



Biomass conversion to low carbon cellulosic ethanol and SAF

Roman Grosman

National Business Development Director, Linde

Robert Graham, PhD

Chairman, Ensyn

ABLC Next Meeting, San Francisco

October 19, 2023

Making our world more productive

ENSYN



Introduction to Linde



- The leading industrial gases and engineering company
- 2022 sales \$33 billion
- Formed in 2018 with the merger of Linde AG and Praxair, Inc – two world-class companies with nearly 140 years of shared history
- Proven critical project execution knowledge in diverse geographies
- Best-in-Class Safety Performance

One Linde

Uniting with a shared Vision, Mission and Strategic Direction, and demonstrating our Values and Behaviors in everything we do

2 million+
customers

Establishing a more diverse and balanced portfolio

80+
countries

Enabling strong, complementary positions in all key geographies and end markets

~65,000
employees

Achieving our full potential, individually and collectively

\$9.7 million

charitable giving in 2021
Supporting our communities through contributions and employee volunteerism

6,500+

active patent assets
worldwide

Leading with innovative products, solutions and technologies



RECOGNITION

MEMBER OF
Dow Jones Sustainability Indices



In collaboration with a RobecoSAM brand



Introduction to Ensyn



- Ensyn is the global leader in fast thermal conversion of cellulosic biomass to liquid fuels and chemicals
- Core technology is RTP®
- 40 years of commercial operating history
- Eight commercial RTP plants in operation, oldest biomass processing unit has 28 years of continuous commercial operations
- Rapid growth in production capacity is anchored by renewable heating fuel – fully commercial
- Planned increase in capacity will supply the demand for cellulosic ethanol, SAF, marine fuels, hydrogen and materials that are being developed with Linde & LanzaTech
- Production expansion in Maine (USA), Aracruz (Brazil), Nova Scotia (Canada), other USA

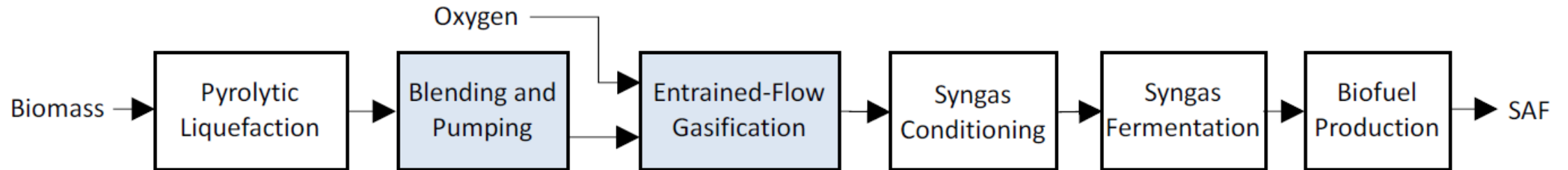
ENSYN



***Producer of low carbon biocrude
from forest and agricultural residues
to offer sustainable energy***



DOE Project: Entrained-Flow Biomass Gasification with Syngas Fermentation for Production of Sustainable Aviation Fuels



R&D/pilot scale gasification
Fuel analysis

1 tpd pressurized O₂-blown
EFG system



Biomass liquefaction (RTP)

Py-oil production



Instrument development
ATJ process development
Techno-Economic Analysis
Life cycle analysis

SAF production Modeling



Gas fermentation (GTL)

