Capital/O&M costs an operational characteristics
  - Utility energy costs
  - Local Infrastructure limits
- Outputs:
  - Optimal Technology Mix
  - Optimal Operation Strategies
  - Plant performance



Results

- Use of H2 is beneficial for micro grid energy storage and load shifting
- Can be economically viable
- Multi input optimization for integration and operation of GT in UCI Micro grid will need to be developed to further optimize operation

Solar H2 Experience

- More than 55 packages operating in H2, 35+ years experience and +2M hours of operation
- 100% capability in Conventional combustion

Dry Low Emission (SoLoNOx™)

1989
Dry Low Emissions (SoLoNOx™) introduced

2003
Titan 130 SoLoNOx run at 9% H_2 (tested to 15%)

2013
Partnered with DOE for High H_2 rig testing & analysis

2021
5 Titan 130 DLE Units running on high H2

Today's Capabilities

Hydrogen Properties

- Lowest specific gravity
- Odorless, Colorless flame
- Not toxic
- Higher diffusivity
- High energy density by mass
- Low energy density by volume
- Higher flame temperature
- High speed of sound

Hydrogen Properties

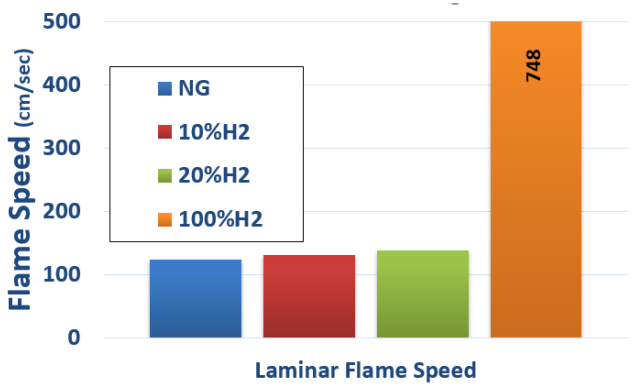
	H2% with Balance Pipeline NG					
H2 Blend	0%	5%	10%	20%	30%	100%
Combustion Parameters						
Laminar Flame Speed (cm/s)	124	127	130	139	150	749
Autoignition Delay Time (msec)	124	112	107	104	103	76
Wobbe Index (btu/scf)	1215	1199	1183	1150	1116	1039
Flame Temperature (°F)[1]	4206	4210	4215	4225	4238	4510
Package & Fuel System						
Flammability (% vol LEL)		4.83	4.79	4.71	4.63	4
Maximum Experimental Spark Gap (MESG)	1.10	1.06	1.02	.94	.86	.28
NEC/CSA & IEC Gas Groups	D & IIA	D & IIA	D & IIA	D & IIA	D & IIB	B & IIC

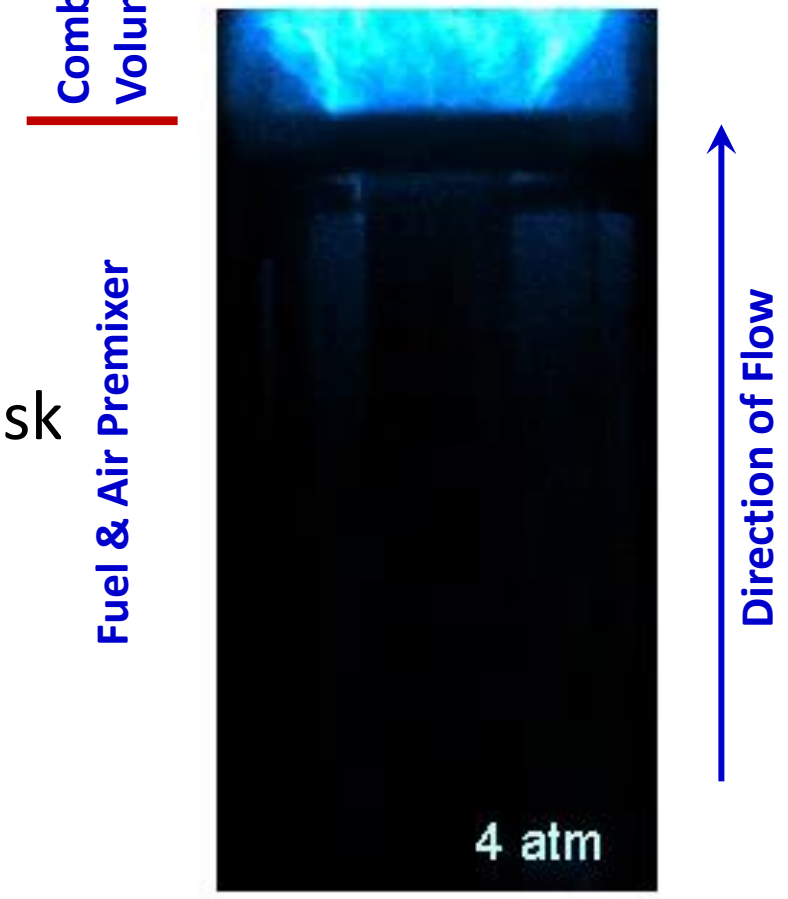
[1] *Adiabatic Stoichiometric Flame Temperature Calculated for a 23000hp class Gas Turbine at Full Load Conditions*

