Metso

The Untapped Potential for Firing Non-Fossil Fuels in Rotary Kilns

by

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TAPPI PEERS
Pulping • Engineering • Environmental
Recycling • Sustainability

PERSONAL BIO PAGE

- Eng.D, University of Sheffield - Mathematical modelling of pf burners
- Metso – Process and CFD Engineer

The Untapped Potential for Firing Non-Fossil Fuels in Rotary Kilns

- Overview of non-fossil fuels and its properties
- Opportunities and benefits
- Process and CFD for optimising burner design
- Operational challenges

Non-Fossil Fuel Options For Paper Mills

- Solid
  - Lignin ✓
  - Biomass ✓
- Liquid
  - Methanol ✓
  - Tall Pitch / Oil ✓
  - Biodiesel ✓
- Gas
  - Hydrogen ✓
  - Gasifier (Producer) gas
  - Ammonia

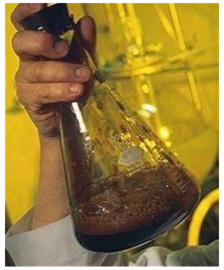
[1] Hart, P.W., 2020. Alternative" green" lime kiln fuels: Part I-Pulping/recovery byproducts. *Tappi Journal*, *19*(5).

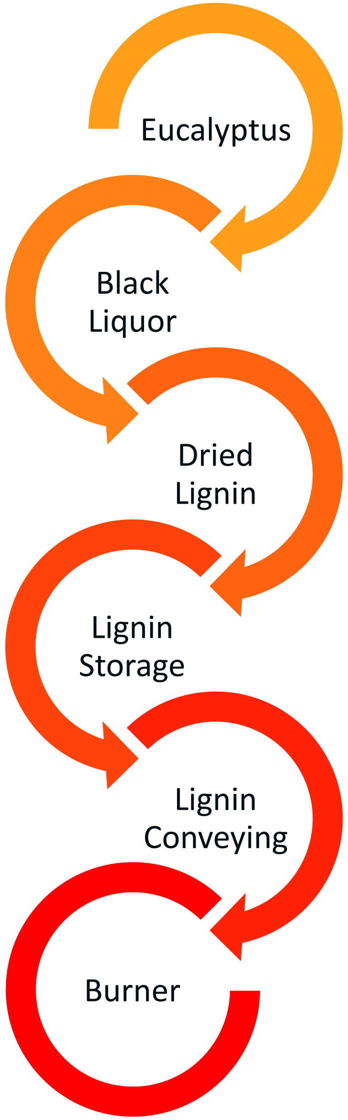
[2] Hart, P.W., 2020. Alternative “green” lime kiln fuels: Part ii—woody biomass, bio-oils, gasification, and hydrogen. *Tappi Journal*, *19*(5), pp.271-279.

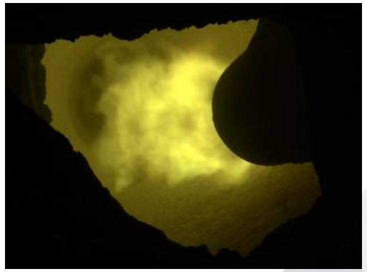
Non-Fossil Fuels Implementation -Solids

Lignin

- Lignin extraction plant, storage, feeders, conveying channels and burner
- Dried and air conveyed to kiln
- Low MIE -> highly explosive
- Challenges in equipment design
- Reduction in NOx from gas to lignin



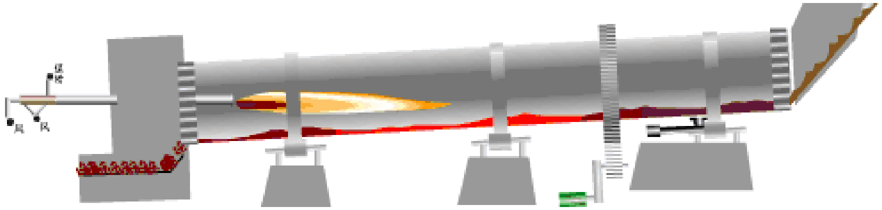




Lignin firing system

Lignin Extraction Plant

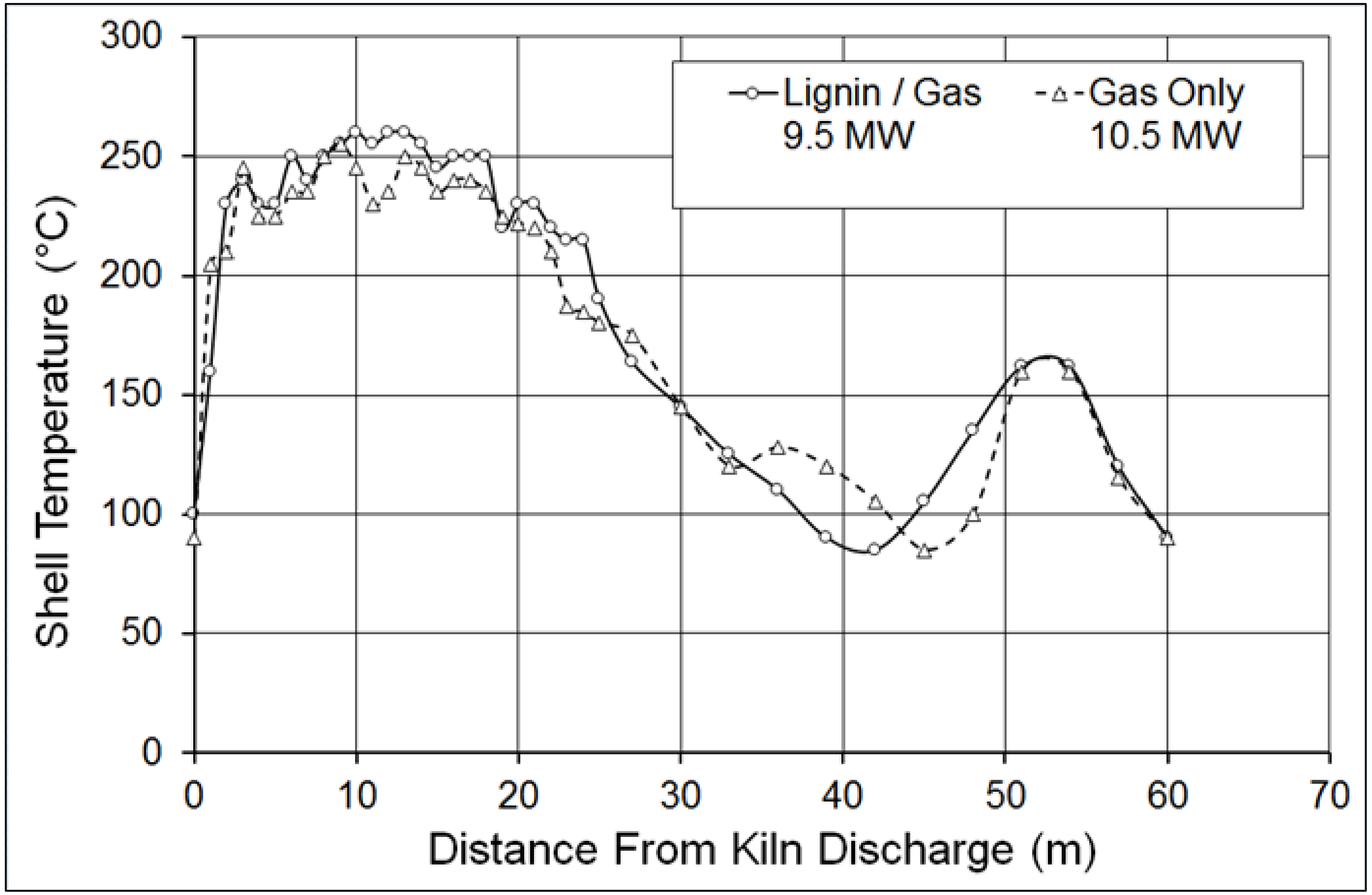
- Silo materials
- Explosion – Ventilation/Suppression
- Fluidisation
- Inerting