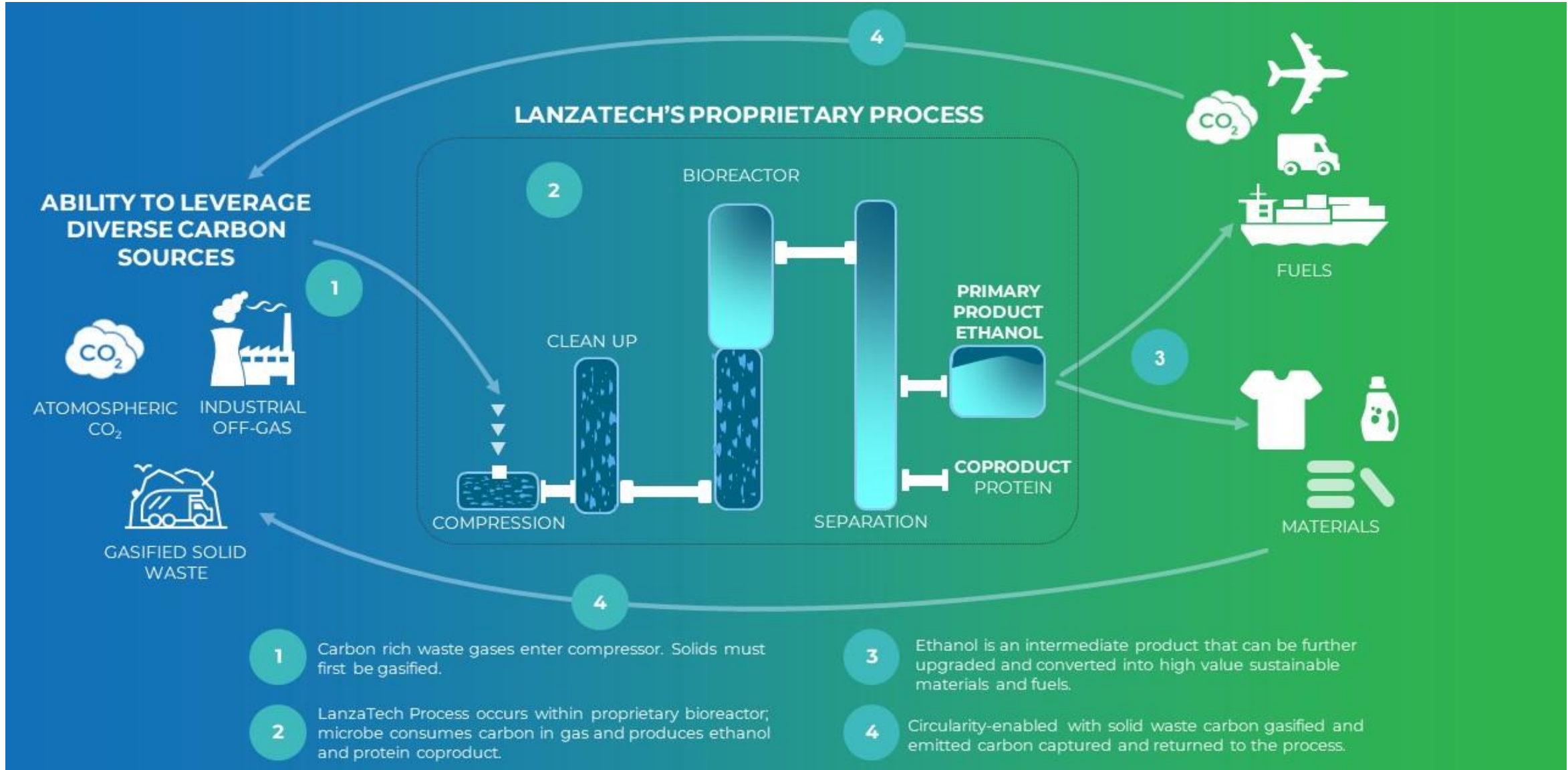
Ethanol and SAF
production using
LanzaJet™ ATJ Process



Gasification development
Hot Oxygen Burner (HOB)

Modeling
Equipment fabrication

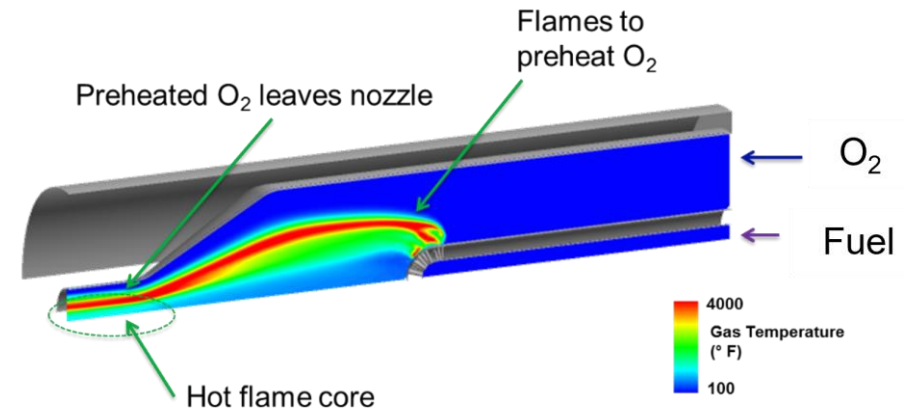
Enabling Technology: LanzaTech Bio-Fermentation



