Solutions for Energy Transition by Innovated Technologies

bangchak

Greenovative Forum 2023

Jeff CATON

Axens

Powering integrated solutions

Axens in Brief

Company Profile

- Technology provider for renewable fuels, bio-based chemicals, oil & gas, and petrochemical industries
- 40+ year experience in biofuels & biotech
- Ownership structure: 100% IFPEN

Business Areas

ALTERNATIVES & RENEWABLES | PETROCHEMICALS | GASES | OIL REFINING | WATER

Offices in **15** countries

3,000+ industrial units under license

3,500+ furnaces sold

500+ modular units references

8 Million fuel barrels produced by units under Axens license

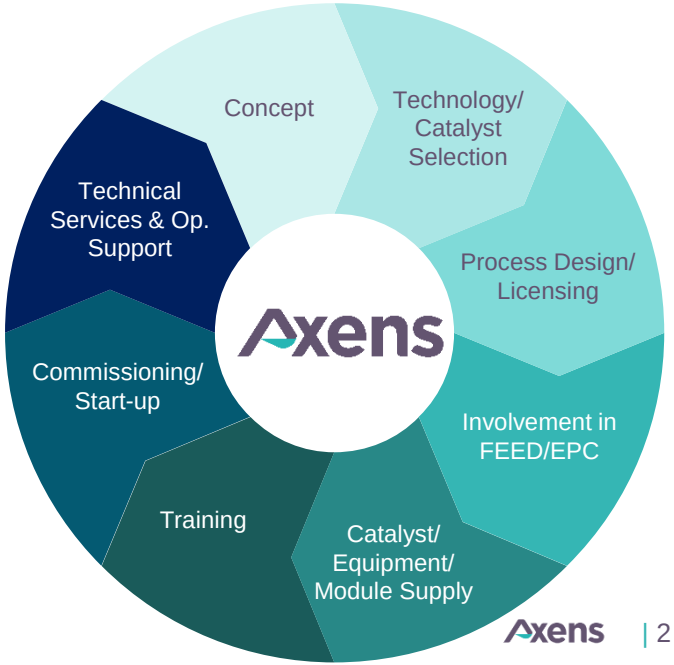
70,000+ Tons catalysts and adsorbents/year

Axens Offer

Integrated solution

Covers entire value chain

Axens HORIZON | Axens SOLUTIONS | Heurtey Petrochem SOLUTIONS



Transition to a Lower Carbon Economy: a Large Range of Solutions

ENERGY TRANSITION/CLIMATE CHANGE

Energy Efficiency

- Energy Efficiency & Low-Carbon Site Audit
- Consulting Offer for Decarbonization
- High Efficiency Equipment
- Electrical Heaters
- Optimized Heater Efficiency
- Digitalization
- CEED, Custom & Efficiency Early Design

Renewable, Low Carbon Fuels & Bio-Based Chemicals

Low Carbon Fuels

- Co-Processing
- Vegan® (HEFA)
- BioTfueL® (gasification & FT)
- Jetanol™ (ATJ)

Petrochemicals Intermediates

- Futurol® (Advanced Ethanol)
- Atol® (bio-ethylene)
- BioButterfly™ (bio-butadiene)
- Bio-TCat™ (bio-aromatics)
- 2G Sugars

Low Carbon Hydrogen

- Blue Hydrogen: Grey Hydrogen & CO2 Capture
- Hydrogen Purification
- Hydrogen Transportation (LOHC)

Carbon Capture Utilization & Storage

- Pre-Combustion: Advamine™
- Post-Combustion: DMX™
- e-Fuels

Joining Forces to Develop Innovative Solutions & Together Contribute to a Lower Carbon Economy

DURABILITY OF RESOURCES

Circular Resources

- Plastic Recycling
  - Rewind MIX
  - Rewind PET
  - TAC
  - PLASTIC ENERGY
- Tire Recycling
- Metal Recycling
- Battery Recycling
- Catalyst Pool Management
  - ORCHESTRA™
- Spent lube-oil reprocessing Revivoil™

