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HYDROGEN IN NATURAL GAS

COMBUSTION AND COMPRESSION

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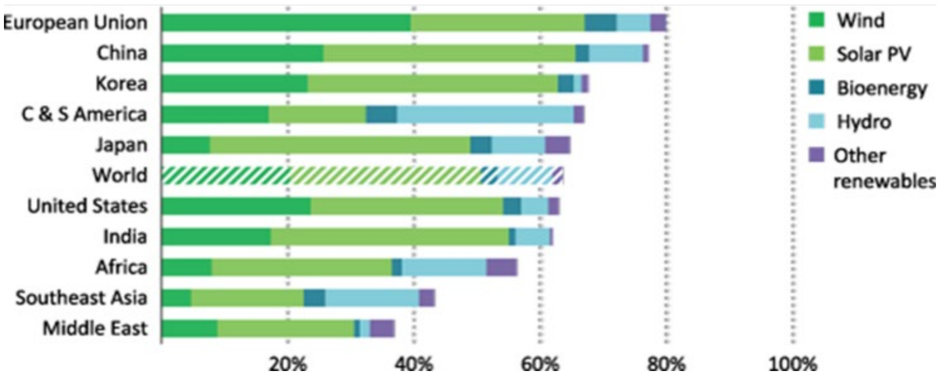
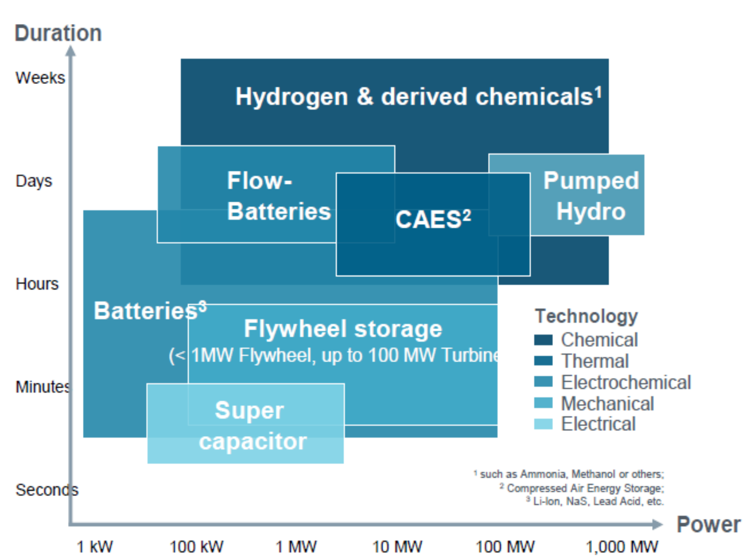
Why?

- Renewables to be 2/3rds of capacity additions to 2040
- As installed capacity increases, greater flexibility is needed



