HIPS-Net Presentation

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GAS TURBINES
New findings on turbines in operation and current developments

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Solar Turbines
A Caterpillar Company

Summary:

- Solar Turbines Incorporated
- SoLoNOx, or how to control emissions
- The importance of the fuel
- H2, not only a engine matter
- Conclusion

SOLAR TURBINES INCORPORATED

Solar Turbines
A Caterpillar Company

SOLAR TURBINES INCORPORATED

- Based in San Diego, California, U.S.A.
- Founded in 1927
- More than 14,810 Gas Turbines Operating in over 100 Countries
- More than 2 Billion Fleet Operating Hours
- World's Largest Manufacturer of Industrial Gas Turbines (1 to 22 MW Range)
- Subsidiary of Caterpillar Inc. since 1981

SOLAR TURBINES INCORPORATED

- Global Workforce - 7800 Employees Worldwide
- 8 Manufacturing Facilities
- 48 Service Locations
- 23 Overhaul / Repair Centers
- Installations in over 100 Countries

SOLAR TURBINES INCORPORATED

- Over 500 packages sold to Europe (incl.Russia) since mid 60's for the gas transmission and gas storage market
- Over 40% use Solar Dry Low Nox (DLE) system
- Power range installed reaches from 1.2 MW to 22 MW.

SOLONOX, OR HOW TO CONTROL EMISSIONS

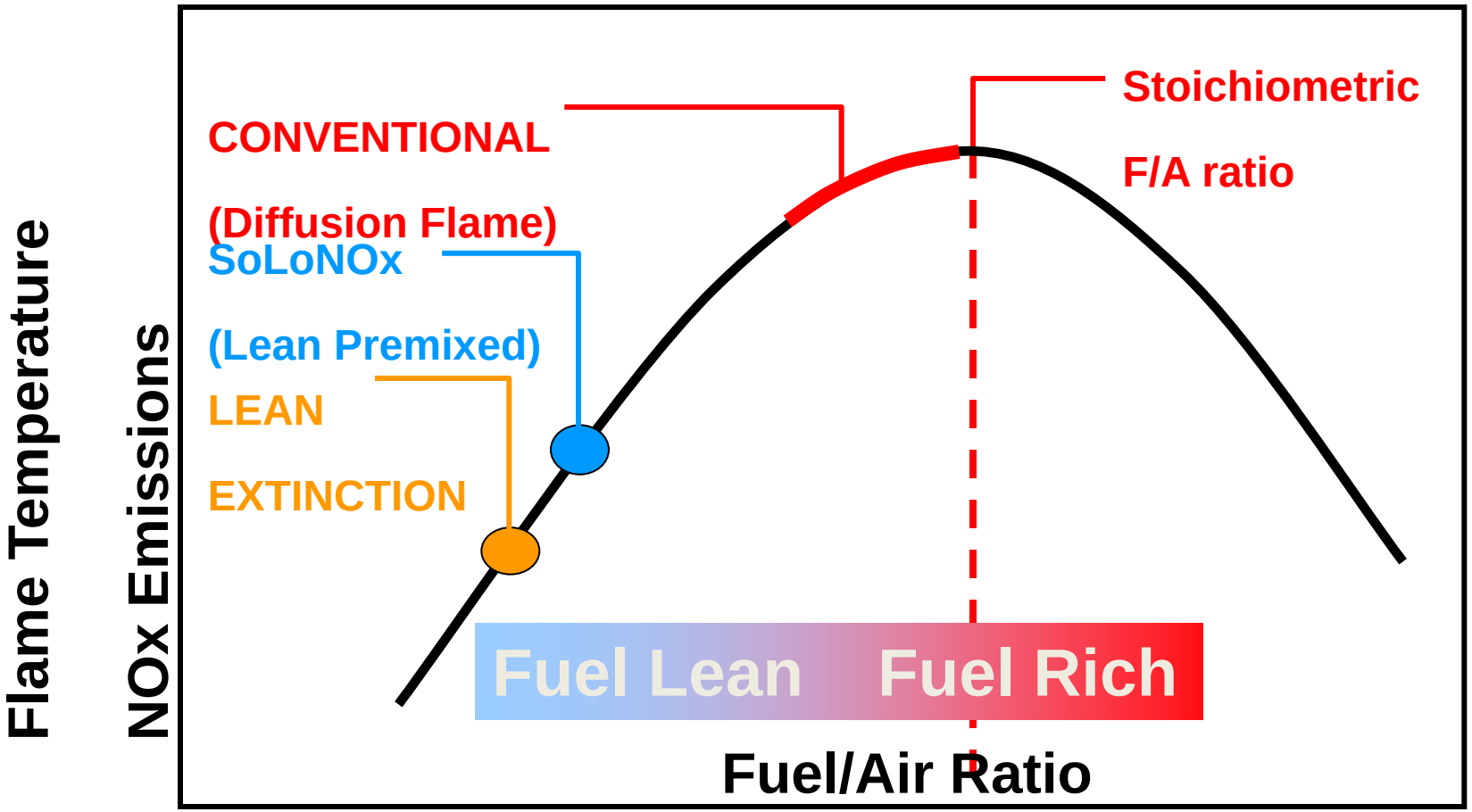
SOLONOX, OR HOW TO CONTROL EMISSIONS

Two types of Combustion flames in Gas Turbines:

- Diffusion Flame (Conventional)
  - Air and Fuel injected into Combustor Separately
  - Combustion takes place at the interface (Flame Front)
- Lean, Premixed Flame (SoLoNOx)
  - Air and Fuel are Premixed in the fuel injector prior injection into combustor
  - Combustion takes place at lower temperature,

SOLONOX, OR HOW TO CONTROL EMISSIONS

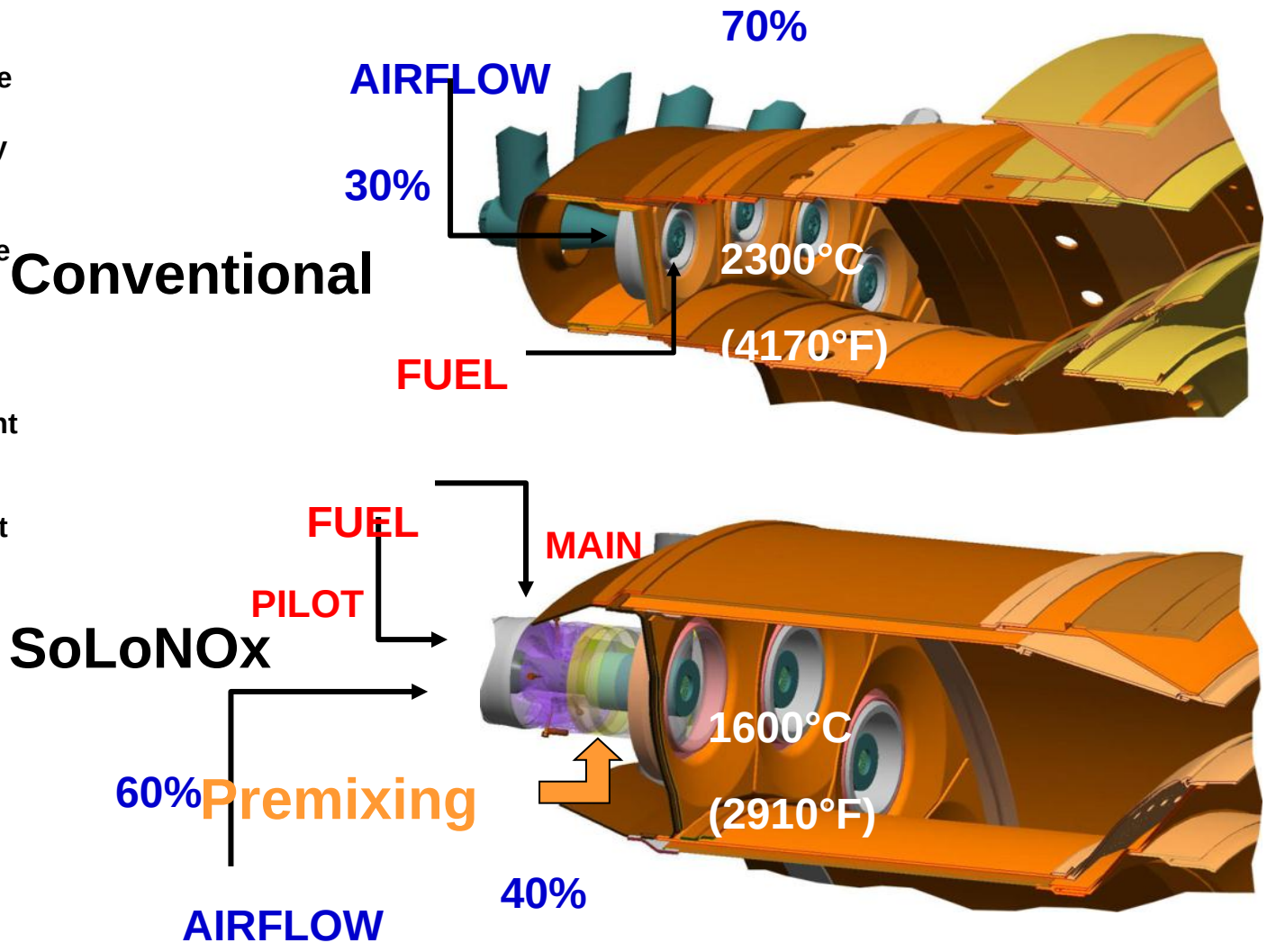
- Effect of Stoichiometry on flame temperature and NOx emissions



SOLONOX, OR HOW TO CONTROL EMISSIONS

The average flame temperature is reduced by putting more air through the injectors and hot spots are minimized with SoLoNox by premixing the fuel and air prior to burning. Cooler flame temperatures produce lower NOx.

An additional fuel circuit is added for SoLoNOx to provide a flame anchor point during start-up, low load operation and during load transients – labels as a pilot fuel.



