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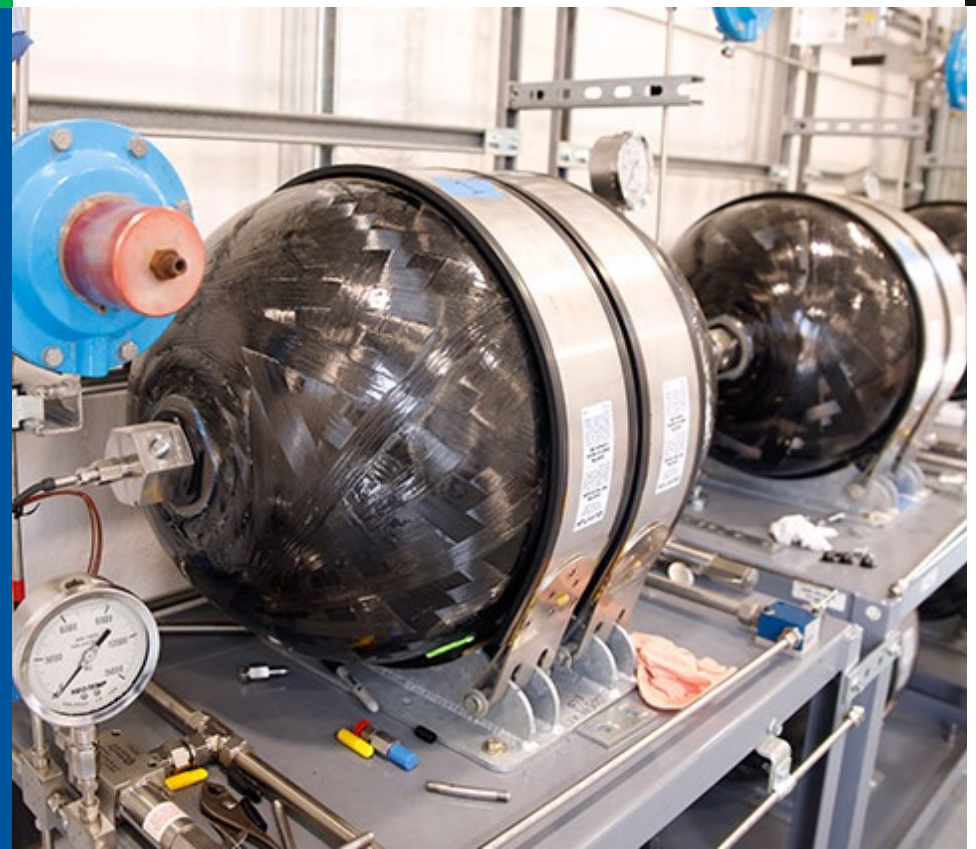
solutions that transform



# R-GAS *Plus*: A Pioneering Pathway for Maximizing Yields of Biofuels from Biomass Gasification

Zach El Zahab, Ph.D. , *Program Director*

IEA Task 33 Workshop on Gasification and Chemicals

12-June-2024

# GTI Energy Overview

GTI ENERGY

*We occupy a unique space between **tradition** and **innovation***

- Moving energy systems solutions from **concept to market**
- Where partners go to **de-risk experimentation**
- Expertise in integrated systems and **low-carbon gases, liquids, infrastructure and efficiency**

**Valued Partners**

**175+**

80+ years of experience and leadership in energy production, storage, delivery and use

**Research & Development**

**$1B+**

In the past decade

Leading and convening collaborative R&D

**Innovation & Commercialization**

**1,300+**

Patents

**500**

Products

**750+**

Licensing Agreements

**10+** Industry Collaboratives

OTD Operations Technology Development

UTD Utilization Technology Development

ETP Emerging Technology Program

LCRI Low-Carbon Resources Initiative

Project ASTRA

Hydrogen Technology Center

$H_4$ Collaboratory

$H_2$@Scale

HyPER

VERITAS

Open Hydrogen Initiative

# We develop, scale and deploy solutions in the transition to low-carbon, low-cost energy systems

GTI ENERGY

## GTI Energy is a leading energy research and training organization

SOURCE | MAKE | MOVE | STORE | USE


**500+** Enterprise Employees

TOP WORK PLACES 2019 Chicago Tribune
TOP WORK PLACES 2020 Chicago Tribune
TOP WORK PLACES 2021 Chicago Tribune
TOP WORK PLACES 2022 Chicago Tribune
TOP WORK PLACES 2023 Chicago Tribune

We work collaboratively to address critical energy challenges impacting gases, liquids, efficiency and infrastructure

OTD Operations Technology Development

UTD Utilization Technology Development

ETP Emerging Technology Program

LCRI LOW-CARBON RESOURCES INITIATIVE

# GTI Energy Gasification Heritage

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Renewable Energy Transition

Syngas to Power
- Integrated-Gasification Combined Cycle
- Gasification to Direct Super-Critical CO2
- Partial Oxidation Turbine