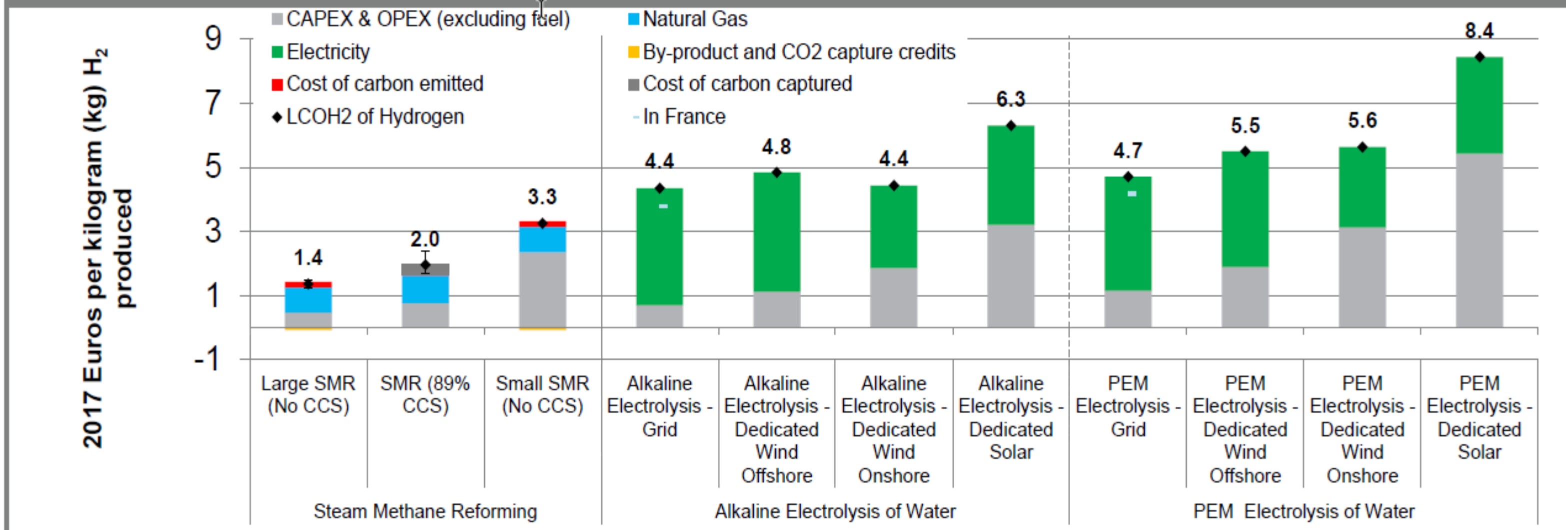


The main methods for generating hydrogen

- Steam Methane Reformation (SMR): Using steam to split methane into H_2 and CO_2. The CO_2 is generally sequestered as part of this process. This is referred to as blue hydrogen.
- Gasification of solid fuels like coal, pet coke, biomass, municipal waste into a syngas. This has which contains CO, CO_2 and other things is then processed to recover H_2. This is referred to as brown hydrogen
- Electrolysis: Using electricity (often using excess renewables) to split H_20 into hydrogen and oxygen. This is referred to as green hydrogen
- Photolytic: Using light energy to split water into hydrogen and oxygen. This is also considered to be green hydrogen.

It's not cheap…..

Levelized cost of Hydrogen — Current – Germany (representative of North West Europe)



Note: H_2 price at the boundary of the production facility. Large SMR plant scale : 100,000 Nm3/h H_2 output, large SMR Capacity factor = 95%. Small SMR plant scale = 2,000 Nm3/h H_2 output (equivalent to a 10 Mwe input Electrolyser at full capacity), small SMR Capacity factor = 95%. Alkaline Electrolyser capacity = 100 MWe input (H_2 output 20,000 Nm3/h at full capacity). PEM Electrolyser capacity = 10 MWe input (H_2 output 2,000 Nm3/h at full capacity). Natural gas price: 16 Euros/MWh. Carbon price of 21 Euros per metric ton. Wholesale grid electricity: 95% capacity factor (CF) at 44.9 Euros/MWh with 20 Euros/MWh grid fees (10 Euros/MWh grid fees for France). Utility scale solar PV: 14% CF at LCOE 55.1 Euros/MWh. Onshore Wind = 25% CF at LCOE 45.7 Euros/MWh. Offshore Wind = 54% CF at LCOE 66 Euros/MWh. For France, assumes only reduction in grid fees with same wholesale electricity price. CO2 transport mode: 500 km offshore pipeline with injection and storage in a depleted oil and gas field. Error bars reflect the uncertainly and variability in capex for SMR and carbon capture and storage. Average cost of CCS: 72 euros per tonne of CO2. Solar PV in Spain: LCOE = 45.9 euros per MWh, capacity factor = 18%. Onshore wind in Spain: LCOE = 34.5 euros per MWh, capacity factor = 28%. Offshore wind in Spain: LCOE = 75.9 euros per MWh, capacity factor = 38%.

Source: IHS Markit

Open Questions

- What is the impact of hydrogen in natural gas on gas turbine combustion and safety?
- What is the impact of Hydrogen on transportation efficiency in a pipeline?