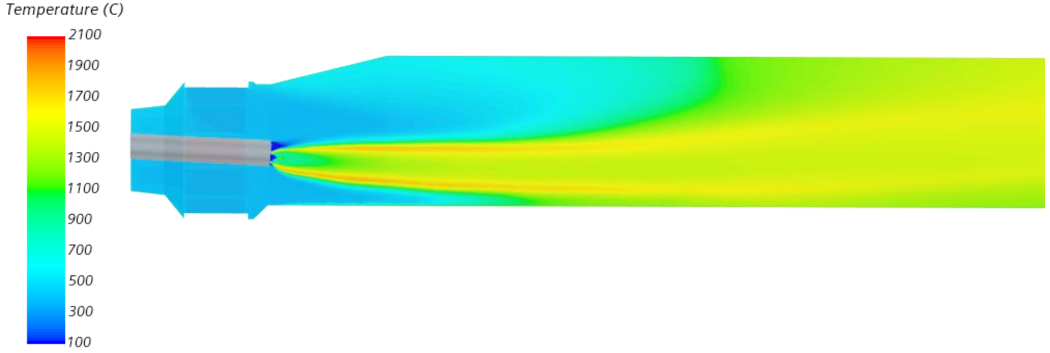
Conveying line ~ 400 ft

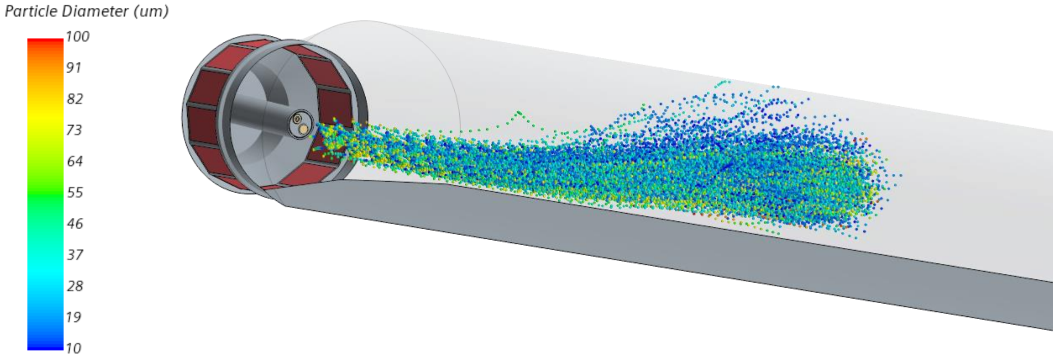
Non-Fossil Fuels Implementation – Solids

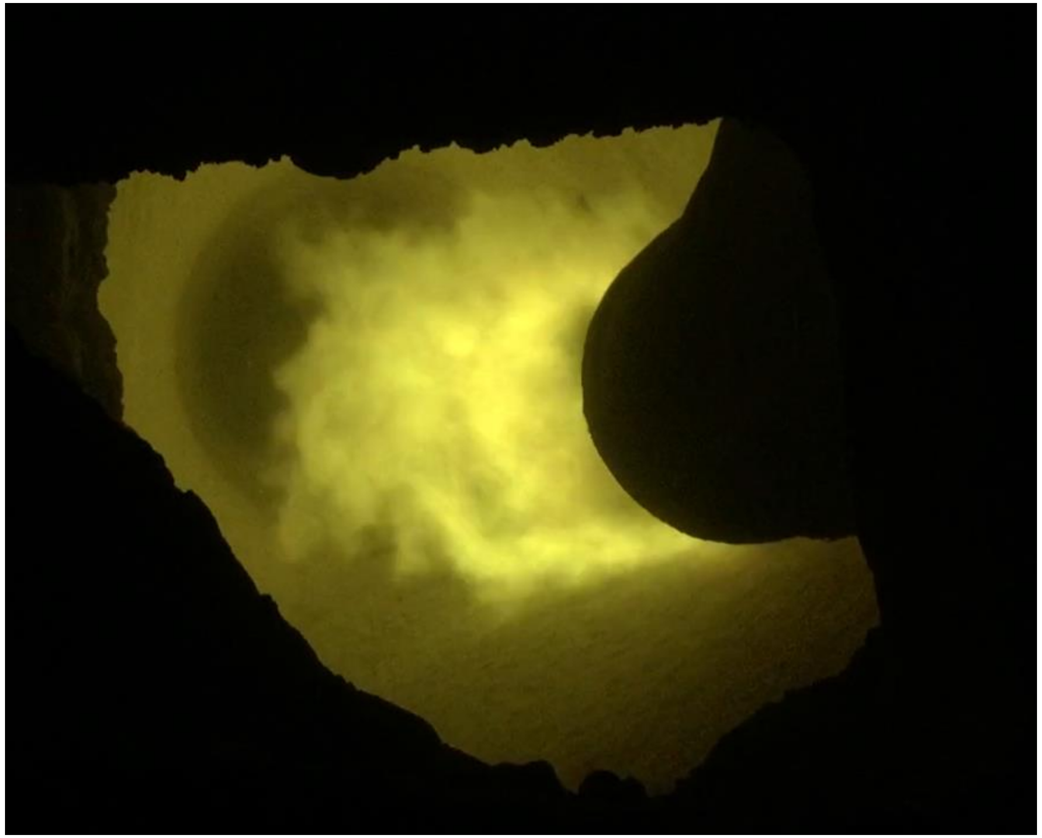
Comparison Gas (100%) vs Lignin/Gas (70%/30%)– Shell Scans