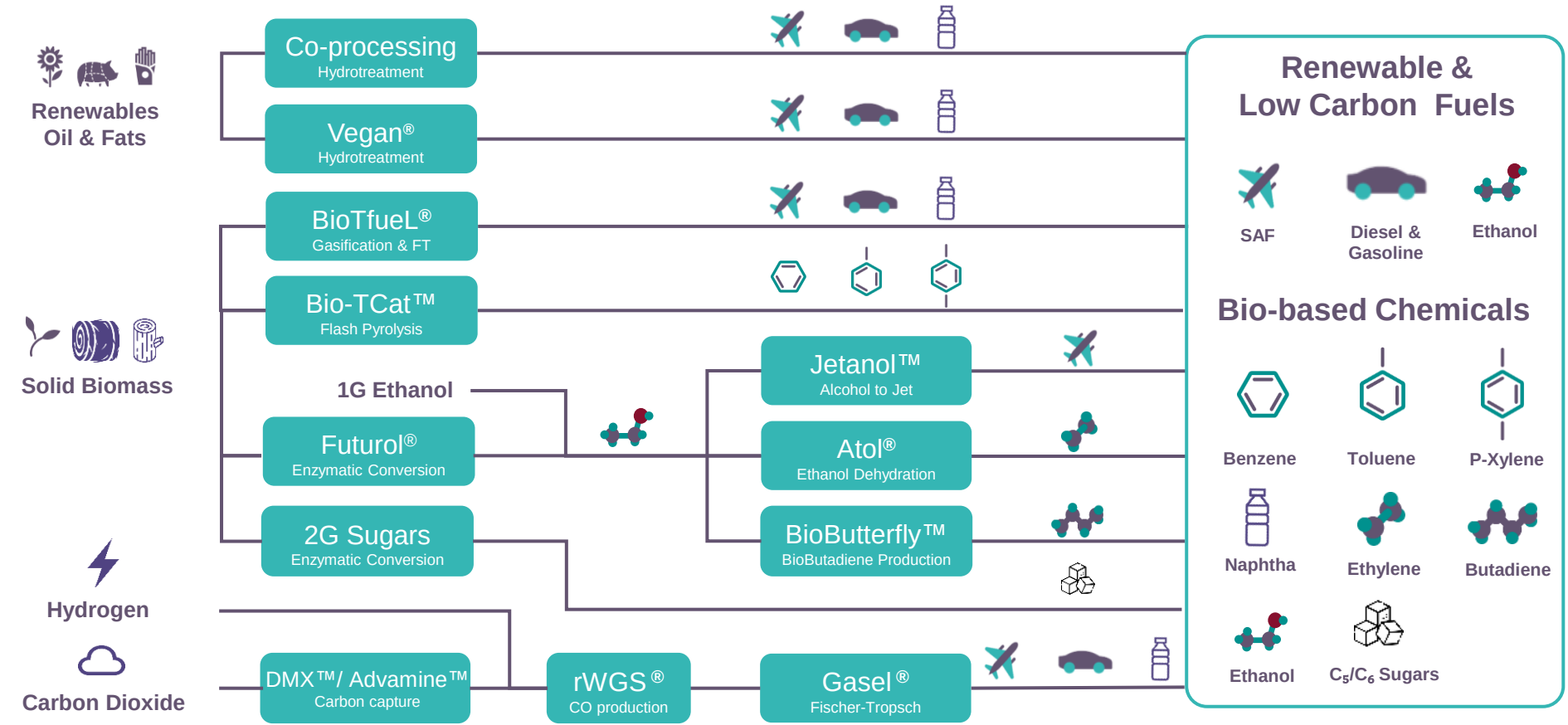
POLLUTION

Air Treatment

- Air Pollution Control
  - FLOWVISION
- Water Purification with a Large Portfolio of Adsorbents
- Industrial Waste Water Treatment
  - HydroThane
- Sulfur recovery
  - SulShine