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Gas Turbine Combustion Systems

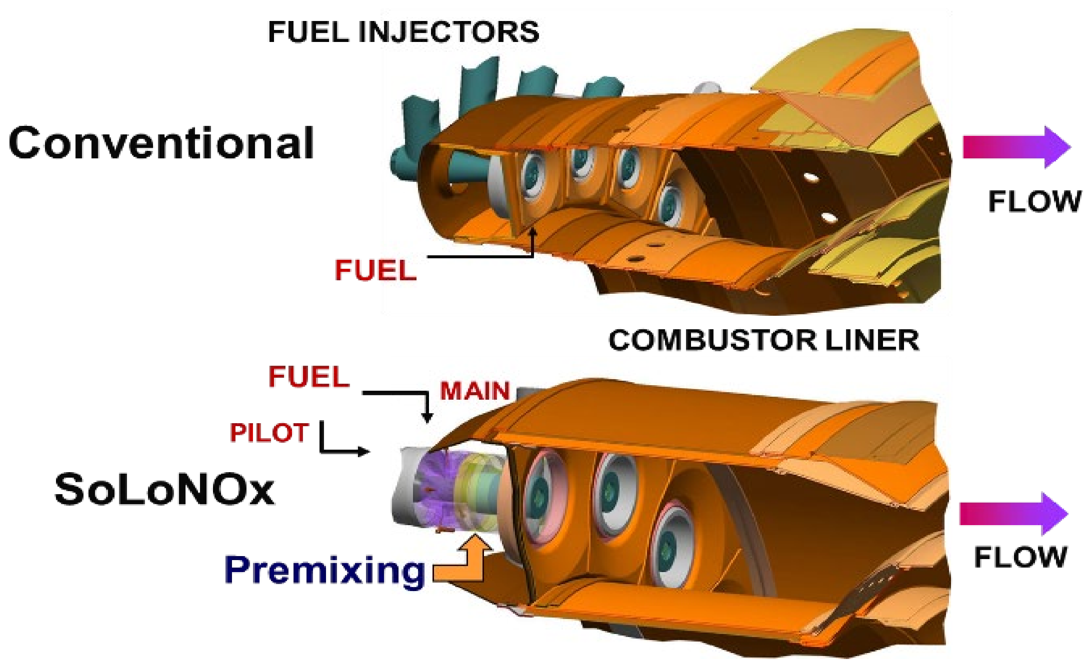
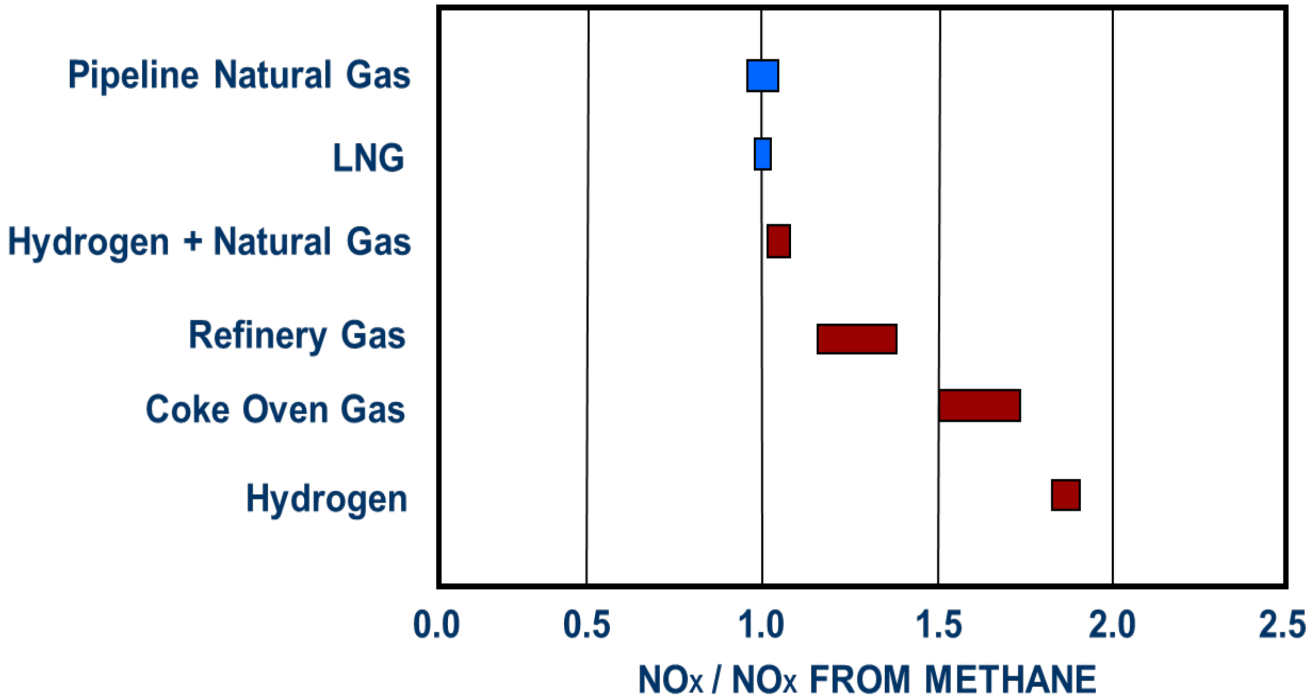