Syngas to Products
- Fuels
- Chemicals
- Synthetic Natural Gas

Feedstocks
- Coal
- Biomass

**R-GAS™ Pilot Plant**

**R-GAS™ 800 tpd Demo**

Shanxi - 2020

**Advanced Gasification Test Facility**

**Flex Fuel Test Facility**

Shanghai Plant - 1995

2020

2010

2000

1990

1980

1970

1960

1950

1941

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**RENUGAS Pilot Plant**

**U-GAS Pilot Plant**

**HYGAS Pilot Plant**

Early PDU

gti

gri

Skive - 2007

Zaozhuang - 2007

Lab Facility - 1947

Dr. James L. Johnson

Yima - 2012

SunGas RENEWABLES

HALDOR TOPSØE CATALYSING YOUR BUSINESS

AEROJET ROCKETDYNE

ANDRITZ

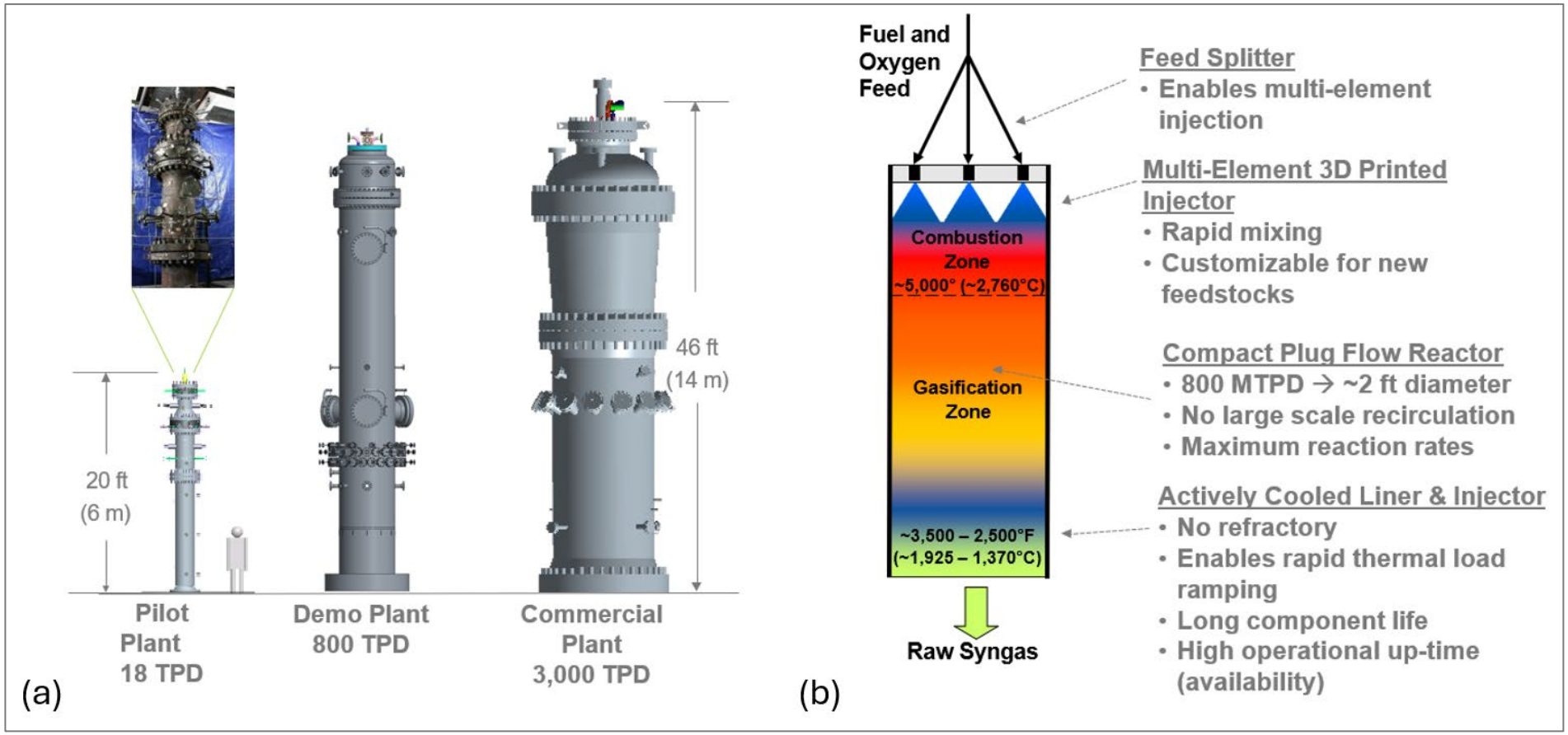
e·on

UPM

GreatPoint ENERGY

SES SYNTHESIS ENERGY SYSTEMS

# R-GAS Technology Background



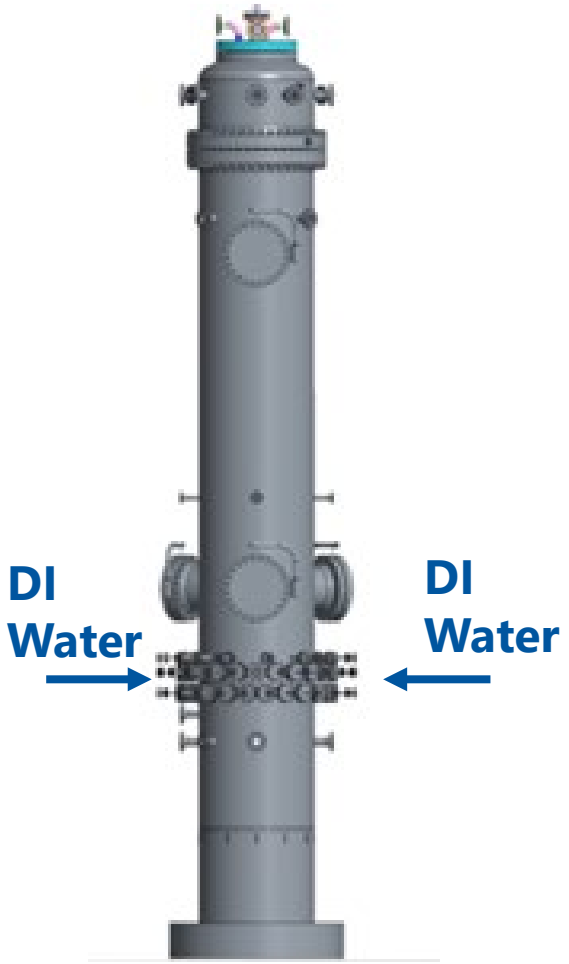
# R-GAS Pilot Facility


- Rated for 18 TPD coal or biomass
- Flexible test facility to evaluate advanced gasification and sygnas post-treatment technologies
- Fully integrated pilot plant to address the "real-world" aspects of gasification operations at relevant scale
- Full suite of instrumentation and analytical laboratory capability to provide detailed performance data