Water Treatment

Axens Renewable / Low Carbon Fuels & Bio-based Chemical Solutions



Axens Group: A Long History with Low Carbon

1992 First Biodiesel plant start-up **Esterfip-H** Technology

1998 Beginning of **Gasel®** development

2001 **Gasel®** demonstration plant start-up

2006 1st **Esterfip-H** start-up

2008 Beginning of **Atol®** and **Jetanol™** development

Beginning of **Futurol®** development

2010 Beginning of **BioTfuel®** development

Gasel® ready for commercialization

2011 **Futurol®** pre-commercial plant start-up

2015 **Futurol®** industrial demo plant start-up

1st industrial reference of **Vegan®** TotalEnergies La Mède Biorefinery project

2018 **Futurol®** ready for commercialization

BioTfuel® demonstration plant start-up

2020 1st industrial reference of **Futurol®** INA Sisak Biorefinery project

2021 **Jetanol™** 1st industrial reference, in collaboration with Gevo

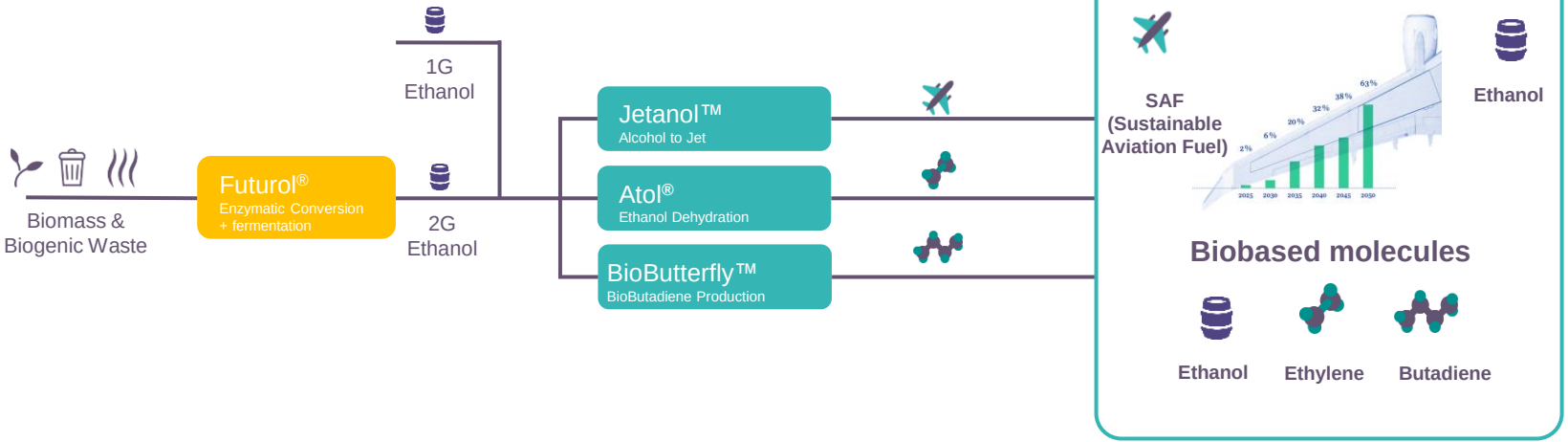
BioTfuel® testing program completed

Vegan® 10 units under construction/design

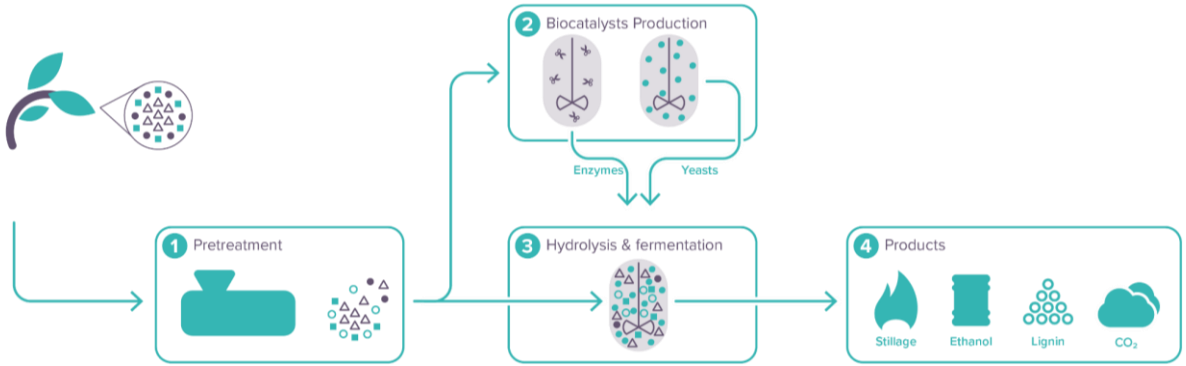
2022 **BioTfuel®** ready for commercialization

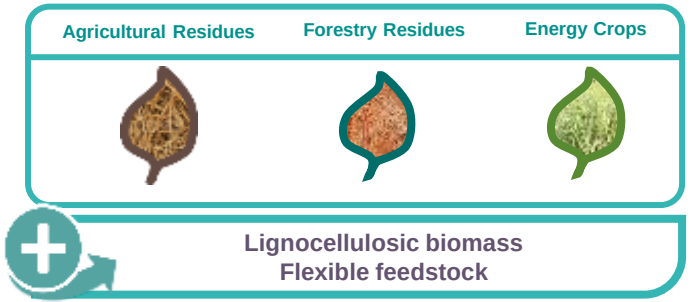
1st **Atol®** plant start-up

2023 **BioTfuel®** 1st industrial reference **(BioTjet)**


1G
Ethanol
Biomass &
Biogenic Waste
Futurol®
Enzymatic Conversion
+ fermentation
2G
Ethanol
Jetanol™
Alcohol to Jet
Atol®
Ethanol Dehydration
BioButterfly™
BioButadiene Production
Advanced biofuels
SAF
(Sustainable
Aviation Fuel)
2%
6%
20%
32%
38%
63%
2025
2030
2035
2040
2045
2050
Ethanol
Biobased molecules
Ethanol
Ethylene