Table 1: The Variation of Key Gas Turbine Characteristics with Hydrogen Additions to Pipeline Gas Focusing on the Range of 5 to 30%.

Hydrogen Blend Combustion Characteristics

	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

Emissions (Diffusion Flame)

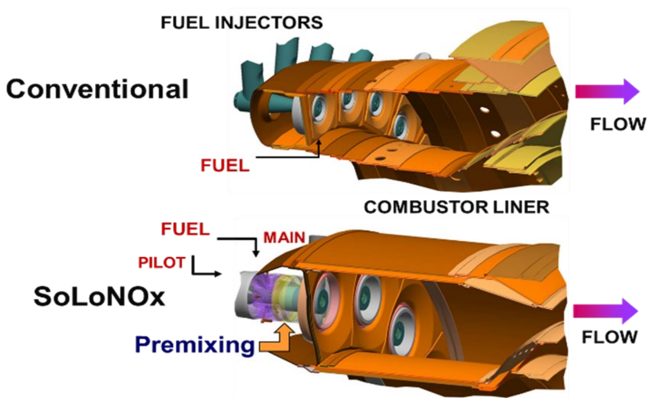


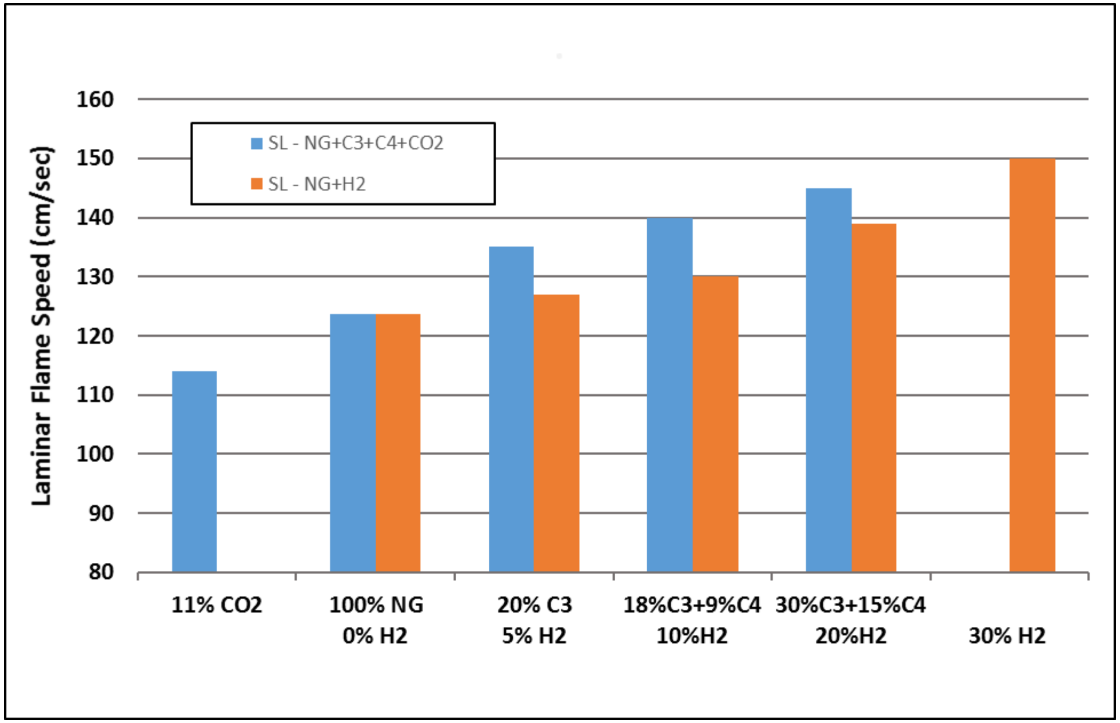
Package Issues

- Safety
- Purge
- Failed Starts

H_2 Flammability range: 4%-75% by volume (Natural Gas: 5-15%)
H_2 Autoignition Temperature 500°C (Nat Gas : 580°C)
H_2 Ignition Energy: 0.02mJ (Nat Gas: 0.29mJ)