THE IMPORTANCE OF THE FUEL

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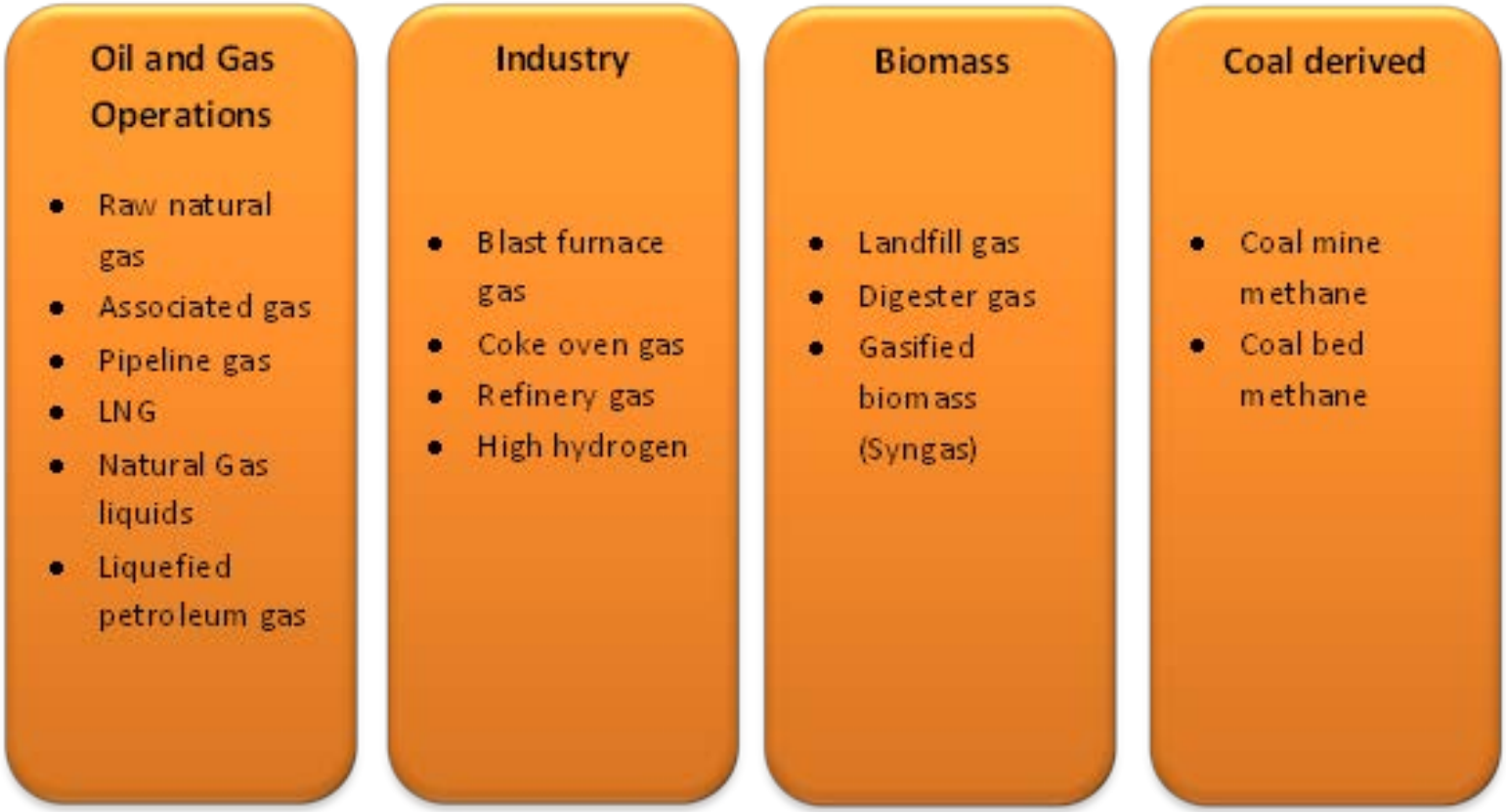


THE IMPORTANCE OF THE FUEL

Conventional

- Heating Value
  - Skid Edge Pressure
- Flammability Limits
- Adiabatic Flame Temperature
- Dew Point
- Contaminants

SoLoNOx

- Heating Value
  - Skid Edge Pressure
- Flammability Limits
- Adiabatic Flame Temperature
- Dew Point
- *Flame Speed (C4++H2+Alkenes)*
- *Autoignition Delay Time*
- *Emissions*
- *Combustion Stability*
- Contaminants