Butadiene

Futurol® from Biomass to Advanced Ethanol





- **Technology key features**
  - Robust biomass pretreatment technology
  - On-site production of tailor-made biocatalysts
    - → Full control of operating cost
    - → Less logistic, not relying on external supplier
  - One-pot enzymatic hydrolysis & fermentation
    - → CAPEX and OPEX minimization, high ethanol yield
- **Products quality**
  - Advanced / Drop-in Advanced Ethanol
  - First gate to bio-molecules platform: Ethylene, Renewable fuels / SAF, 2G Sugars
- **Commercial technology**
  - 1 reference (55 KTA of 2G ethanol – INA Croatia)
  - 9+ years of operation of pre-commercial plant
  - 2 years of industrial pretreatment plant operation

Pre-Commercial Plant

Diverse Feedstock

Commercial Experience: Allotrope

A Cellulosic Ethanol Platform

ACDC Differentiation and Deployment Strategy

- ✓ Technology Performance and EPC Guarantees
- ✓ Feedstock Expertise in Forestry and Agriculture
- ✓ Deep Local/State Regulatory/Government Support
- ✓ Addresses Multiple Regional Biomass Crises
- ✓ Overcomes Cellulosic Biofuels Shortcomings
- ✓ Strategic Offtake & Corporate Partnerships
- ✓ Local Management & Strong Operations Expertise

Timeline to Scale

2022-2024

- Complete FEL-3 on pioneer US Futurol™ plant and commencing on 2nd/3rd/4th plants
- Fabrication/Construction of pioneer plant commenced
- Provisional contracting of >1M BDT of woody biomass feedstock
- Pursue initial de-carbonization of biomass trucking and processing
- Pursue modularization of key engineering elements of technology