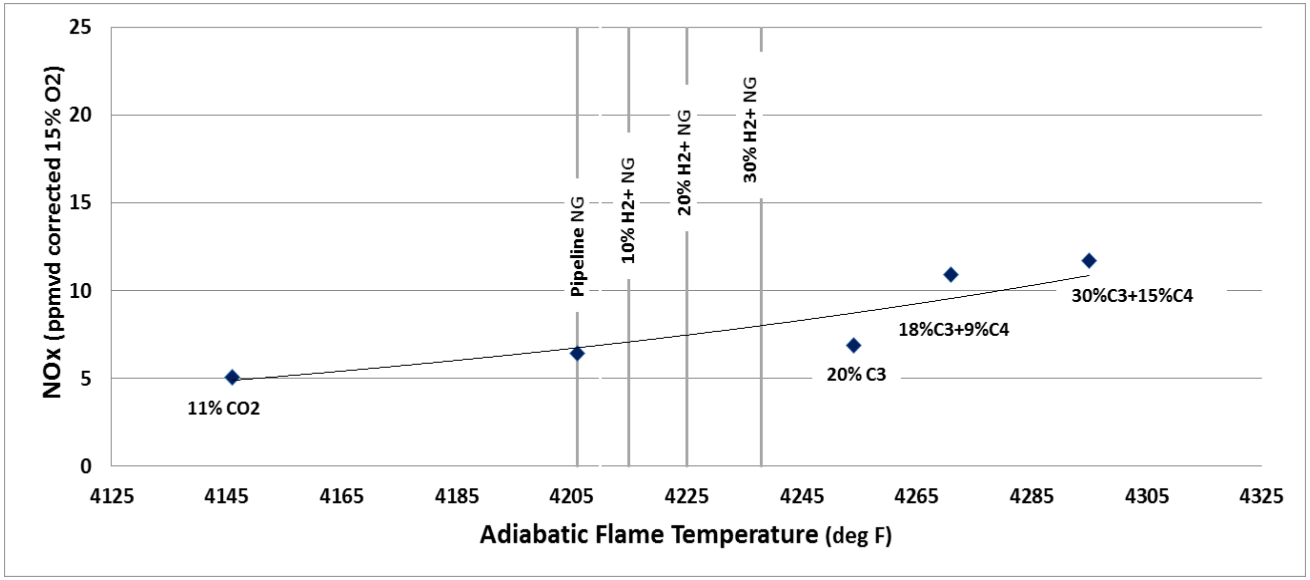
Flame Speed





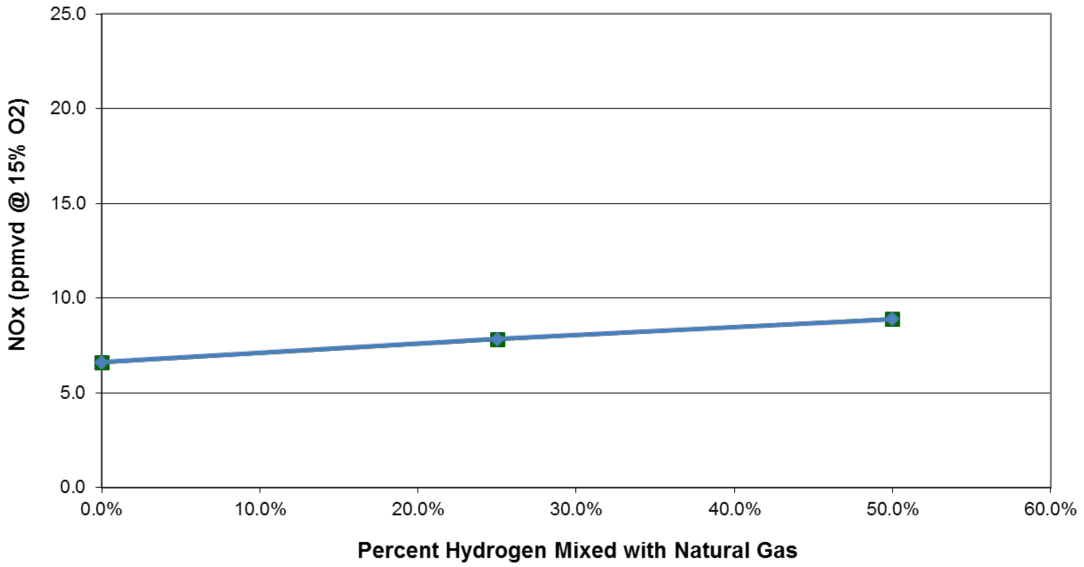
Varying Levels of Propane, Butane and CO_2 Mixed with Natural Gas Compared to Mixtures of Hydrogen and Natural Gas

Lean Premix-NO_x Emissions



NOx Emissions Variation at Full Load and Standard Pilot with Associated Gas Test Fuels with Different Values of Adiabatic Flame Temperature

Lean Premix-NO_x Emissions