Hydrogen Impact on GT

Higher Flame Speed

- No Impact on Conventional Combustor
- DLE Combustor Impacts:
  - Flame Position in Combustor - “Flashback” Risk
  - Slight Change at 20% H2 and Below
  - Combustion Stability





Flashback in DLE Injector

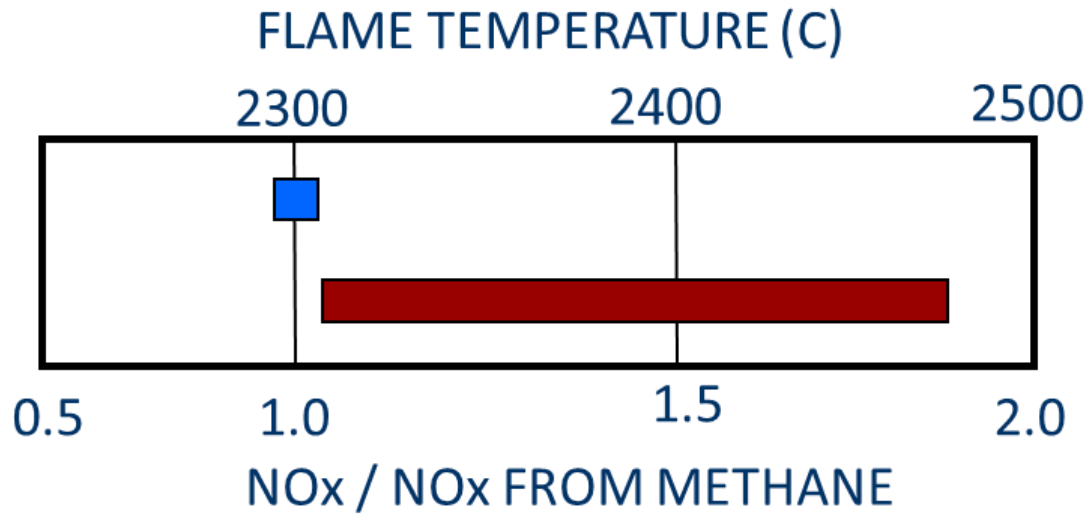
Hydrogen Impact on GT

Higher Flame Temperature

- Higher NOx Emissions
- Low impact depending on H2 content

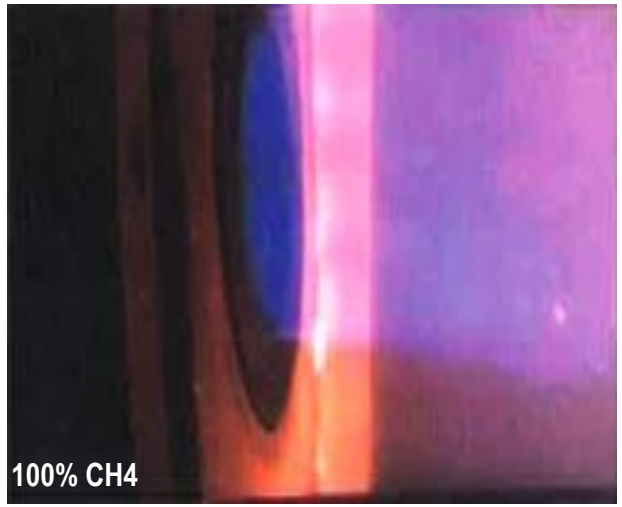