Non-Fossil Fuels Implementation – Solids



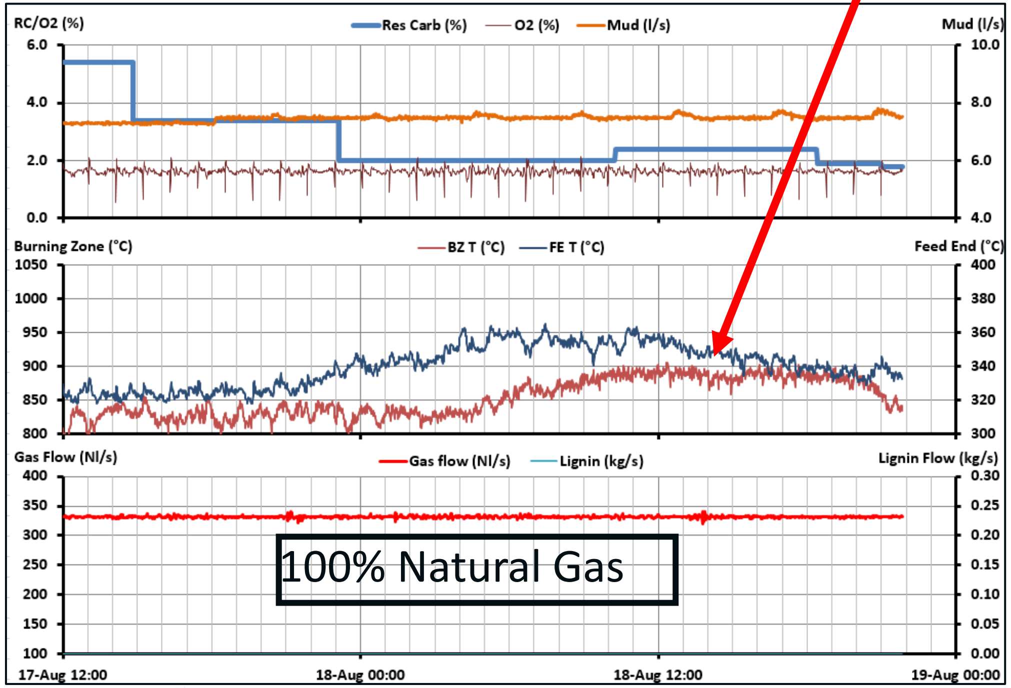


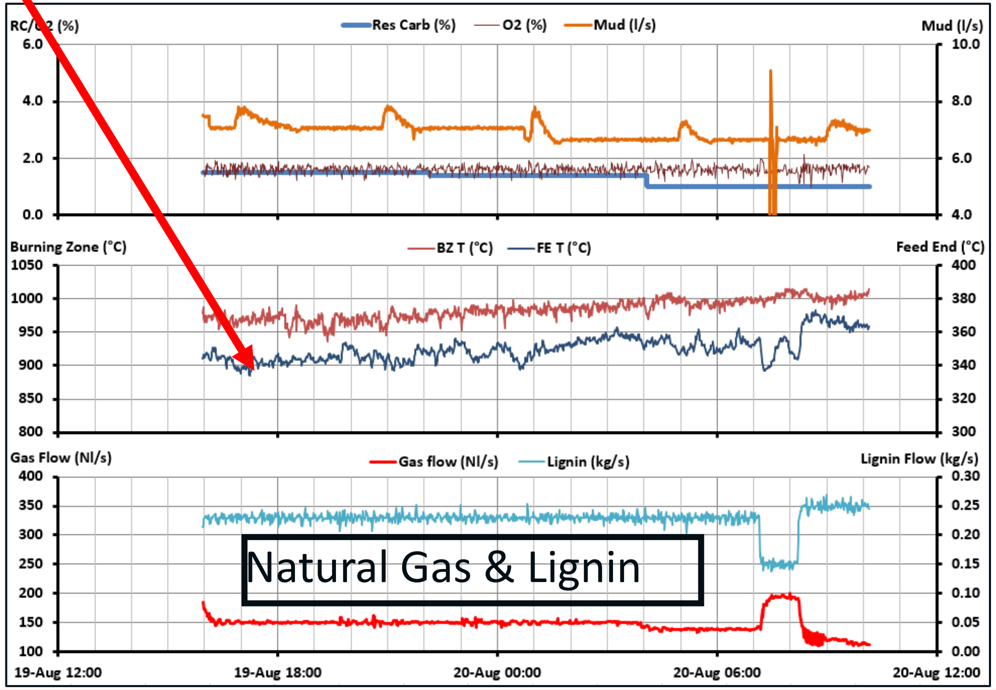


Non-Fossil Fuels Implementation – Solids

Comparison 100% Gas vs. Lignin/Gas

- Similar feed-end temperature - performs like gas

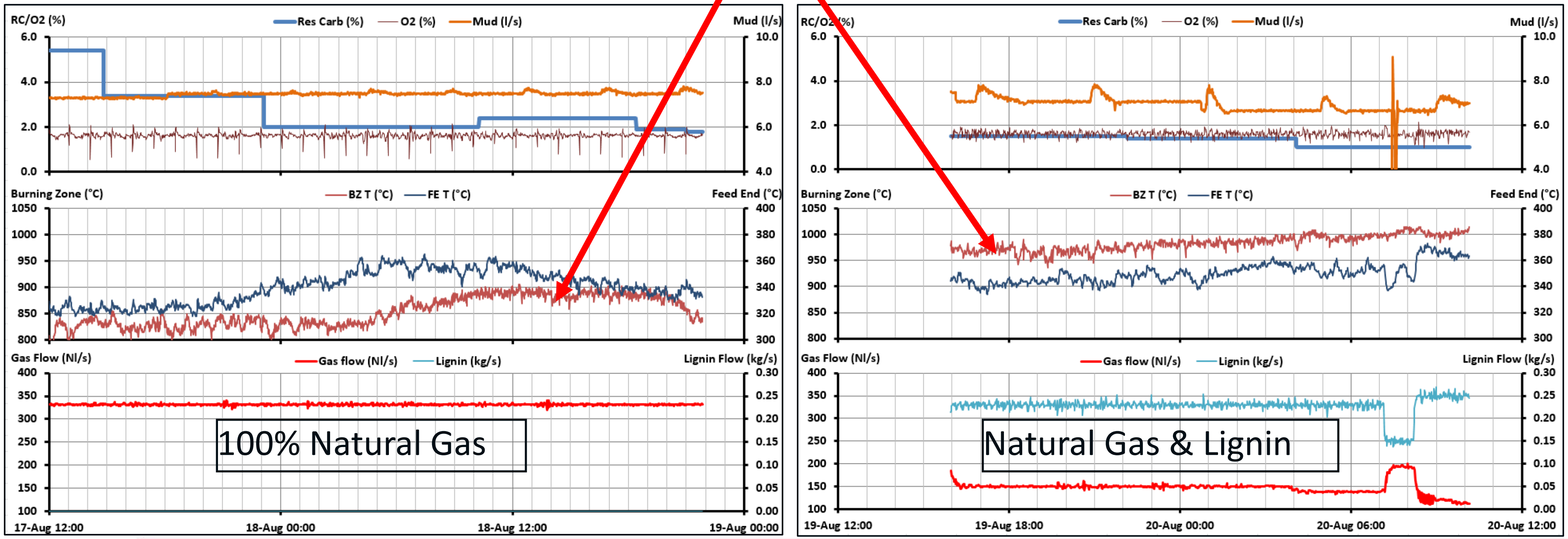




Non-Fossil Fuels Implementation – Solids

Comparison 100% Gas vs. Lignin/Gas

- Similar feed-end temperature - performs like gas
- Lignin has higher burning zone temperature –performs like oil



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Non-Fossil Fuels Implementation – Solids

Comparison 100% Gas vs. Lignin/Gas

- Similar feed-end temperature - performs like gas
- Lignin has higher burning zone temperature –performs like oil
- Similar energy usage per tonne production

Parameter	Value	Units
Corrected Wet Mud Feedrate	5.374	l/s
Wet mud density	1.339	kg/l
Production total	130	te/d
Production CaO	116	te/d
Dust loss	11.3%	% wt
Heat loss	13.4%	%
Corrected Natural Gas	0.332	Nm3/s
Corrected Lignin	0	gpm
Corrected Primary Air	500	l/s
Lignin % Heat	0.0%	%
Total Heat Release (net)	12.0	MW
SFC - total	8.0	MJ/kg
SFC - CaO	9.0	MJ/kg
ENERGY BALANCE	0.1%	
EXCESS AIR	14.3%	%
% PRIMARY AIR	15.7%	%

Parameter	Value	Units
Corrected Wet Mud Feedrate	5.216	l/s
Wet mud density	1.339	kg/l
Production total	125	te/d
Production CaO	113	te/d
Dust loss	11.6%	% wt
Heat loss	13.7%	%
Corrected Natural Gas	0.149	Nm3/s
Corrected Lignin	826	gpm
Corrected Primary Air	550	l/s
Lignin % Heat	54.4%	%
Total Heat Release (net)	11.8	MW
SFC - total	8.2	MJ/kg
SFC - CaO	9.0	MJ/kg
ENERGY BALANCE	0.2%	
EXCESS AIR	14.4%	%
% PRIMARY AIR	18.6%	%

Non-Fossil Fuels Implementation – Solids

Biomass

- Substitution rates dependent on degree of upstream material preparation (namely dryness and firing particle size/uniformity)
- Drying improves the heating value, makes the material easier to transport and burn
  - Material must be assessed on individual basis for most appropriate technology (ring dryer, rotary dryer, belt dryer etc.)
  - Can utilize hot off gases for the kiln for this purpose (low oxygen and recovers waste heat)
- Particle size reduction improves consistency of operation and ease of transportation
  - Material must be assessed on individual basis for most appropriate technology (shredding, milling, grinding etc.)
  - Depending on material, may be possible to combine with drying
- Consideration must be given to Non-Process Elements (NPEs). Sodium, sulfur and chlorine generally not an issue unless excessive but ash content will derate system overtime

Non-Fossil Fuels Implementation – Solids

Summary – Lignin / Biomass

- Commercial scale lignin systems (extraction, kiln firing and packaging) have been implemented and provides similar performance to gas
- Demonstrated NOx reduction (up to 20%)
- Commercial scale biomass systems have been implemented (mostly in Europe) with varied substitution rates subject to material preparation investment

Non-Fossil Fuels Implementation – Liquids

- Methanol and other volatile compound are formed during pulping process
- Crude tall oil -> tall oil pitch is a byproduct of pulping process
- Bio-diesel can be obtained from plants and animal fats

Injected as auxiliary fuel

Atomising media not necessarily required for combustion, can be pressure atomised.

Easy to fire using a similar infrastructure to HFO (need for stainless steel components).

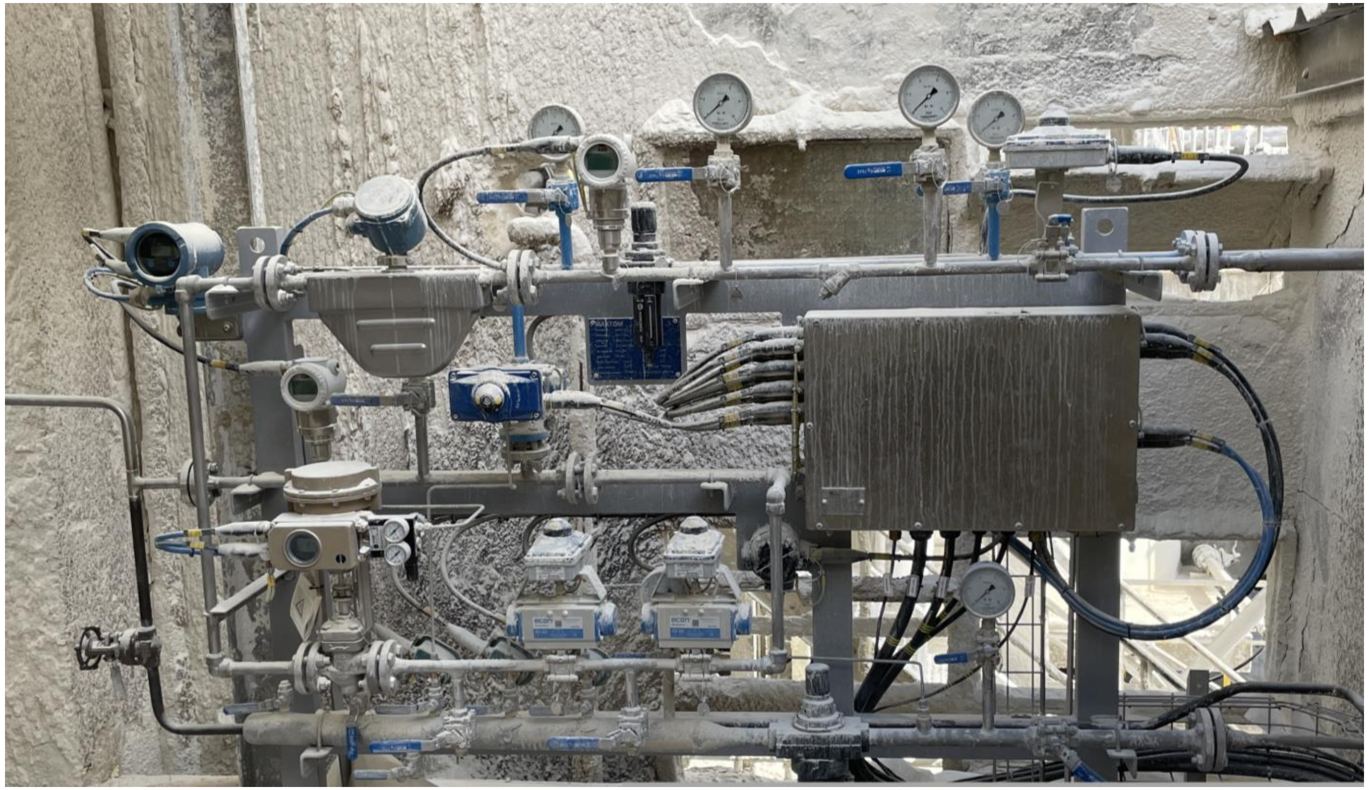
Typically atomised with air (instead of steam) due to lower flash points.