NOx Emissions Variation at Combustion Rig Testing at Simulated Full Load Conditions for a 59°F Day and Constant Pilot Level with Varying Blends of Hydrogen Mixed with Natural *Gas.*

Combustion Summary

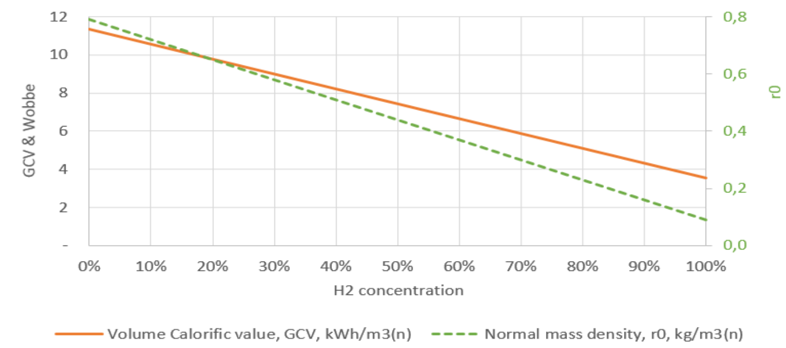
- Conventional combustion systems are proven for H_2 + NG blends up to 30%.
- Even for Lean Premix systems, H_2+ NG mixtures of 5 to 10% are not problem today.
- Concerns are related to safety, for example at failed starts. These are manageable with todays technology