Pipeline Natural Gas

Hydrogen + Methane
(10 – 100%)



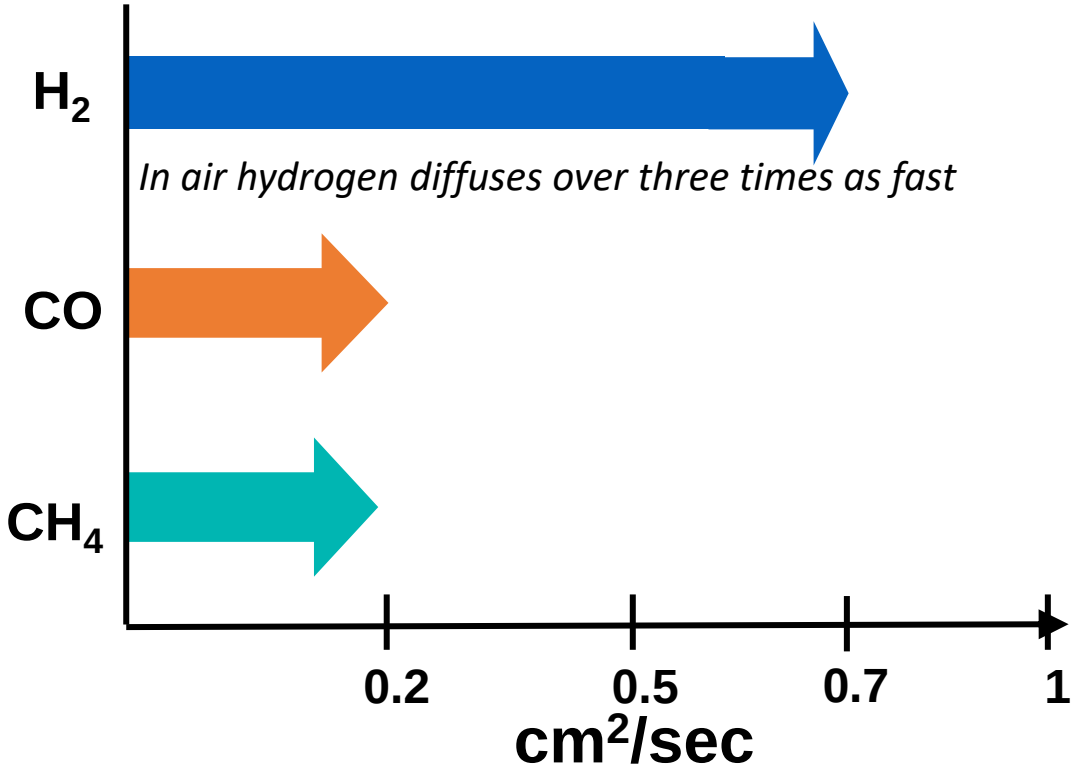
Hydrogen Impact on GT

Hydrogen Flames - *Nearly invisible in daylight irradiating mostly in the infrared and ultraviolet region*



May require duplicate detection if CH_4 and H_2 present

Leakage of hydrogen from flanges and fittings is expected to be 2 times as large as gaseous methane leakage – but diffusivity is much greater