Generally, not pre-heated due to already having suitable viscosity at ambient temperatures.

Non-Fossil Fuels Implementation – Liquids

Methanol

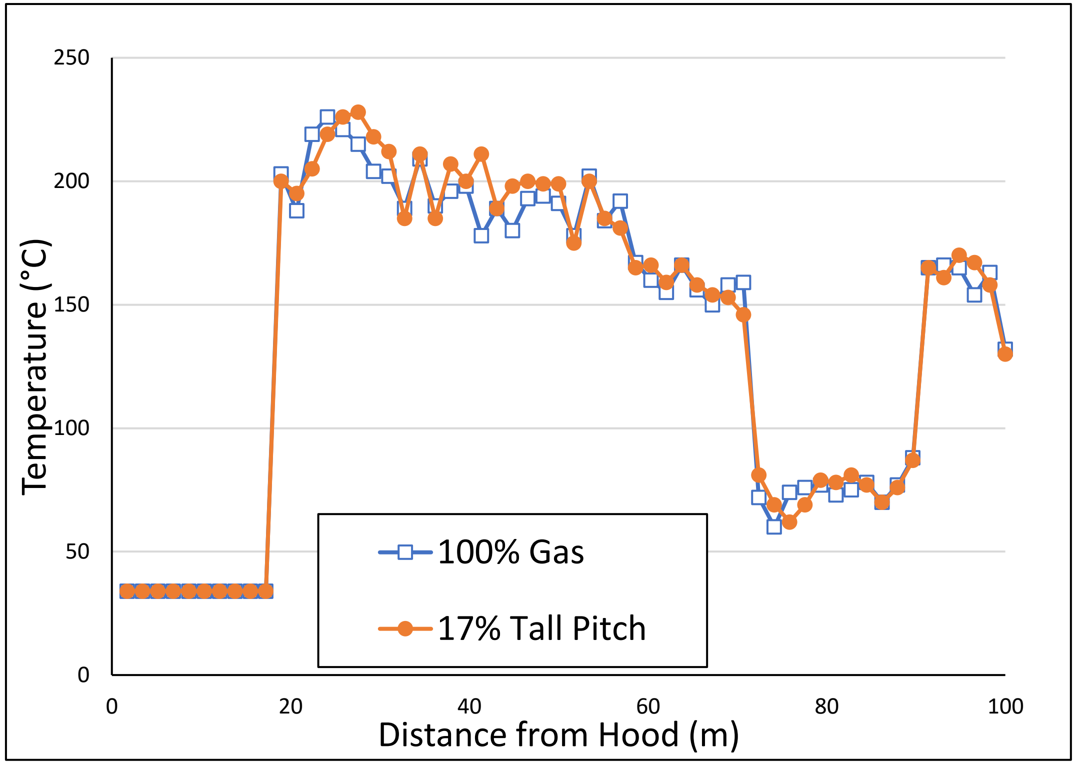
- Methanol firing solution (pump skid, valve skid and firing lance) can be integrated to the existing and new systems
- Methanol is highly corrosive -> Stress cracking -> Higher material grade required
- Methanol firing can improve fuel economy with little to no change in the product quality or operation



Non-Fossil Fuels Implementation – Liquids

Tall Oil Pitch

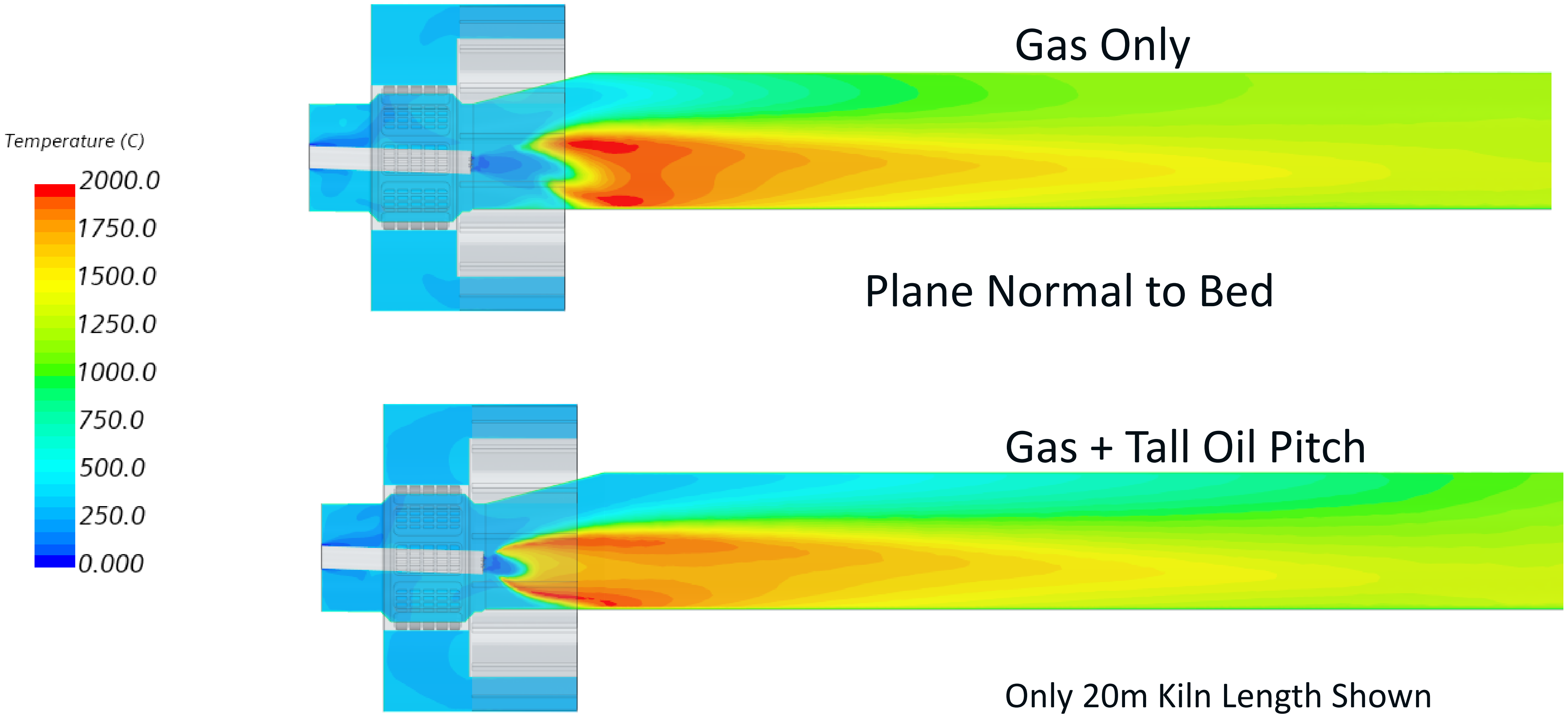
- Tall oil pitch can be fired using existing liquid fuel firing infrastructure (assuming stainless steel)
- The flame and performance is comparable to traditional HFO