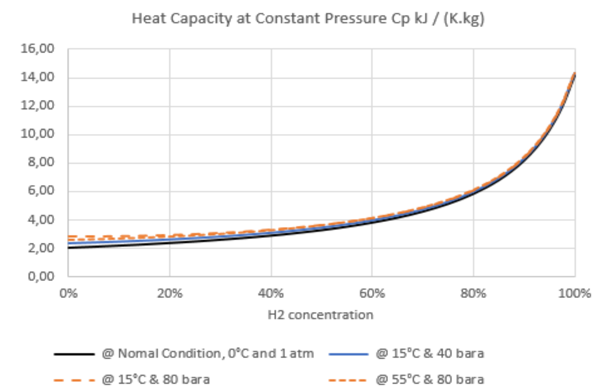
Open Questions

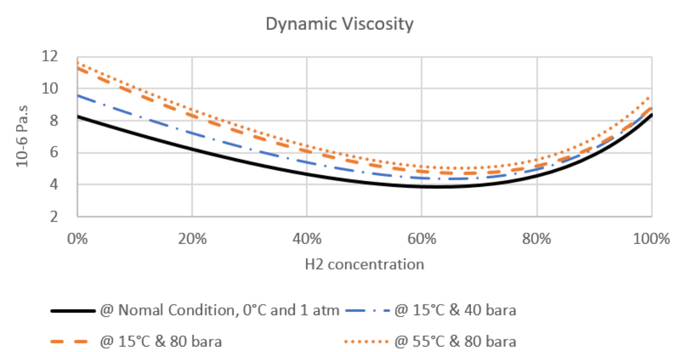
- What is the impact of hydrogen in natural gas on gas turbine combustion and safety?
- What is the impact of Hydrogen on transportation efficiency in a pipeline?

Hydrogen Properties

- It's lighter
- Lower volumetric heating value
- Higher Heat capacity
- Different Viscosity