THE IMPORTANCE OF THE FUEL

Wobbe Index

$$WI = \frac{LHV}{\sqrt{SG}}$$

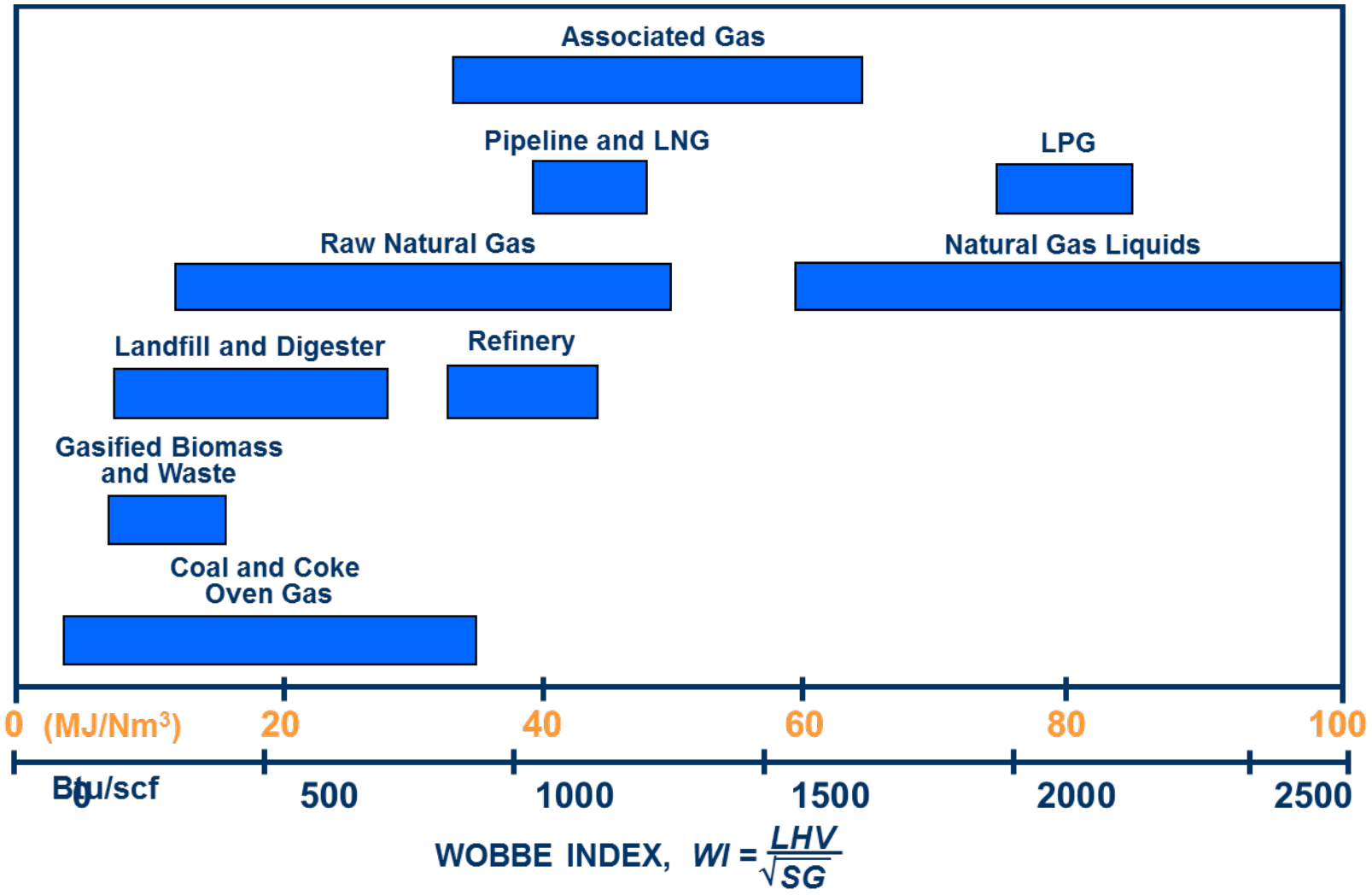
LHV = Lower Heating Value
SG = Specific Gravity

Corrected Wobbe Index

$$WI_{CORR} = WI \sqrt{\frac{60 + 459.67}{T_{fuel} + 459.67}}$$

U.S. Pipeline Natural Gas Ranges Gas Processors Association (1998)				
	Btu/scf		MJ/Nm3	
	Minimum	Maximum	Minimum	Maximum
Higher Heating Value	950	1150	35.4	42.9
Lower Heating Value	856	1040	34.9	38.8
Wobbe index	1085	1296	40.5	48.3