**Enables evaluation and verification of operation with new feedstocks at relevant scale and conditions**

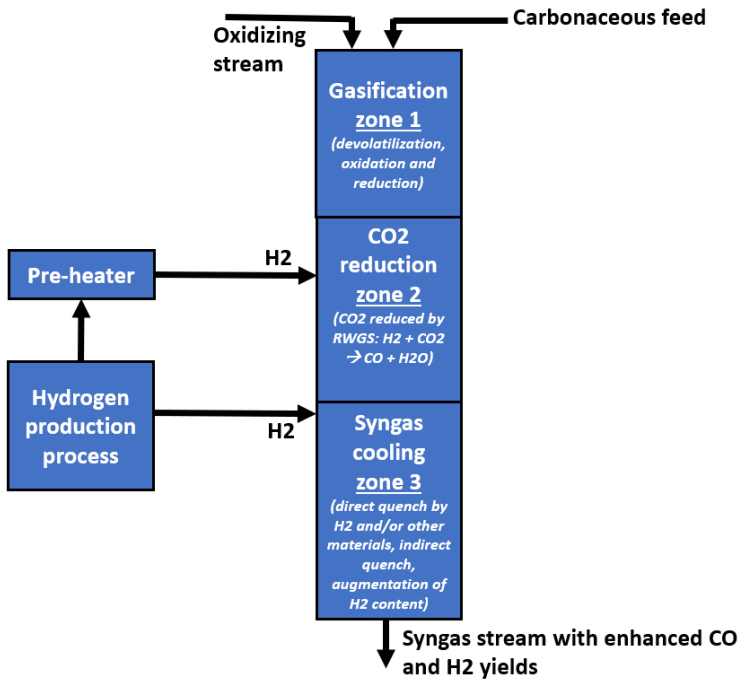
# R-GAS Rapid Quench Shortcomings

- The R-GAS entrained flow technology can operate at very high temperatures (>2500C) thanks to its unique and sophisticated rapid-mixing and water-cooling schemes that are inspired from combustion and cooling techniques that are employed in rocket engine technologies → high carbon conversion efficiencies.
- The expected temperatures of the syngas exiting the gasification zone can be in the 1450C to 1550C range depending on the ash fusion temperature and need to be cooled quickly.
- Traditionally, we have implemented a 'rapid quench' system whereby deionized (DI) water is injected right at the gasification zone exit to quickly cool the syngas down to temperatures (<350C).
- 'Rapid quench' comes at the expense of the overall R-GAS island thermal efficiency, i.e., we are not optimally recovering the energy input to produce the significant quantities of O2 for the R-GAS high temperature operation.