Shell scans comparison 100% Gas vs Tall Pitch/Gas 17%/83%

Non-Fossil Fuels Implementation – Liquids

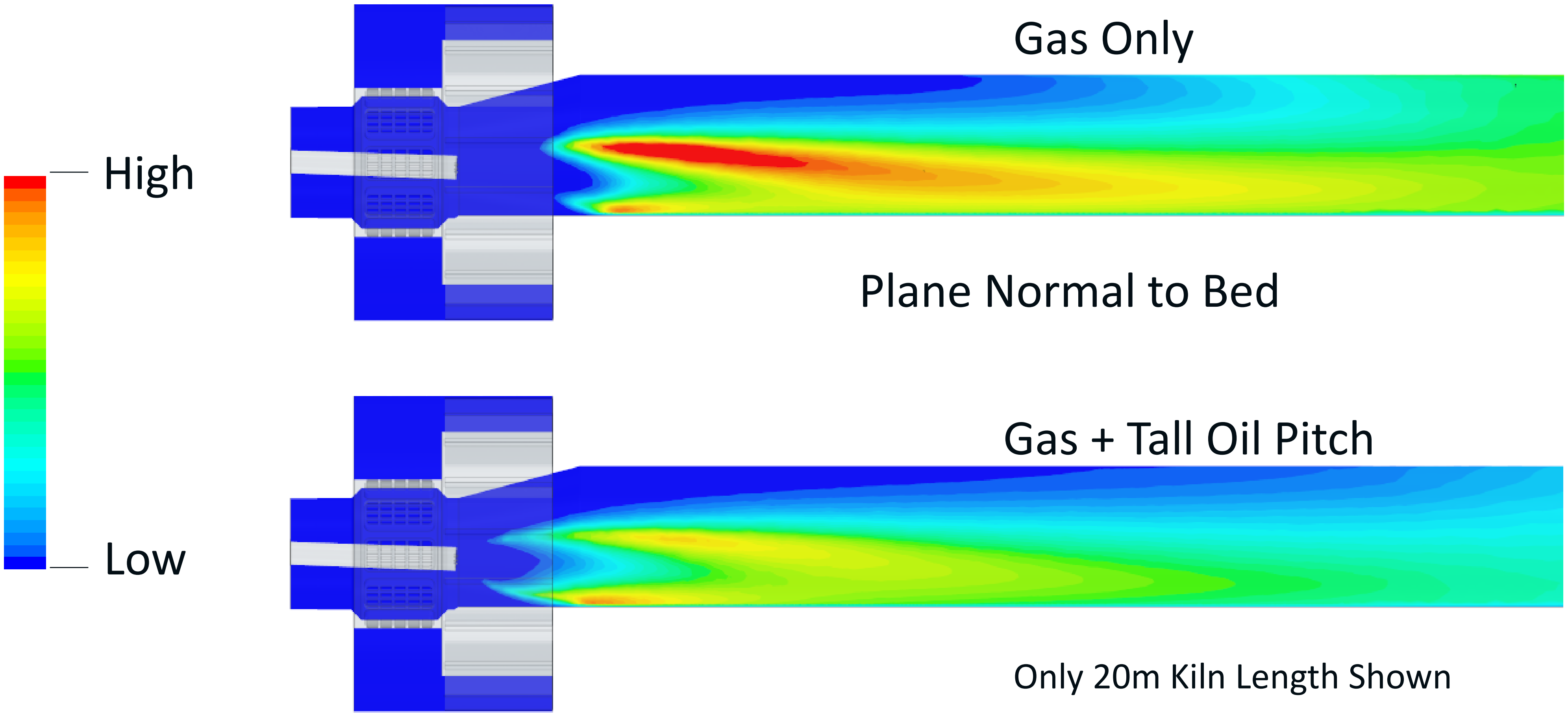
Temperature Contour – Comparison



Only 20m Kiln Length Shown

Non-Fossil Fuels Implementation – Liquids

NOx Contour– Comparison

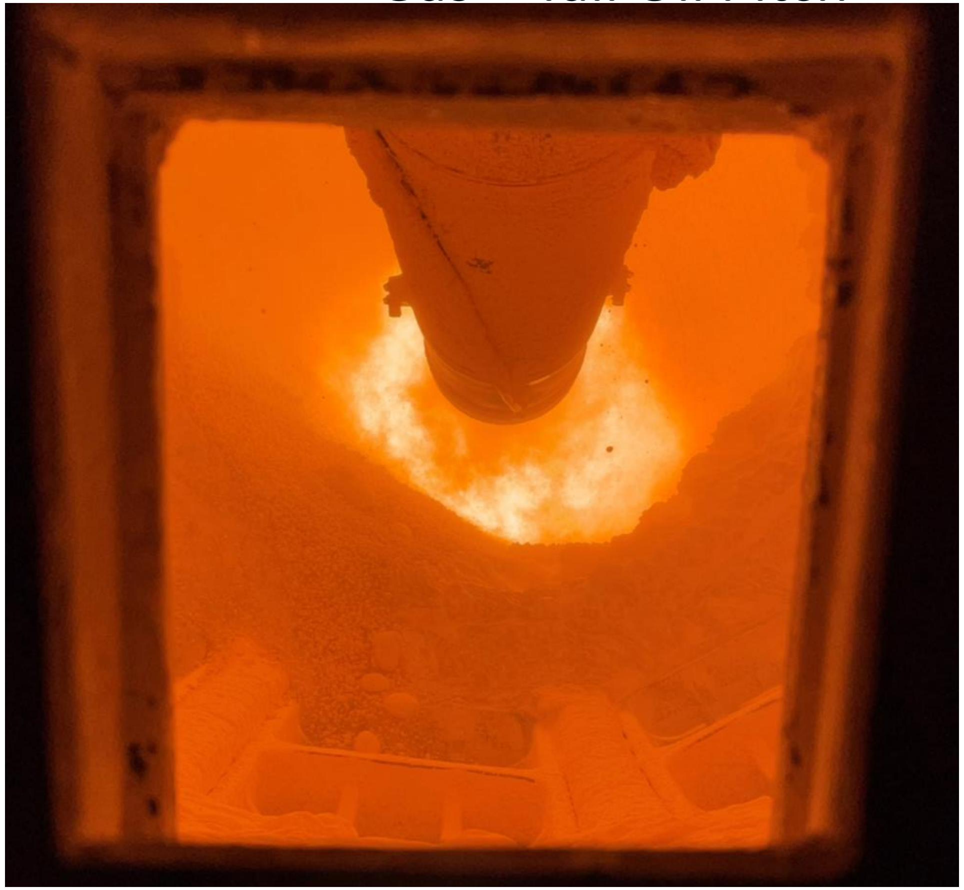


Non-Fossil Fuels Implementation – Liquids

Flame Profile from Site Photos – Gas Only vs Gas + Tall Oil Pitch

Gas Only

Gas + Tall Oil Pitch

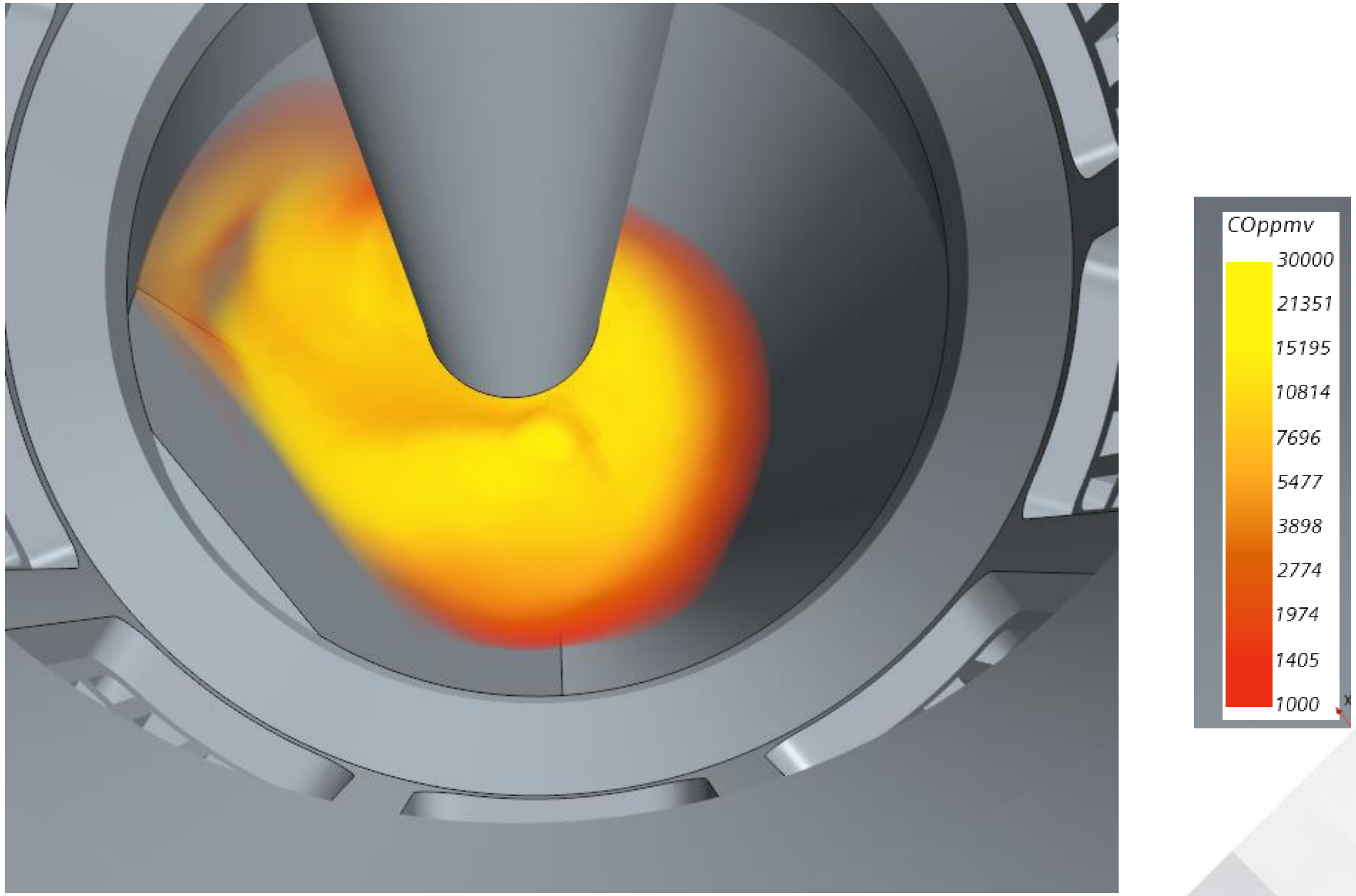


Non-Fossil Fuels Implementation – Liquids

Flame Profiles – Site vs CFD Gas Only

Site

CFD

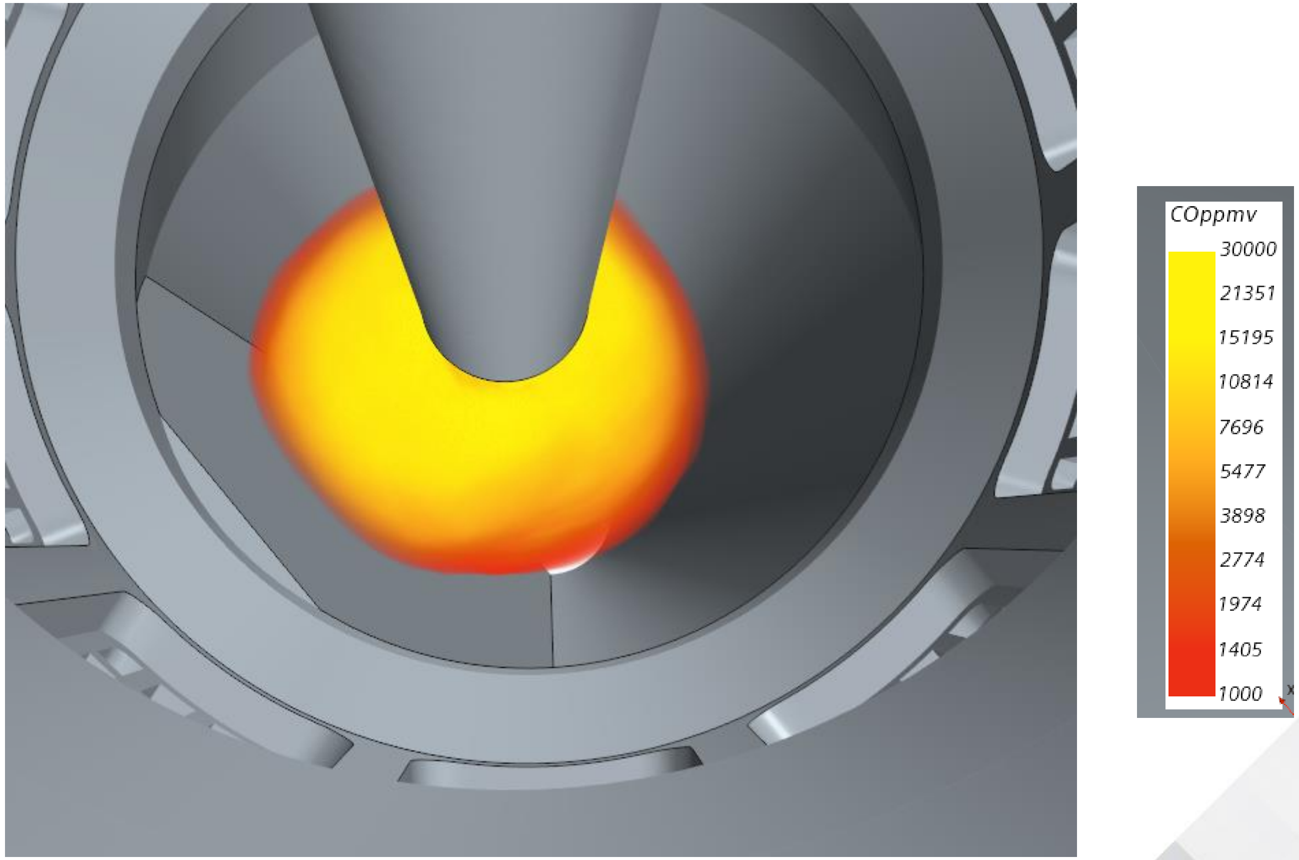


Non-Fossil Fuels Implementation – Liquids

Flame Profile – Site vs CFD Gas + Tall Oil Pitch

Site

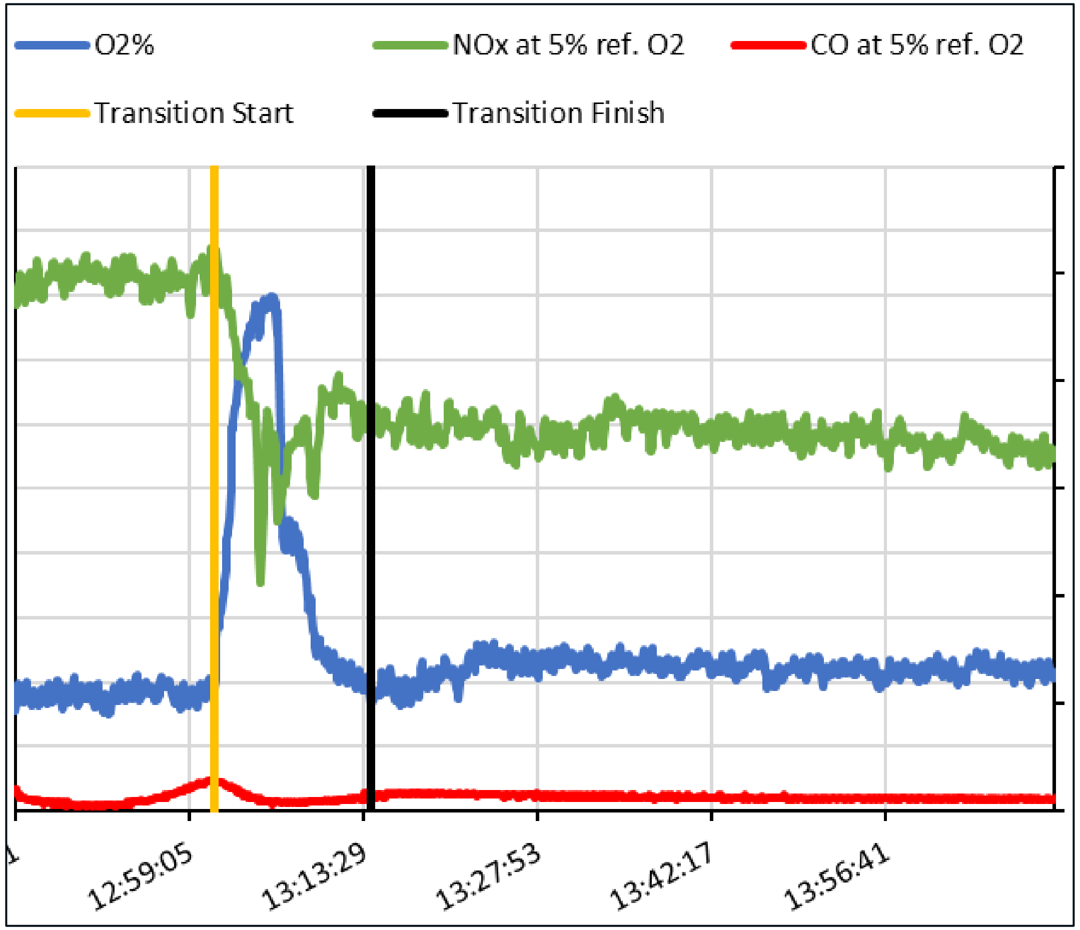
CFD



Non-Fossil Fuels Implementation – Liquids