THE IMPORTANCE OF THE FUEL



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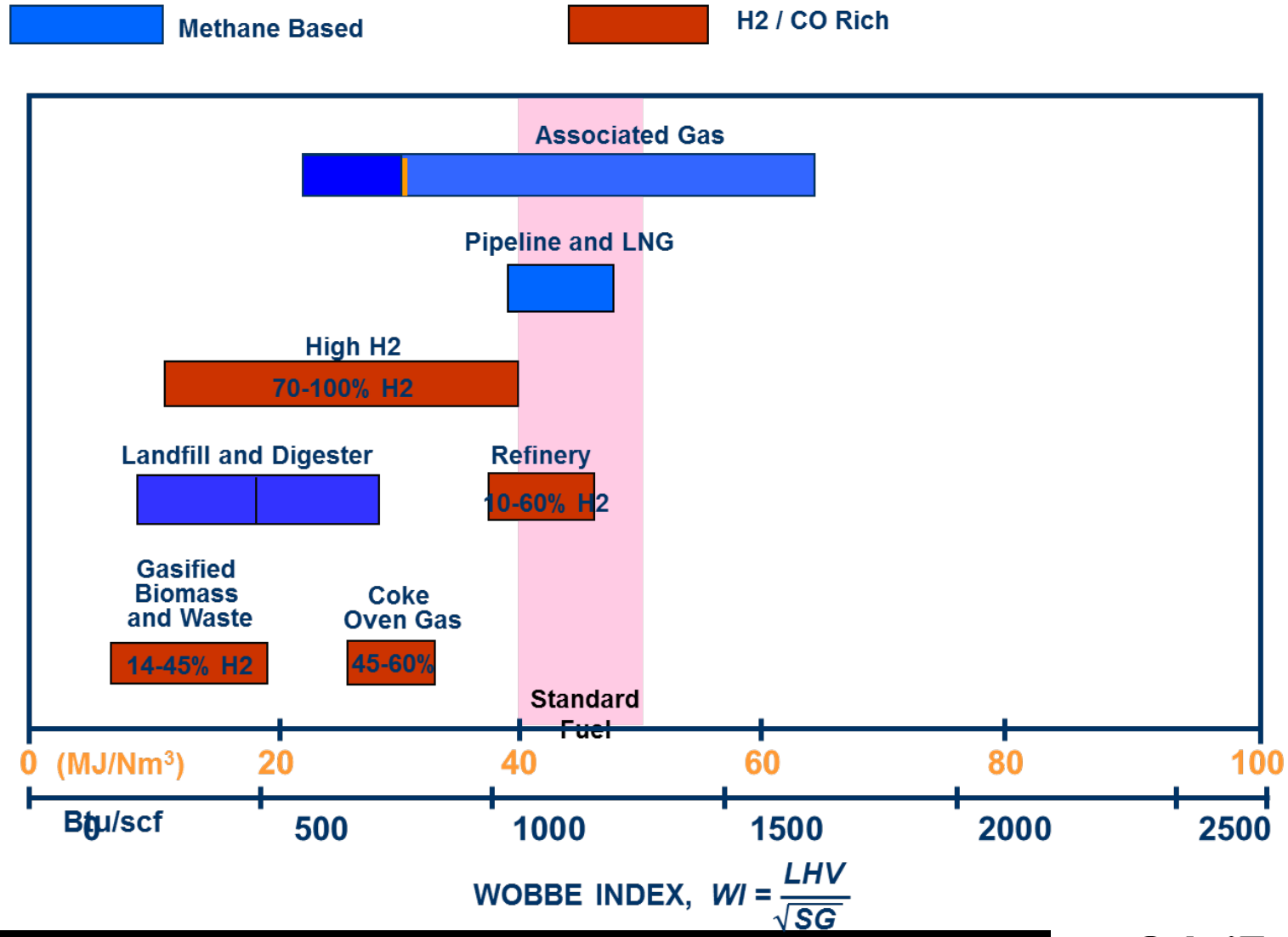

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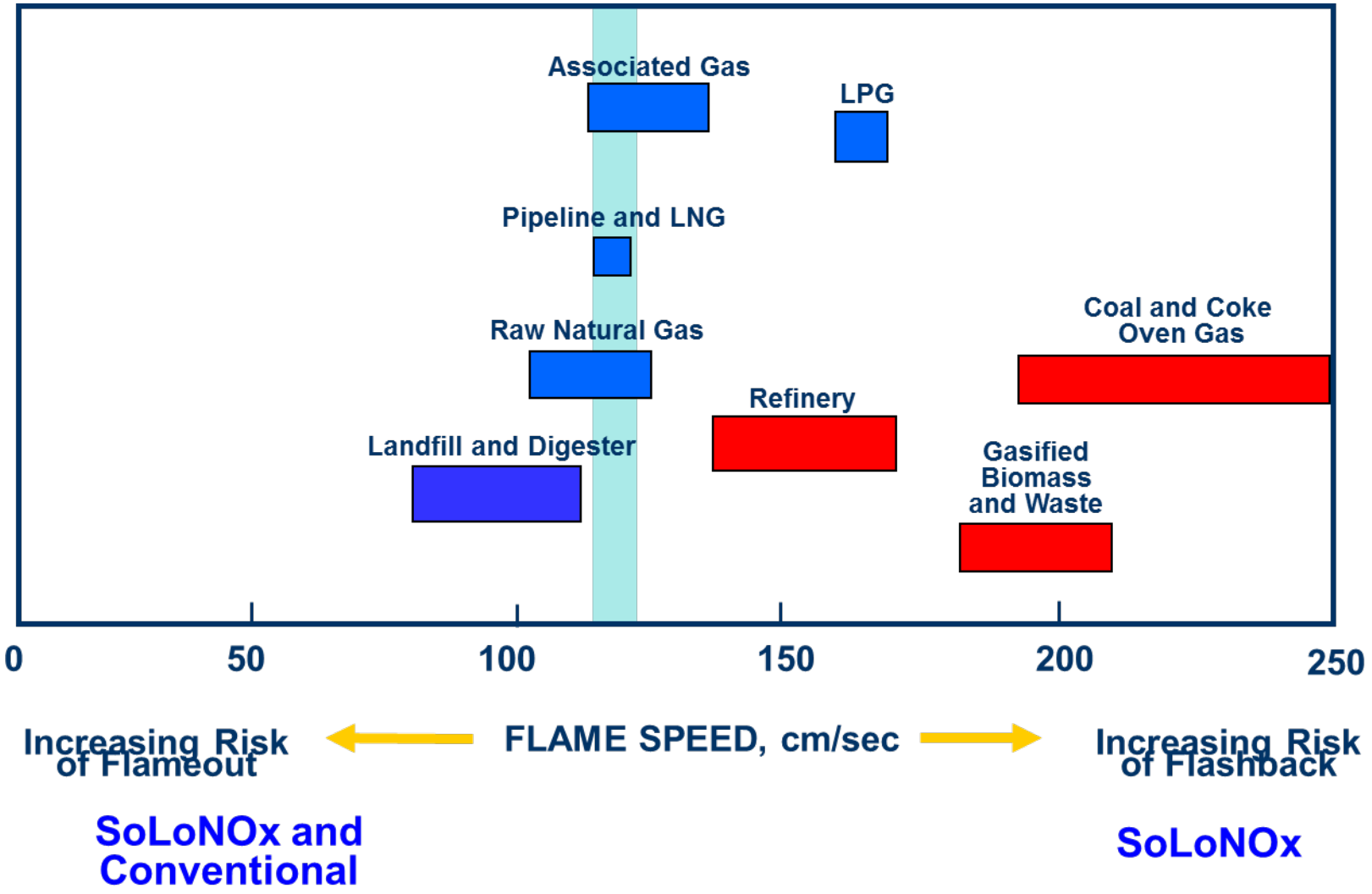