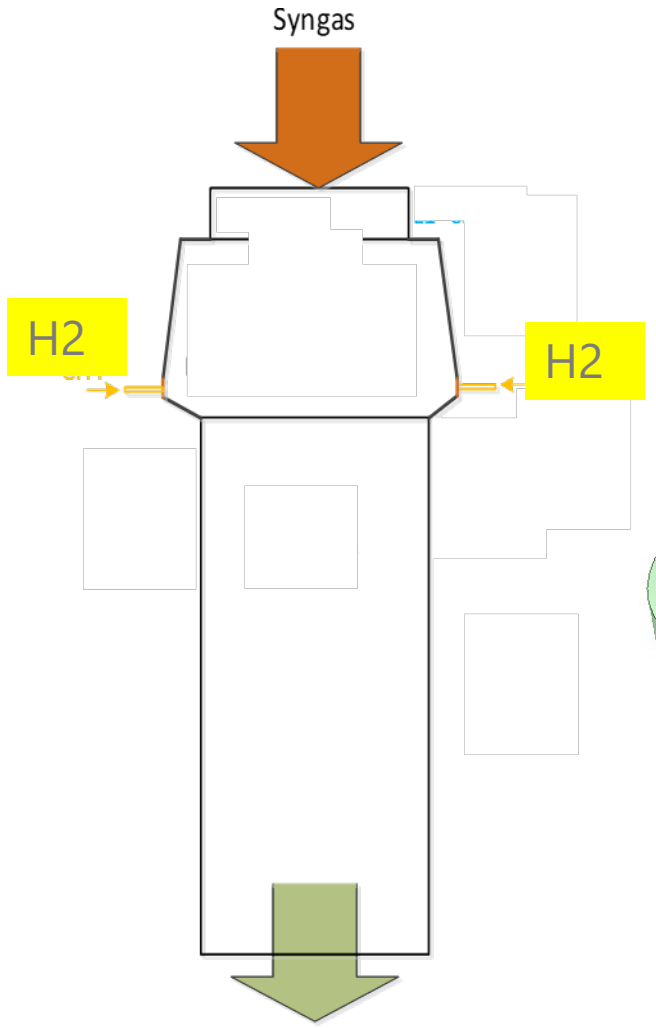


# R-GAS *Plus* Syngas Enhancement Solution

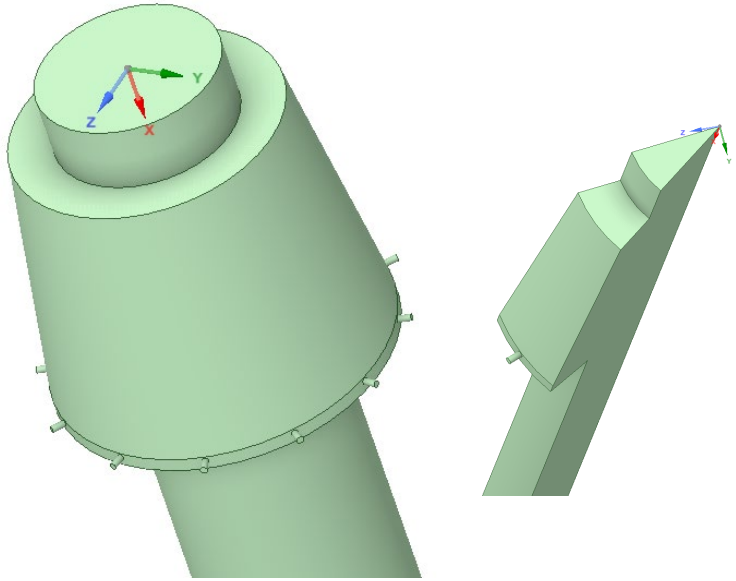
- The current R-GAS technology roadmap entails developing novel techniques that would utilize the heat in the syngas exiting the gasification zone to improve the final biofuel product yields and the overall thermal efficiency of the biorefinery.
- We have invented a new technique that relies on cooling the syngas through fast-reacting endothermic chemical reactions, namely reverse water gas shift (non-catalytic).
- Hydrogen can be indirectly heated by syngas and injected right at the R-GAS gasification zone exit to quickly react with the CO2 gasification products and endothermically cool the syngas down to temperatures in the ~1100-1150 degC range.
- This technique takes great advantage of the high heat content in the syngas to drive the fast endothermic reactions, significantly reducing the residence time for the conversion of CO2 into CO.