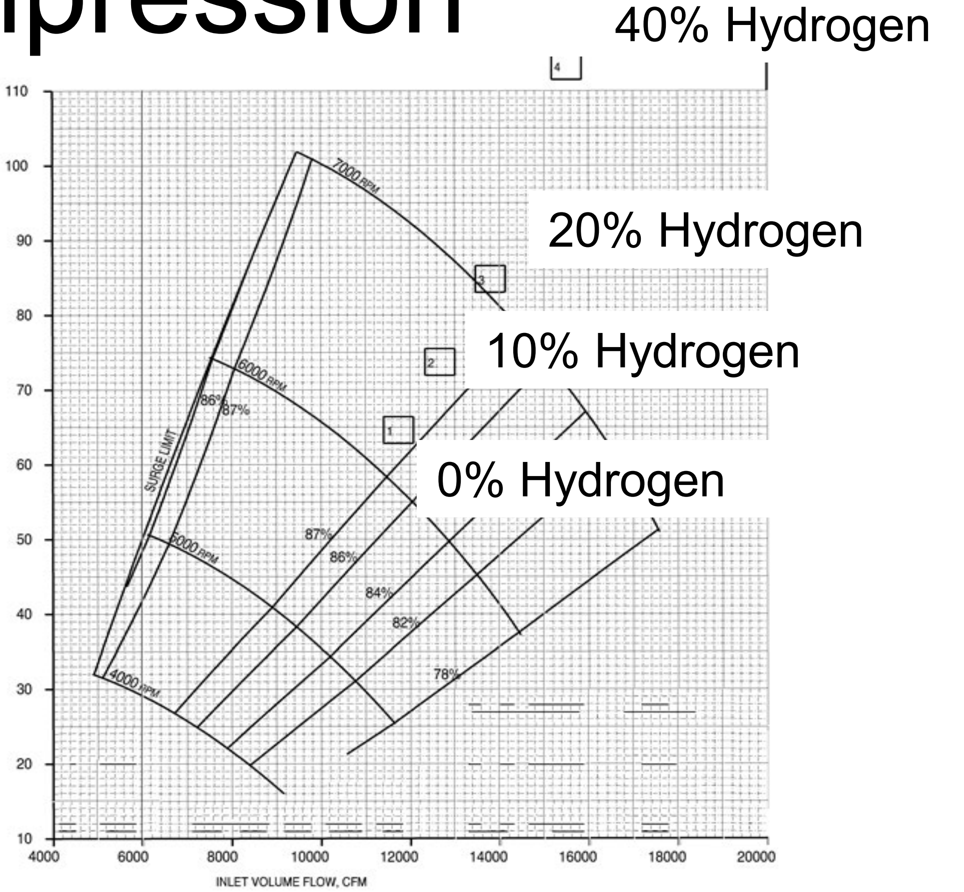




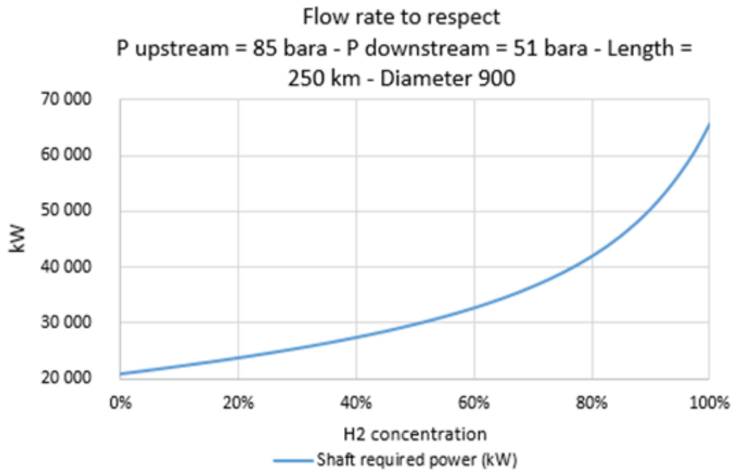


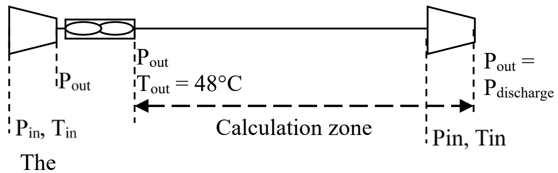
Impact on Compression

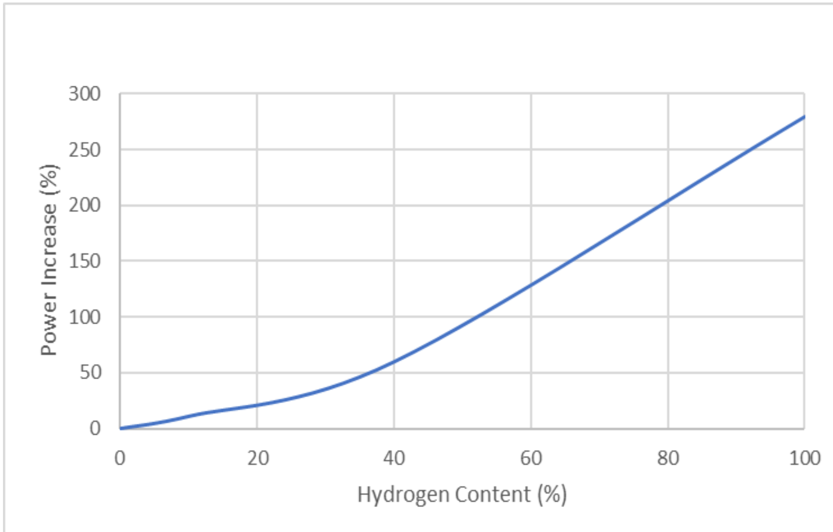
- Operating points for constant inlet conditions and discharge pressure.
- Flow adjusted to maintain energy flow



Pipeline Simulation







Power Increase for Constant Energy Flow

Transport Efficiency

- Gas compressors are able to handle hydrogen in natural gas, but the will have to run faster (ie, re-stages may be required on existing units), and will consume more power.
- The transportation efficiency of pipelines will be reduced when hydrogen is added.

Summary

- It can be done
- Viable to Balance Renewables
- Economic Justification?
- What are realistic concentrations (based on production capability)