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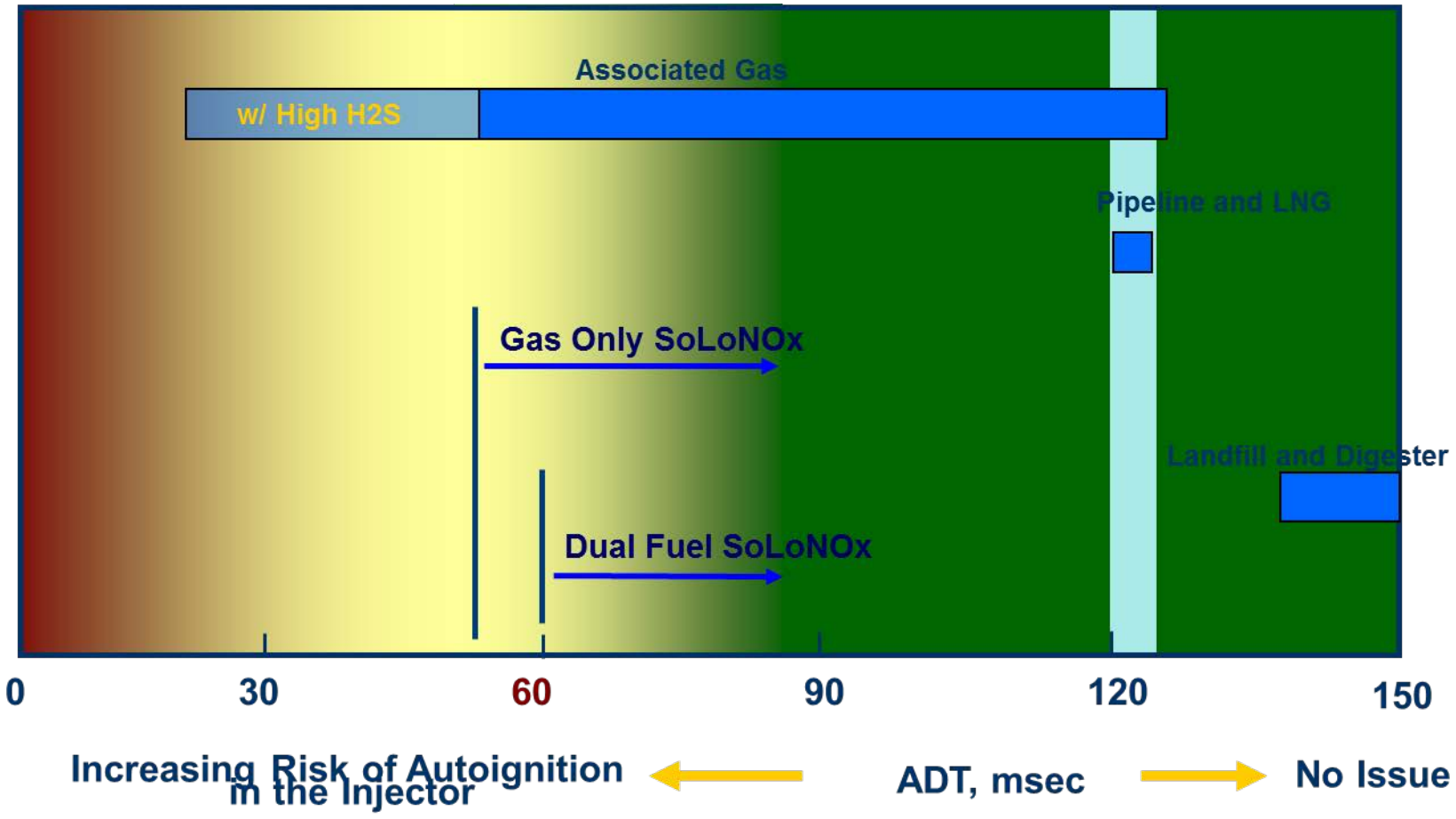