Summary – Tall Oil Pitch

- Cofiring results in improved product quality due to increase in radiative heat transfer
- Potential NOx reduction with moderate substitution rates (up to 30% reduction in some cases)
- A similar trend can be observed when firing bio-diesels
- Each fuel needs to be assessed individually (viscosity, materials of construction etc.)



Non-Fossil Fuels Implementation – Gases

Hydrogen

- Hydrogen as a fuel is classified in three main types:
  - Grey – from fossil fuels
  - Blue – From fossil fuels with CCS
  - Green – Clean or renewable energy
    - e.g. Electrolysers combined with wind/solar

Advantages

- Reduction in carbon emissions

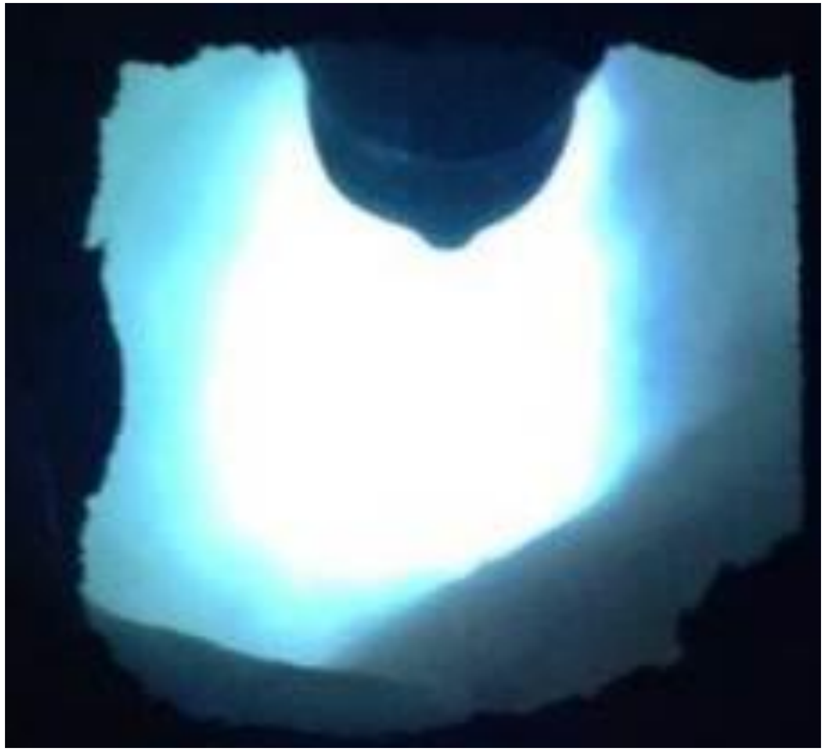
Challenges

- Infrastructure
- Expensive to produce
- Highly flammable -> Difficult to handle
- Turndown