2025-2027

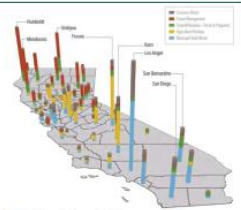
- 6 plants statewide built, in construction or in development
- 150 million gallons equivalent of Futurol™ using ~2M BDT of up-valued forest waste and ag biomass
- Encourage state support of decarbonization policies across the industrial molecules
- Pursue opportunities as LCFS programs expand nationally and globally

Years 7-10

- Global Futurol™ Plants
- In-house SAF can be addressed after scaling up Futurol™
- Expand into more complex Green Ethylene opportunities – bioplastics, lubricants and other fossil fuel replacements

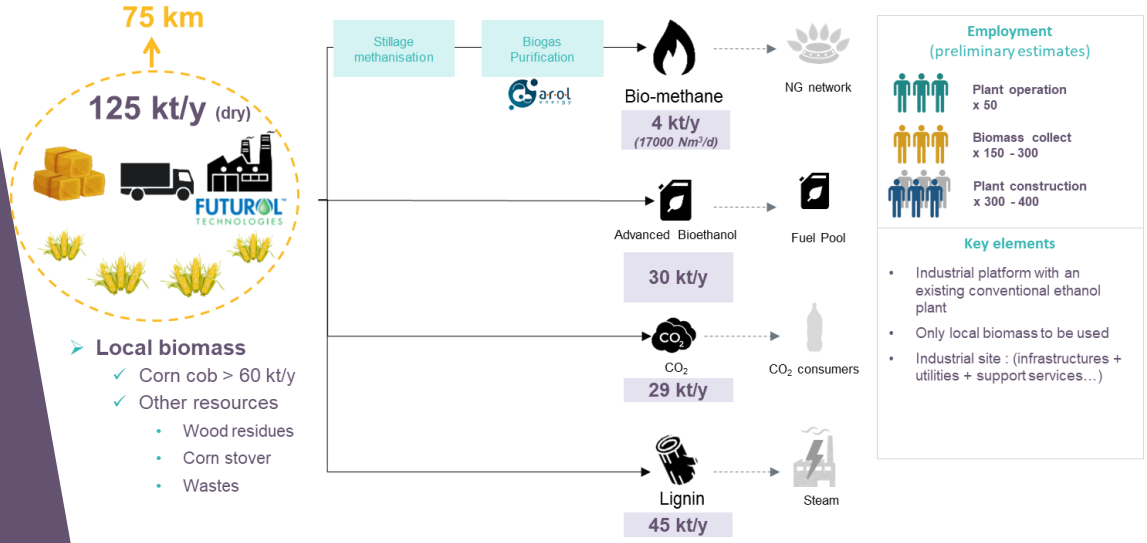
Identified Target Locations


2022 California Wild Fires

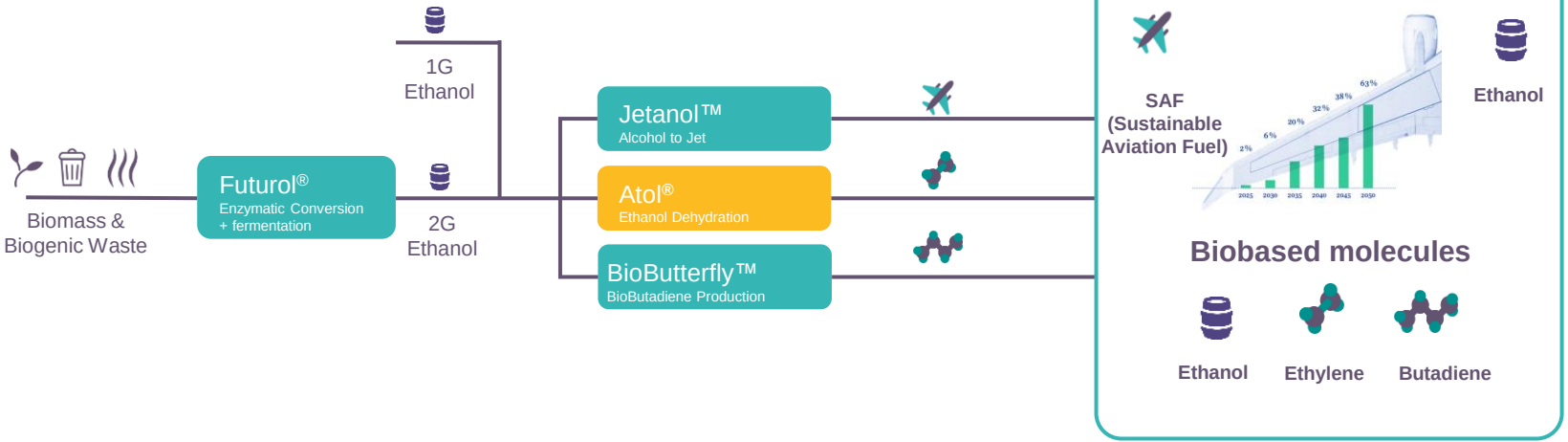

Distribution of Biomass Resources

Customer	**Allotrope Partners**
Location	United States (California)