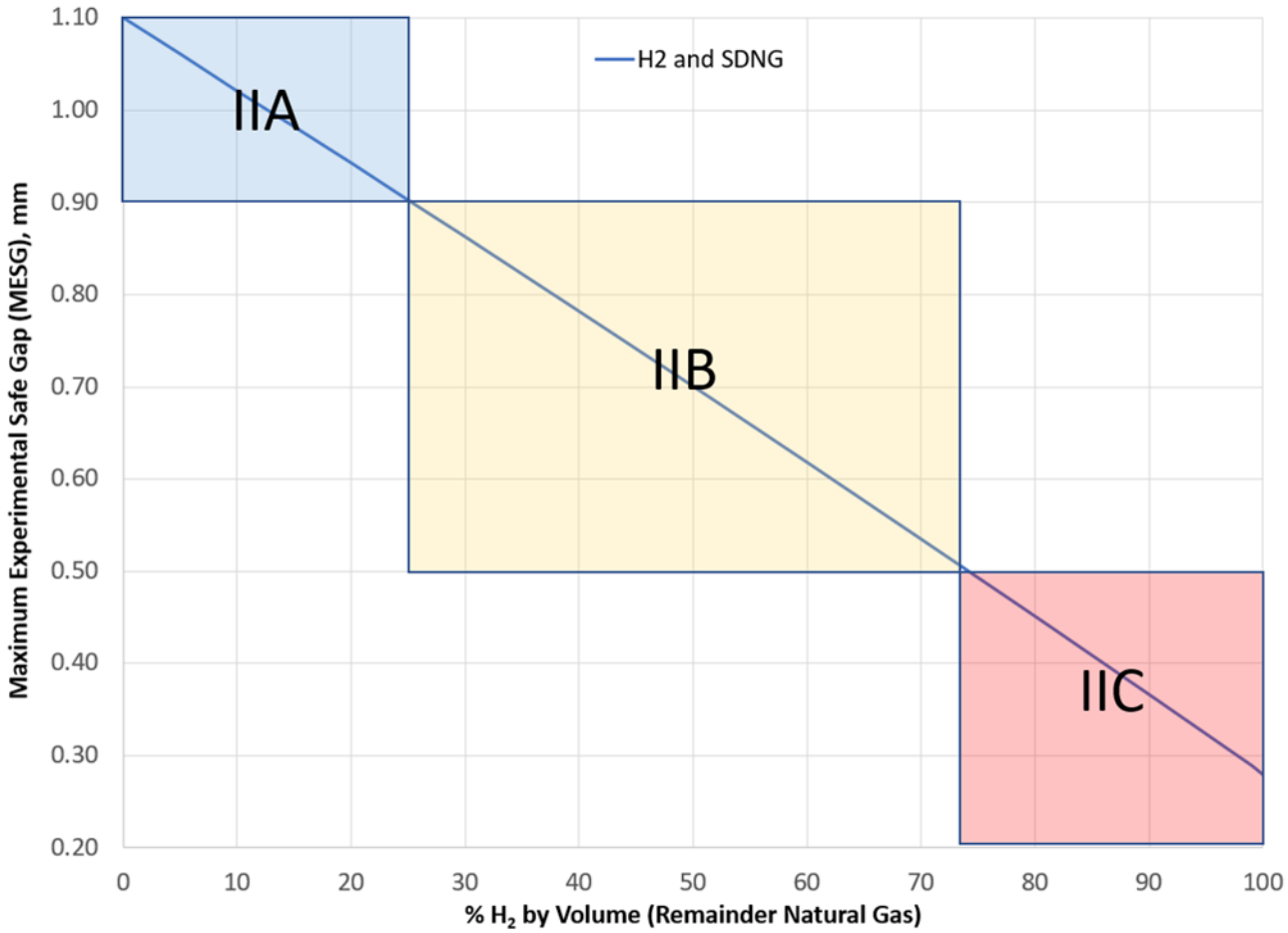


Hydrogen Impact on GT

Electrical Devices – Hydrogen Content Decreases MESG

MESG

- Classify flammable gases for the design and/or selection of electrical equipment in hazardous areas.
- "Maximum clearance between two parallel metal surfaces that has been found, under specified test conditions, to prevent an explosion in a test chamber from being propagated to a secondary chamber containing the same gas or vapor at the same concentration."