THE IMPORTANCE OF THE FUEL

Concerns on burning H2

- Risk of fail to light during start-up leading to an explosion in the exhaust section
- Resulting fuel/air mixture more likely to be in the flammable range then natural gas
  - Mitigation is to use natural gas or diesel for start-up

THE IMPORTANCE OF THE FUEL

Concerns burning on H2

- Combustor oscillations: different fuel combustion reaction rates could drive combustor pressure instability
- Geometry changes may be required:
  - Flame in the injector premixer: hydrogen has a higher laminar flame speed, thus flame may propagate back up into the premix duct and burn out injectors

THE IMPORTANCE OF THE FUEL

Influence of H2 on the emissions

- Potential for higher NOx emissions
- EU regulations don’t take into account the impact of fuel composition and fuel quality on emissions
- Plants operating prior to JAN 7, 2014 should still have the “other gas” limit of 120 mg NOx.

H2, NOT ONLY A ENGINE MATTER

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H2, NOT ONLY A ENGINE MATTER

Impact on the package design

- Nitrogen purge of fuel gas system after running
- Fire detection: additional detectors required
- Fire suppression: increase of fire suppression gas (CO2)
- Gas detection: catalytic gas sensors are required, increased calibration
- Electrical system to be certified IIB+H2 if Maximum Experimental Safe Gap MESG<0.5
- Hydrogen embrittlement: requires 300 series stainless steel.
- Additional testing (X-ray, hydrostatic testing)

H2, NOT ONLY A ENGINE MATTER

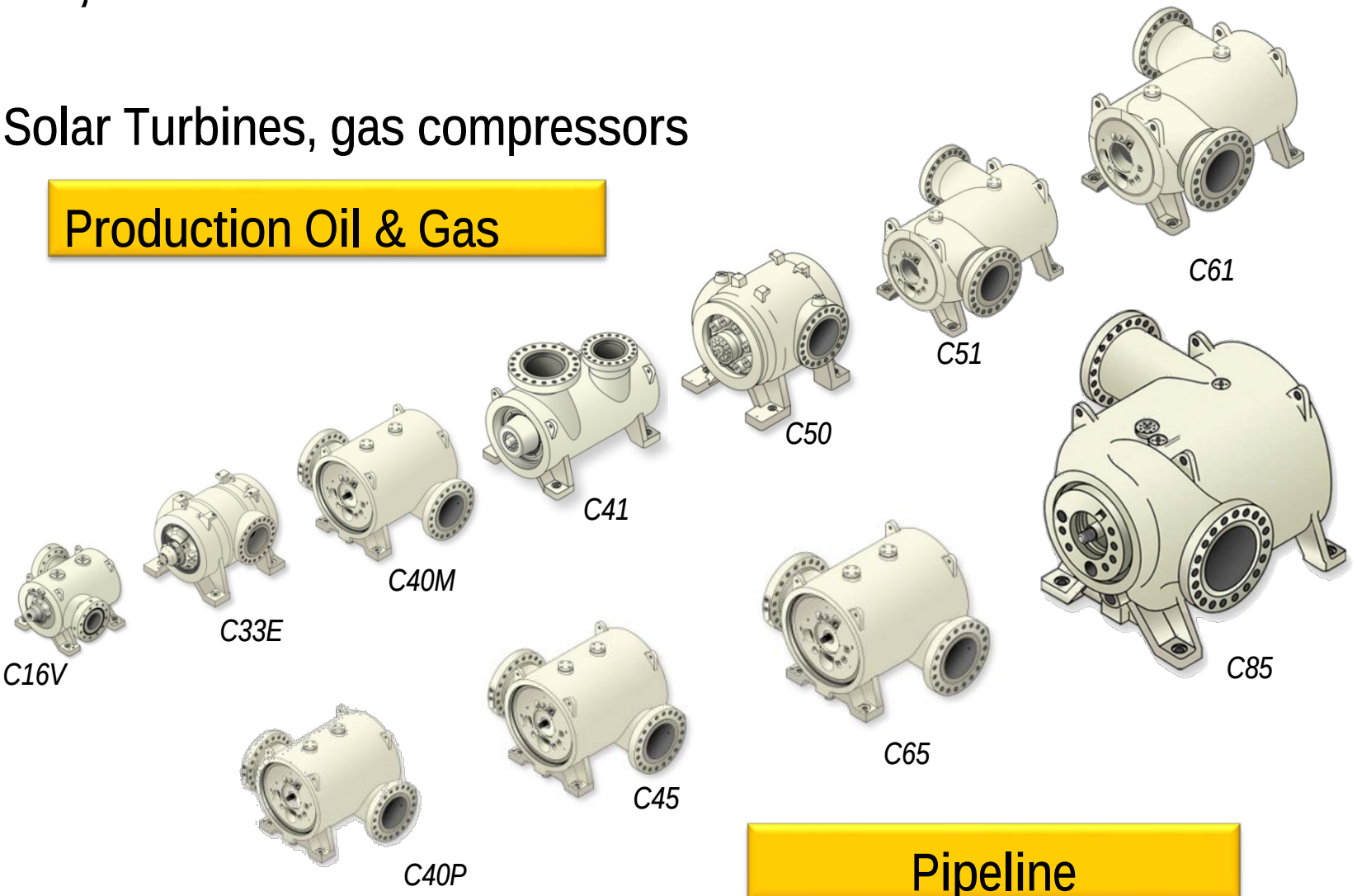
Solar Turbines, a gas turbine manufacturer….