Non-Fossil Fuels Implementation – Gases

Equipment Challenges for Hydrogen firing

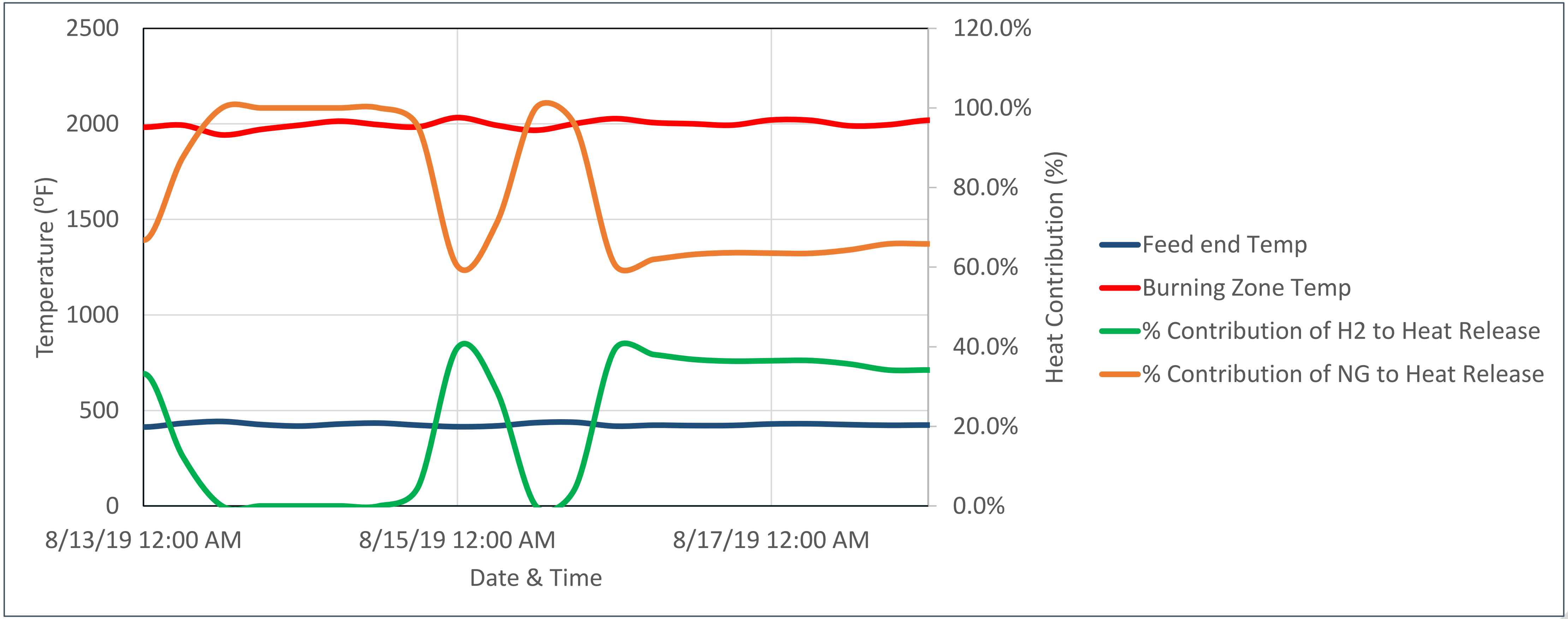
- Standard natural gas pipeline materials are suitable for low hydrogen substitution, typically 5-20% vol range
- Material durability – Embrittlement (Nickel based alloys to be avoided)
- Smaller molecule (low density), highly volatile and high tendency to leak compared to natural gas -> Integrity management system (leak detection, monitoring device etc.)
- Storage can be eliminated if electrolytic cells are used in an online integrated manner
- Burner specific
    - High flame propagation velocities -> High exit velocities at the burner tip to avoid overheating
    - Higher NOx
    - Less radiative flame -> lower efficiency (subject to substitution rates)