GT Package Evaluations

0-5% H2

- No Impact

GT Package Evaluations

5-20% H2 — Limited Changes

0-5% H2 — No Impact

Fire & Gas Detection Calibration

Engine & Ancillary Exhaust System review

Controls Settings update to fuel characteristics

Fuel System update

GT Package Evaluations

20-100% H2 — Significant Changes

5-20% H2 — Limited Changes

0-5% H2 — No Impact

Fire & Gas Detection Modifications

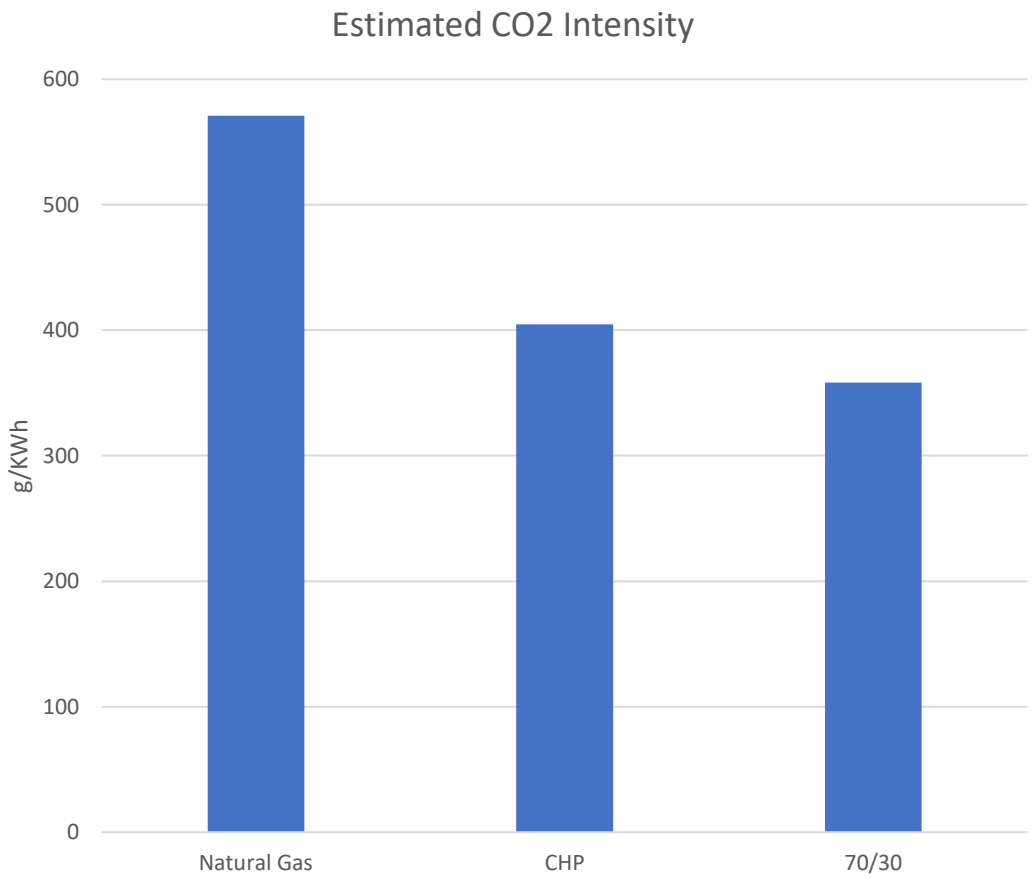
Engine & Ancillary Exhaust System Modifications

Controls Settings & Operating conditions

Fuel System Modifications

Electrical Devices upgrade (i.e. IIB, IIC..)

Carbon Intensity Reduction



- Additional 10% reduction in Carbon intensity
- More than 35% reduction in CI!
- Annual CO2 savings depends on turbines load and annual hours of operation

Conclusions

- Use of Gas Turbines and Hydrogen supports the Carbon-neutral goal of UC
- A technico-commercial modeling coupled with an optimizer will minimize emission, reduced CAPEX and OPEX by defining:
  - The hydrogen production chain on campus
  - The required energy mix to be used based on the available grid dispatch of renewables
  - The GT mode of operation

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