Feedstock	Forest thinning materials and agricultural residues
Capacity	60 KTA of advanced bioethanol
Timeline	Feasibility study started Aug 2023 Start-up 2027
Scheme	Futurol®

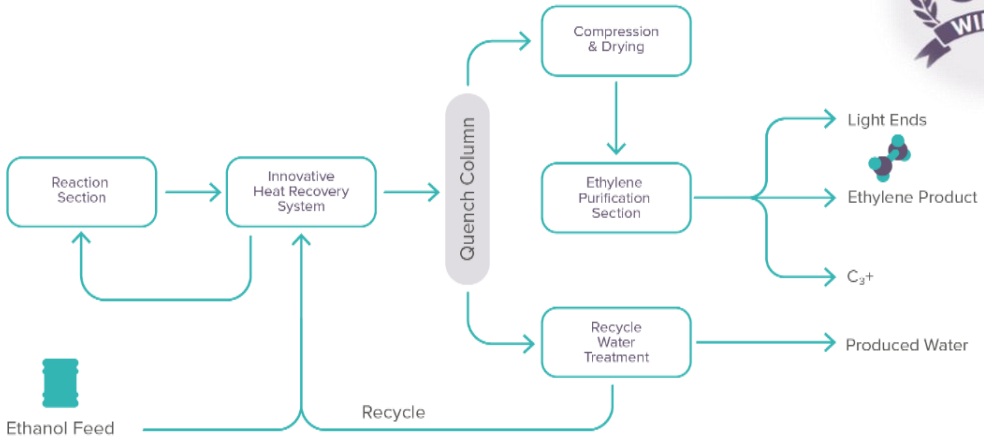
Commercial Experience: NACRE



Customer	**NACRE**
Location	France (Lacq)
Feedstock	Corn cob / Forestry residues / Bamboo
Capacity	30 KTA of advanced bioethanol
Timeline	Basic engineering package starts Sept 2023 Start-up 2027
Scheme	Futurol®


1G
Ethanol
Biomass &
Biogenic Waste
Futurol®
Enzymatic Conversion
+ fermentation
2G
Ethanol
Jetanol™
Alcohol to Jet
Atol®
Ethanol Dehydration
BioButterfly™
BioButadiene Production
Advanced biofuels
SAF
(Sustainable
Aviation Fuel)
2%
6%
20%
32%
38%
63%
2025
2030
2035
2040
2045
2050
Ethanol
Biobased molecules
Ethanol
Ethylene
Butadiene