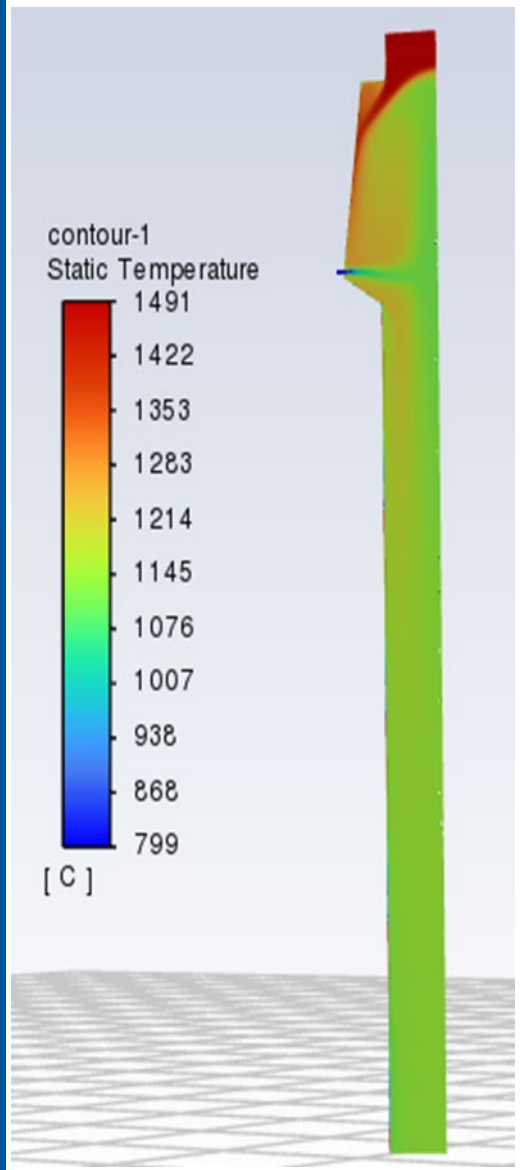
# H2 Injection Simulation

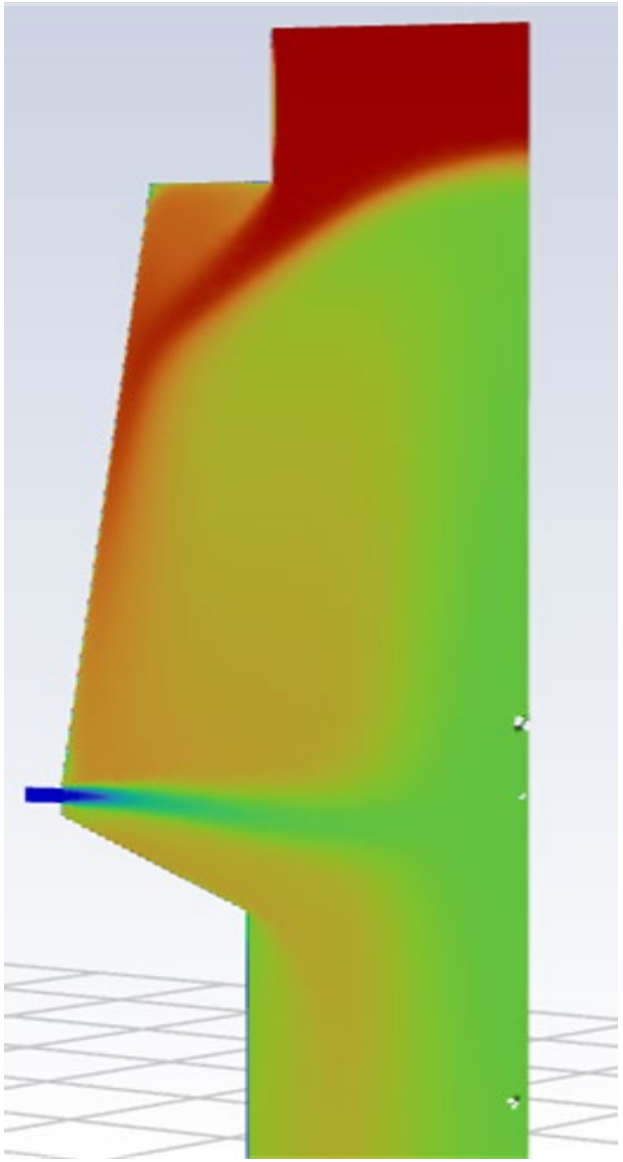


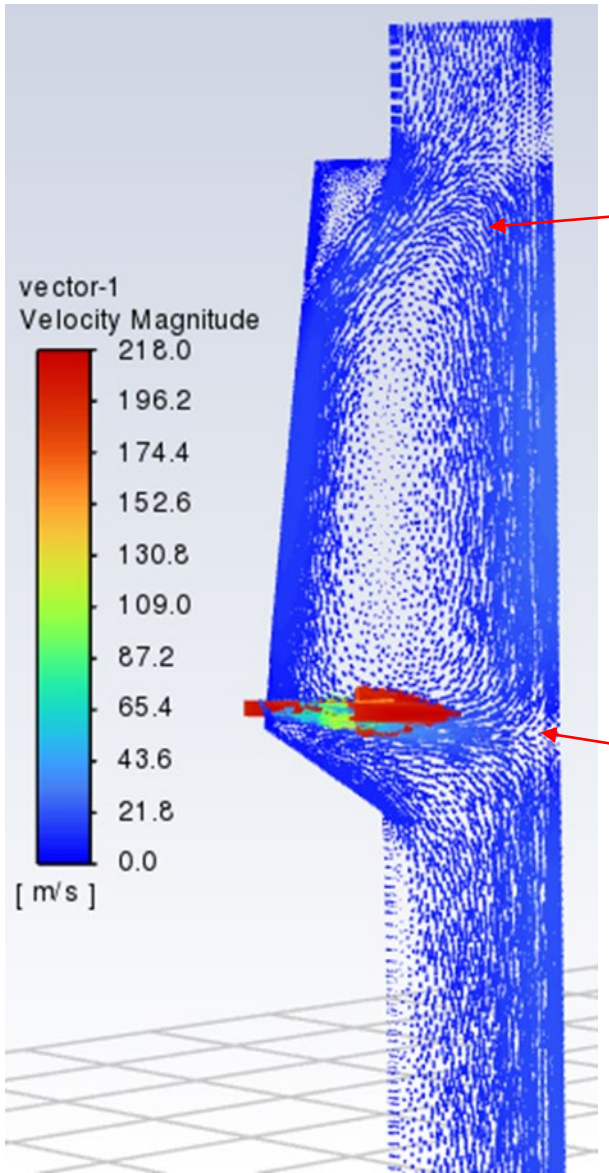

**Total H2 injection nozzles at the end of the