…but not only

H2, NOT ONLY A ENGINE MATTER

Solar Turbines, gas compressors

Production Oil & Gas



Pipeline

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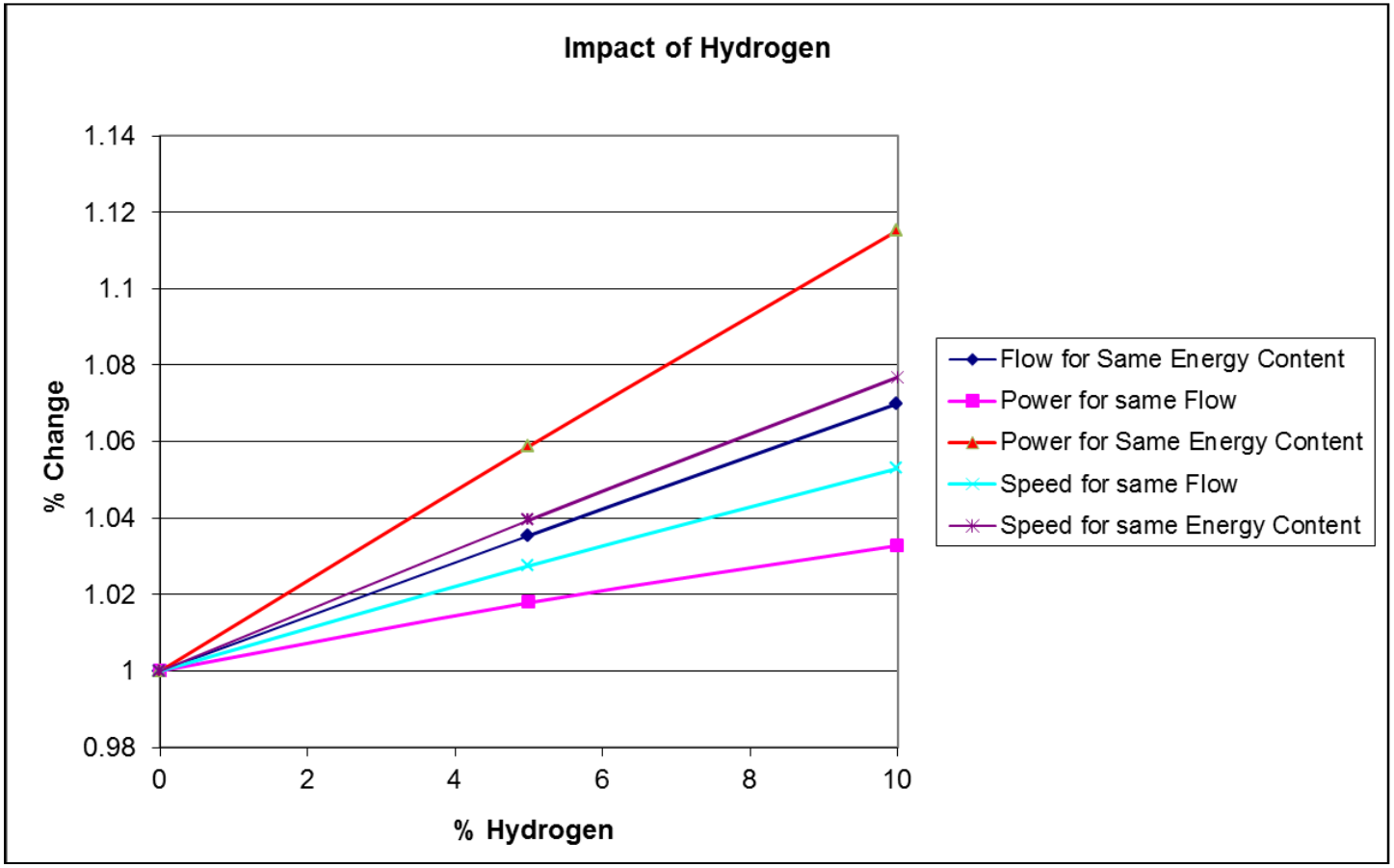
H2, NOT ONLY A ENGINE MATTER

Impact on flow, compressor speed and absorbed power



CONCLUSION

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CONCLUSION

Concerns :

- Start and ramp up
- Flame in the Injector premixer
- Combustor Pressure Oscillation

Further developments and qualifications work required to increase the H2 level to 10%, including a review of the compression capabilities

THANK YOU

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