Enabling Technology: Linde Hot Oxygen Burner (HOB)



- Internal oxy-fired flame
- Residual O₂ and combustion products are hot and highly reactive
 - Accelerate mixture through a nozzle
- High velocity/momentum through the exit nozzle
- High entrainment, excellent mixing



Validated At Commercial Scale



Fulcrum BioEnergy Ships First Fuel by Railcar from Sierra BioFuels Plant

RENO, Nevada., February 1st, 2023

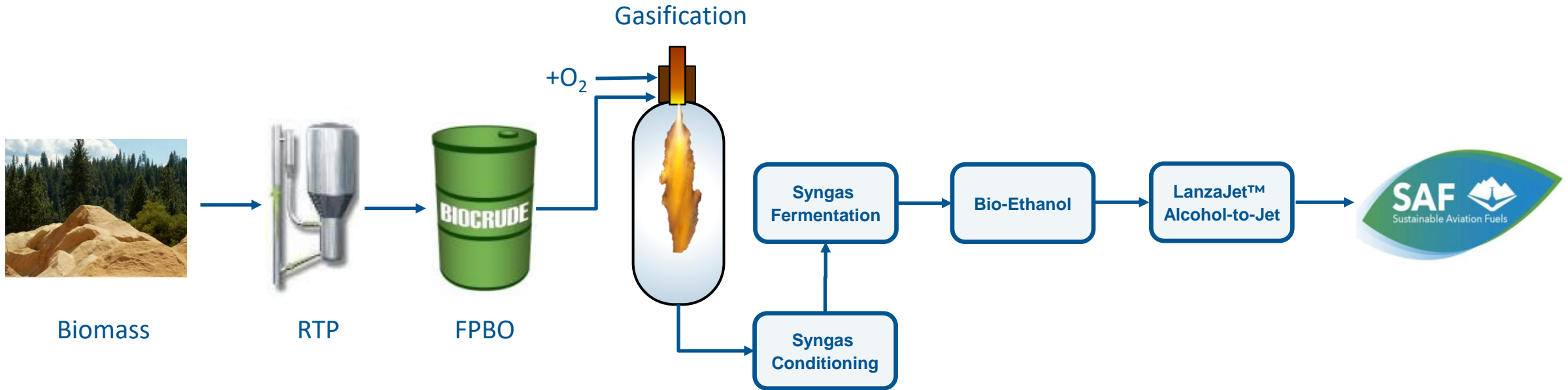
On Wednesday, February 1st, Fulcrum shipped the world's first railcar of syncrude made from landfill waste from our Sierra BioFuels Plant to our strategic partners Marathon Petroleum for upgrading into fuel.

- MSW feedstock
- 11 MM gpy syncrude production
- In commissioning and start-up

From R&D to Commercial Project



Ensyn, LanzaTech and Linde join forces to investigate the commercial production of cellulosic ethanol and SAF through integration of their three respective technologies: RTP, syngas bio-fermentation and Hot Oxygen Technology gasification



SUMMARY



- Biomass-to-SAF low carbon pathway
 - Integration of proven technologies
 - Experienced partners
- Geographic Flexibility
 - Can decouple biomass feedstock source from syngas production
 - Ability to transport bio-ethanol to SAF production location of choice
- Allows to optimize location by
 - Favorable economic and regulatory environment states
 - Reduced power cost
 - Proximity to oxygen networks and/or off-takers

ENABLING COMMERCIAL BIOMASS-TO-SAF PRODUCTION