cone. 1/12$^{th}$ of the domain is simulated due to symmetry**

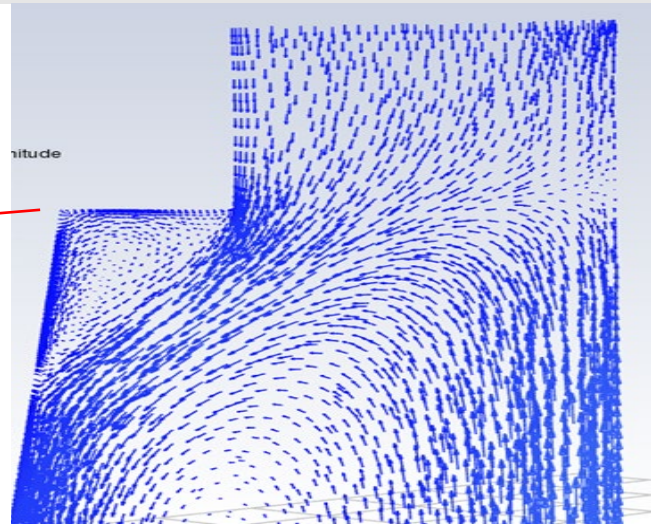


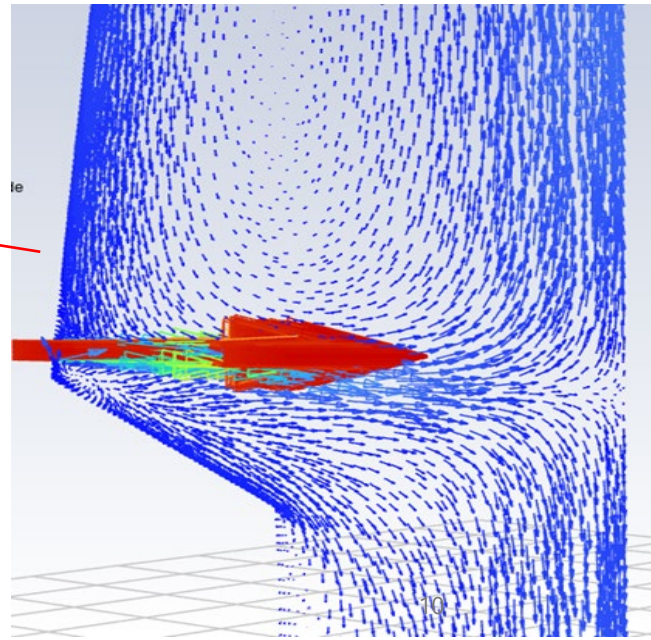
# CFD simulation results