Hydrogen Combustion

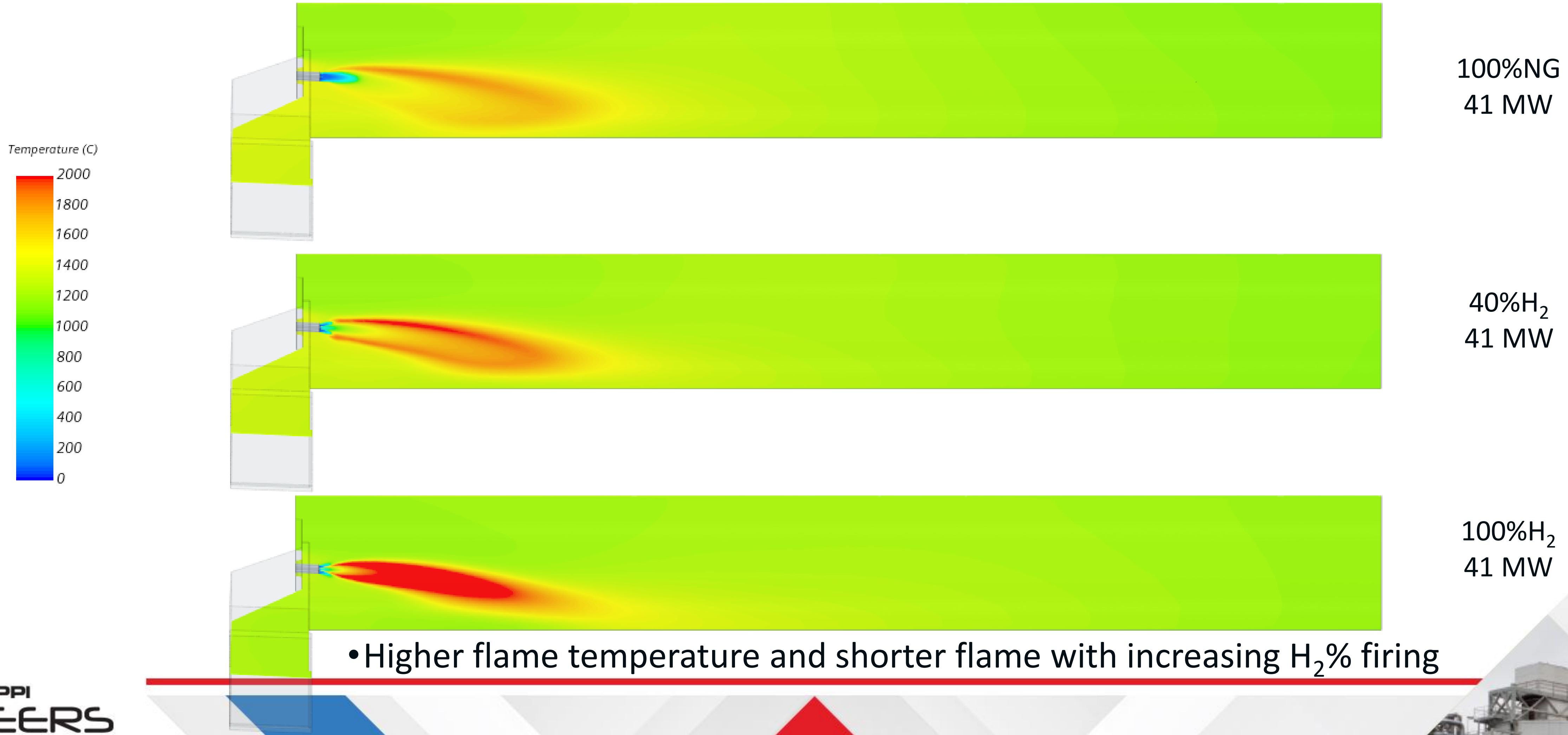
Non-Fossil Fuels Implementation – Gases

Hydrogen Firing Impact



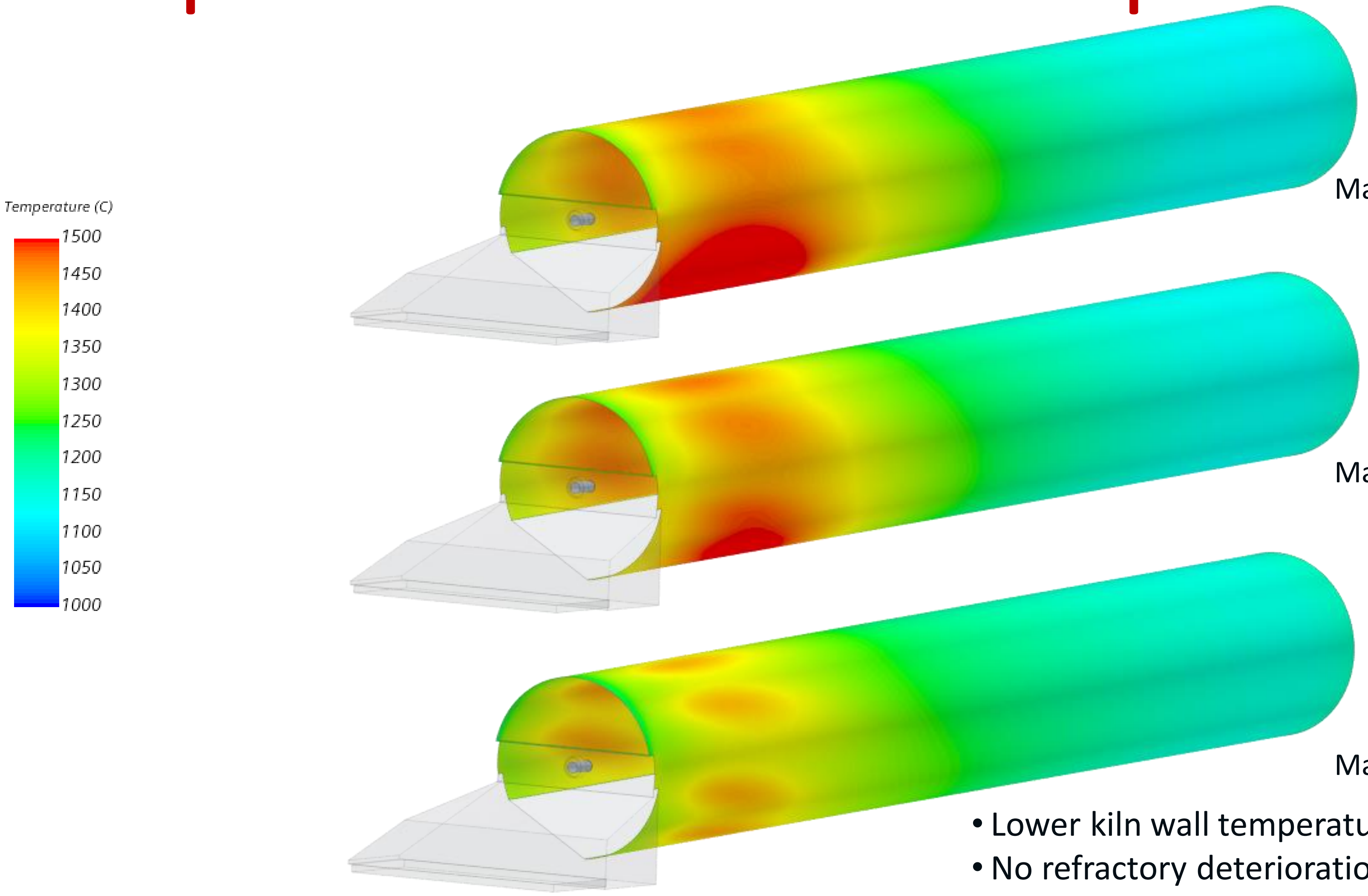
Comparison of Temperature Profile

Plane Normal to Bed



- Higher flame temperature and shorter flame with increasing H_2% firing

Comparison of Kiln Wall Temperature



100%NG
41 MW

Max. Wall Temperature: 1597°C

40%H_2
41 MW

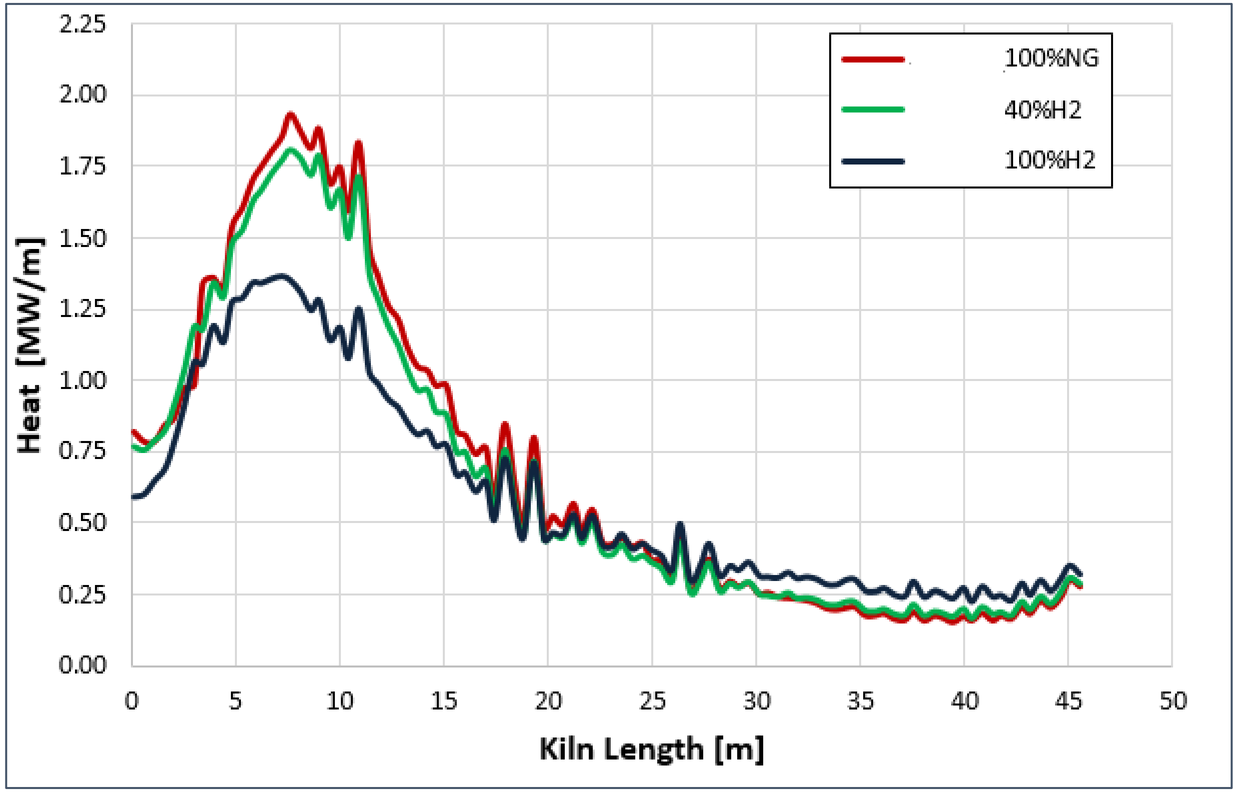
Max. Wall Temperature: 1533°C

100%H_2
41 MW

Max. Wall Temperature: 1441°C

- Lower kiln wall temperature at 100% H_2 firing
- No refractory deterioration at 100% H_2 firing (H_2 has a shorter flame and is less radiative)

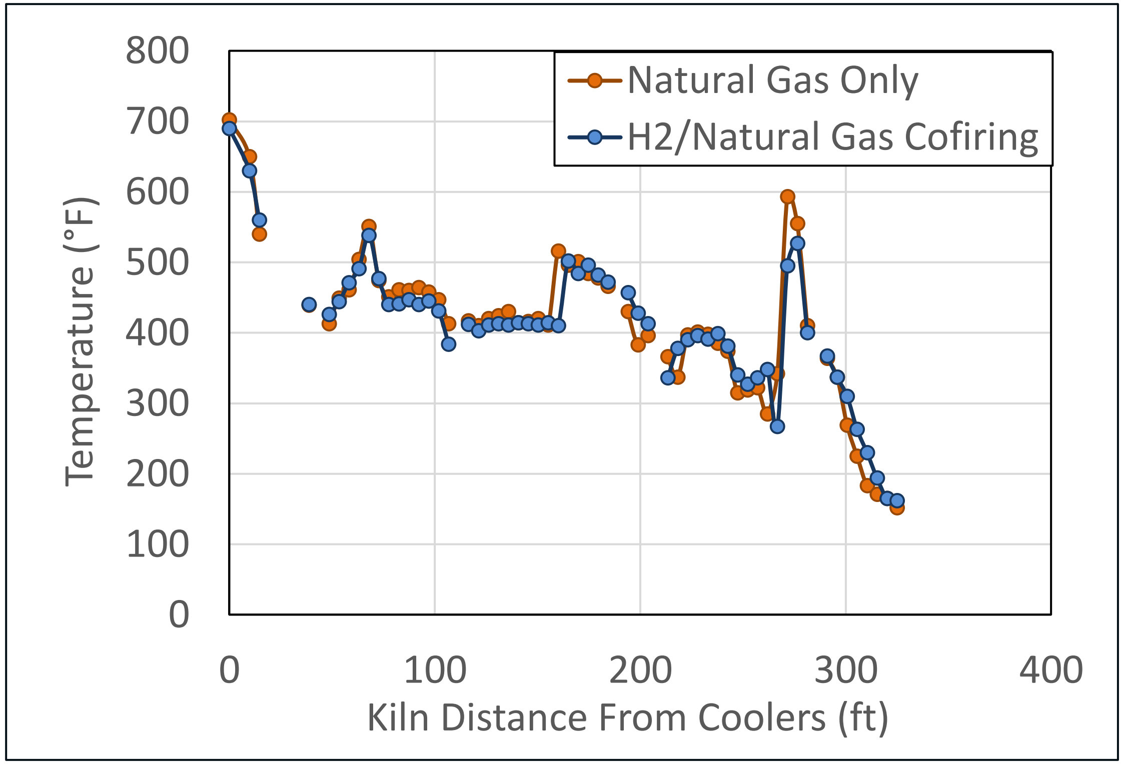
Material Bed Heat Flux Profile



Non-Fossil Fuels Implementation – Gases

Summary - Hydrogen

- The burning zone temperature indicates a steady profile during H2 cofiring phase
- There is no accelerated refractory wear on the kiln
- The product quality can be maintained for H2 substitution of up to 30-40% of heat input
- Hydrogen firing requirements
  - High grade materials
  - Good monitoring system
  - Sustainable supply/production



Thank you for your attention
Questions??