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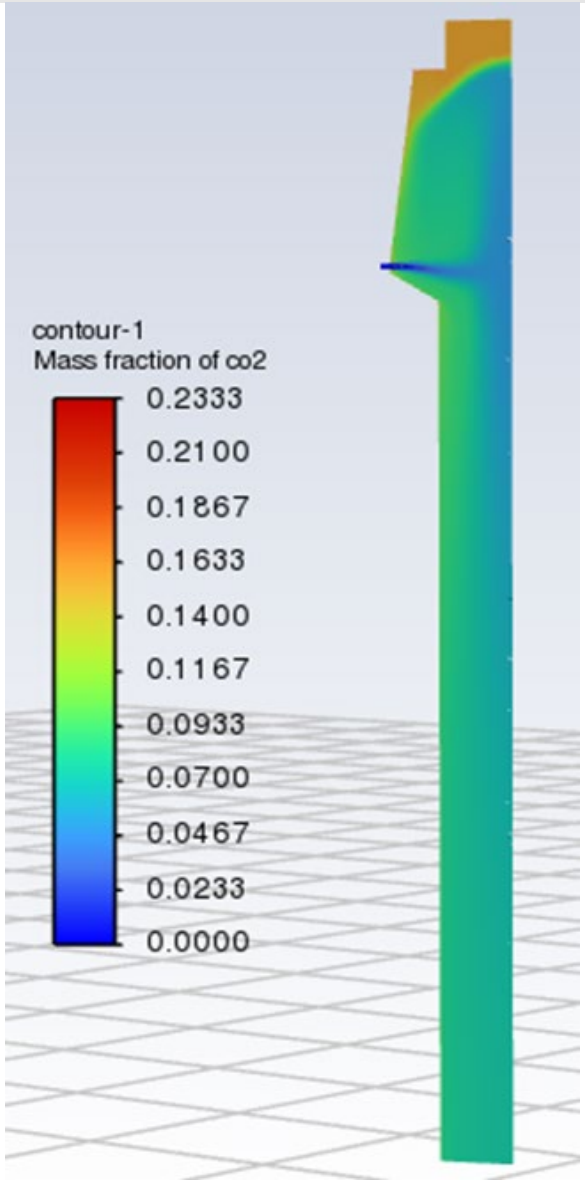
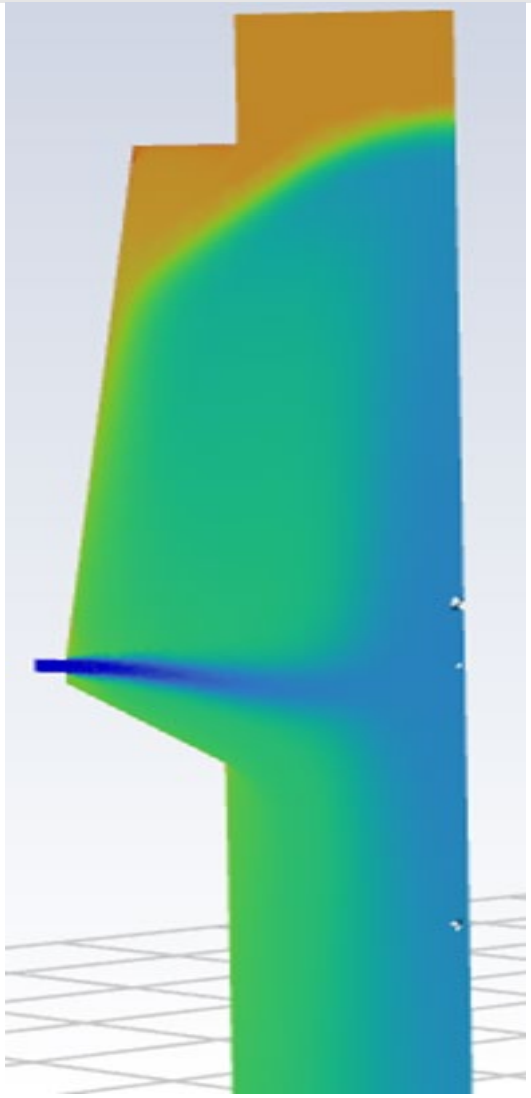
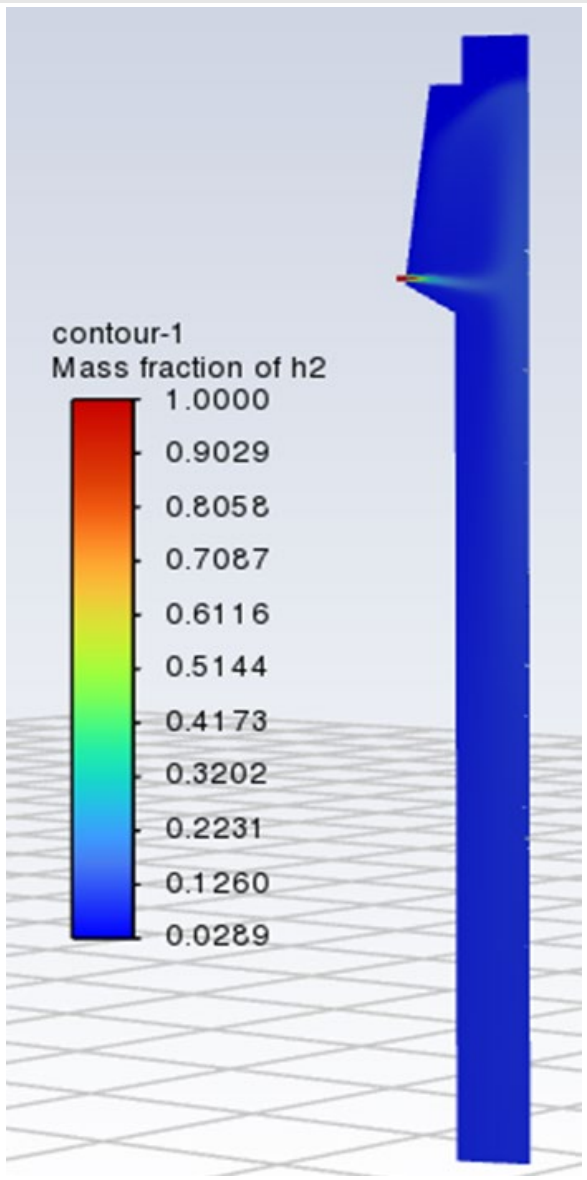
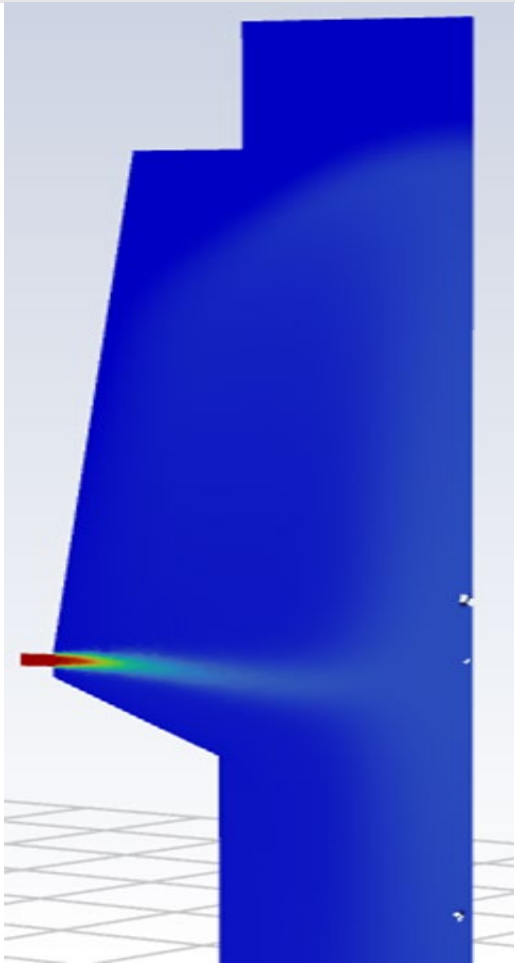


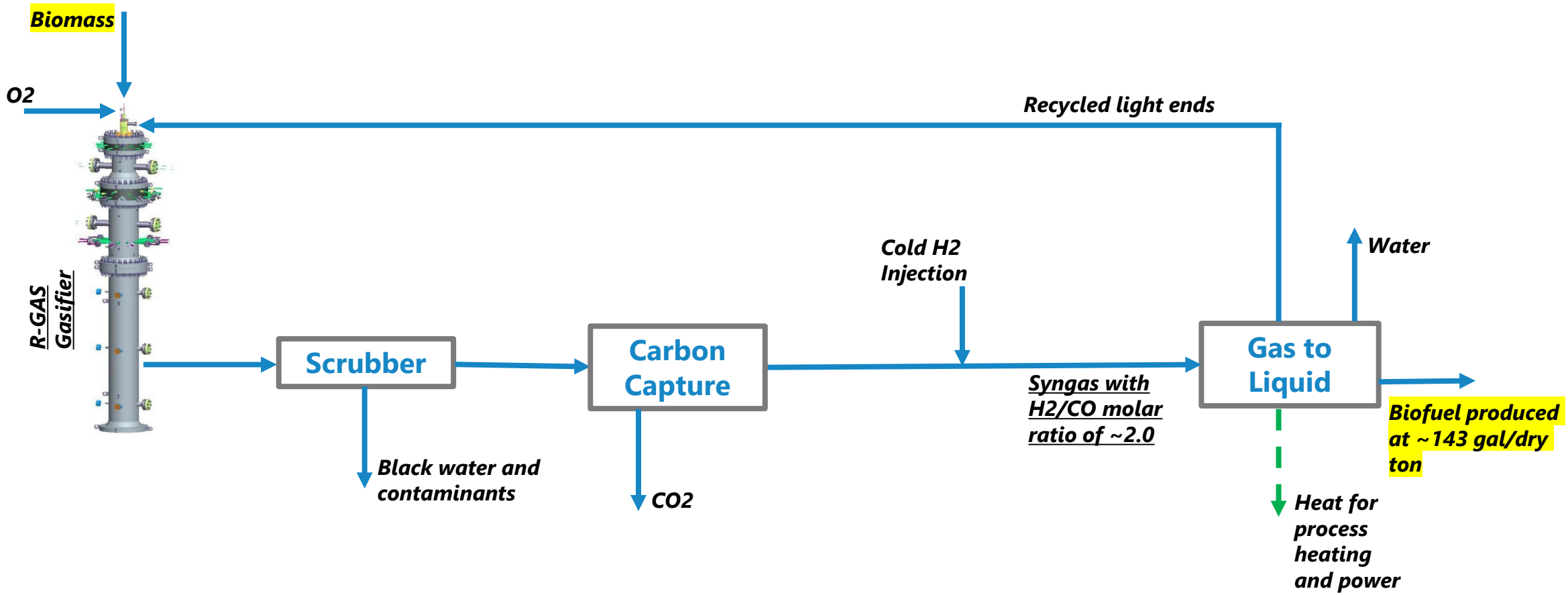





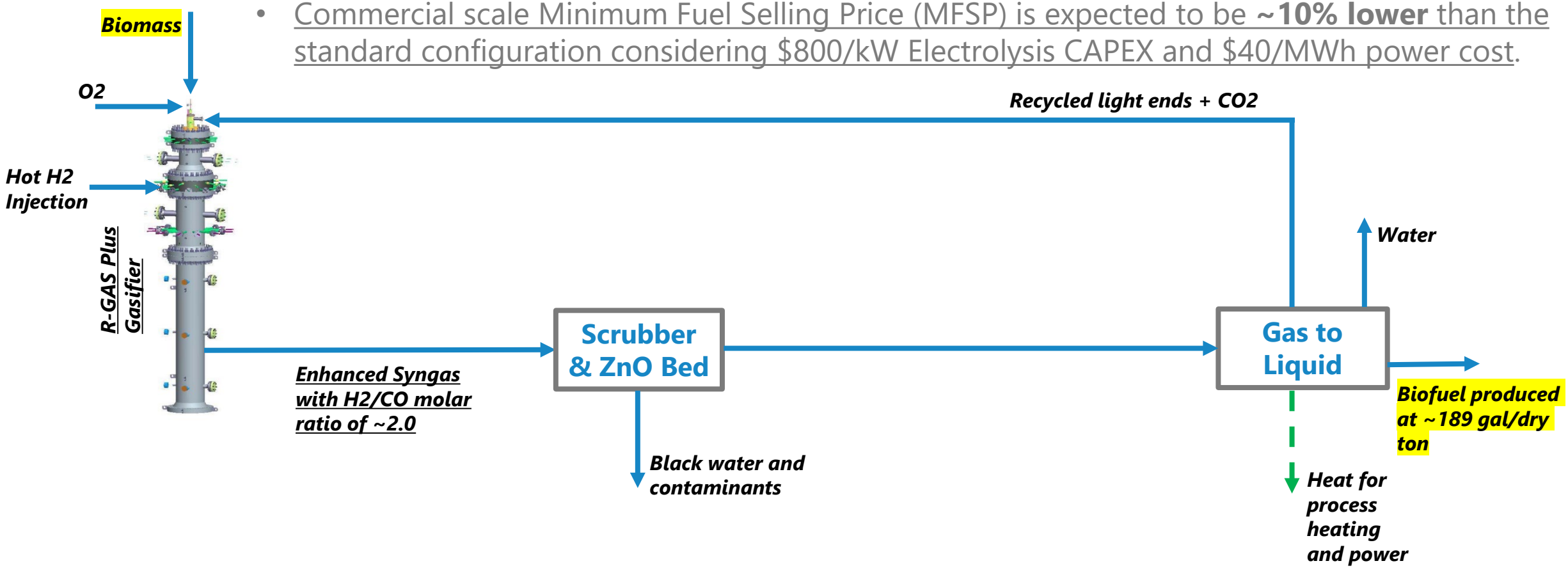
# Biorefinery Performance: Standard Electrolysis + Gasification + GTL Route

- H2 can be easily injected in front of the Gas to Liquid (GTL) block to adjust the H2/CO molar ratio as needed for the synthesis process.



# Biorefinery Performance: Enhanced Electrolysis + Gasification + GTL Route (R-GAS *Plus*)

- Process intensification by eliminating the Carbon Capture block → Lower CAPEX & OPEX.
- FT light ends are recycled directly to the gasifier where they get reformed.
- The gasification process CO2 is reduced inside the gasifier vessel through non-catalytic RWGS reactions with hot H2 that is injected downstream of the gasification zone.
- Commercial scale Minimum Fuel Selling Price (MFSP) is expected to be **~10% lower** than the standard configuration considering $800/kW Electrolysis CAPEX and $40/MWh power cost.



# Development Needs for the R-GAS *Plus* Gasification Approach

- Refine commercial scale TEA.
- Build a cold flow model to physically simulate the RWGS injection.
- Implement specialized injection lances and retrofit the existing R-GAS pilot reactor to enable H2 injections right at the exit of the gasification zone.
- Conduct a 500-hours pilot demonstration of the gasifier with H2 injections according to a very carefully developed test plan.

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GTI Energy develops innovative solutions that transform lives, economies, and the environment