ATOL® to Address Bio-Ethylene



Atol Unit, Sumitomo

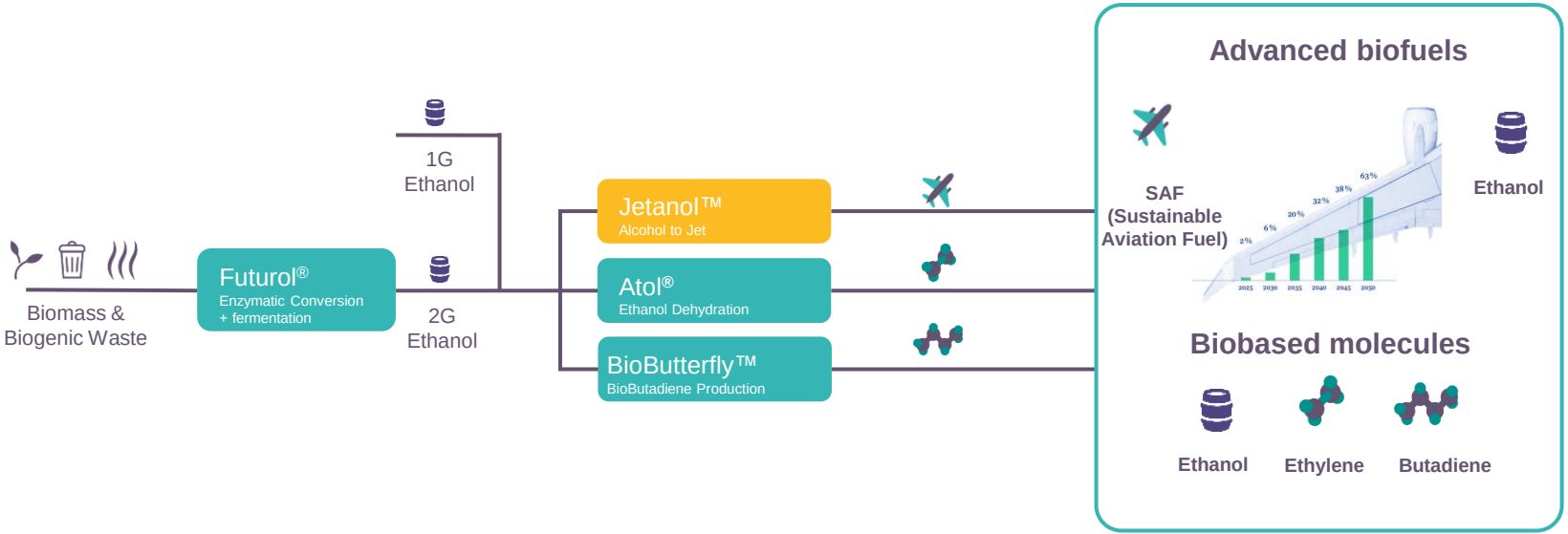
- **Technology key features**
  - Feed flexibility → higher tolerance to impurities, diluted sources possible
  - Proven radial reactors with low pressure drop
  - High yields → Market leading catalyst
  - High selectivity → easier separation/purification
  - Innovative energy system for minimum carbon footprint
- **Products quality**
  - Polymer grade
  - First gate to bio-molecules platform : bio-PE / bio PET / bio PVC / Bio EO
- **Commercial technology**
  - 1 operating plant (Sumitomo, Japan)
  - 5 references (2 ethylene, 3 biofuels)

Commercial Experience: Syclus

SYCLU

cropenergies

Customer	**Syclus (50% Cropenergies)**
Location	Nederland (Geleen)
Feedstock	By Cropenergies (various/wheat)
Capacity	100 KTA of bioethylene
Timeline	Feasibility on-going PDP starts end 2023 Start-up 2026
Scheme	Atol® w/o pretreatment


1G
Ethanol
Biomass &
Biogenic Waste
Futurol®
Enzymatic Conversion
+ fermentation
2G
Ethanol
Jetanol™
Alcohol to Jet
Atol®
Ethanol Dehydration
BioButterfly™
BioButadiene Production
Advanced biofuels
SAF
(Sustainable
Aviation Fuel)
2%
6%
20%
32%
38%
63%
2025
2030
2035
2040
2045
2050
Ethanol
Biobased molecules
Ethanol
Ethylene
Butadiene

Jetanol™ from Ethanol to Renewable Fuels

5 references alcohol dehydration

>100 references oligomerization

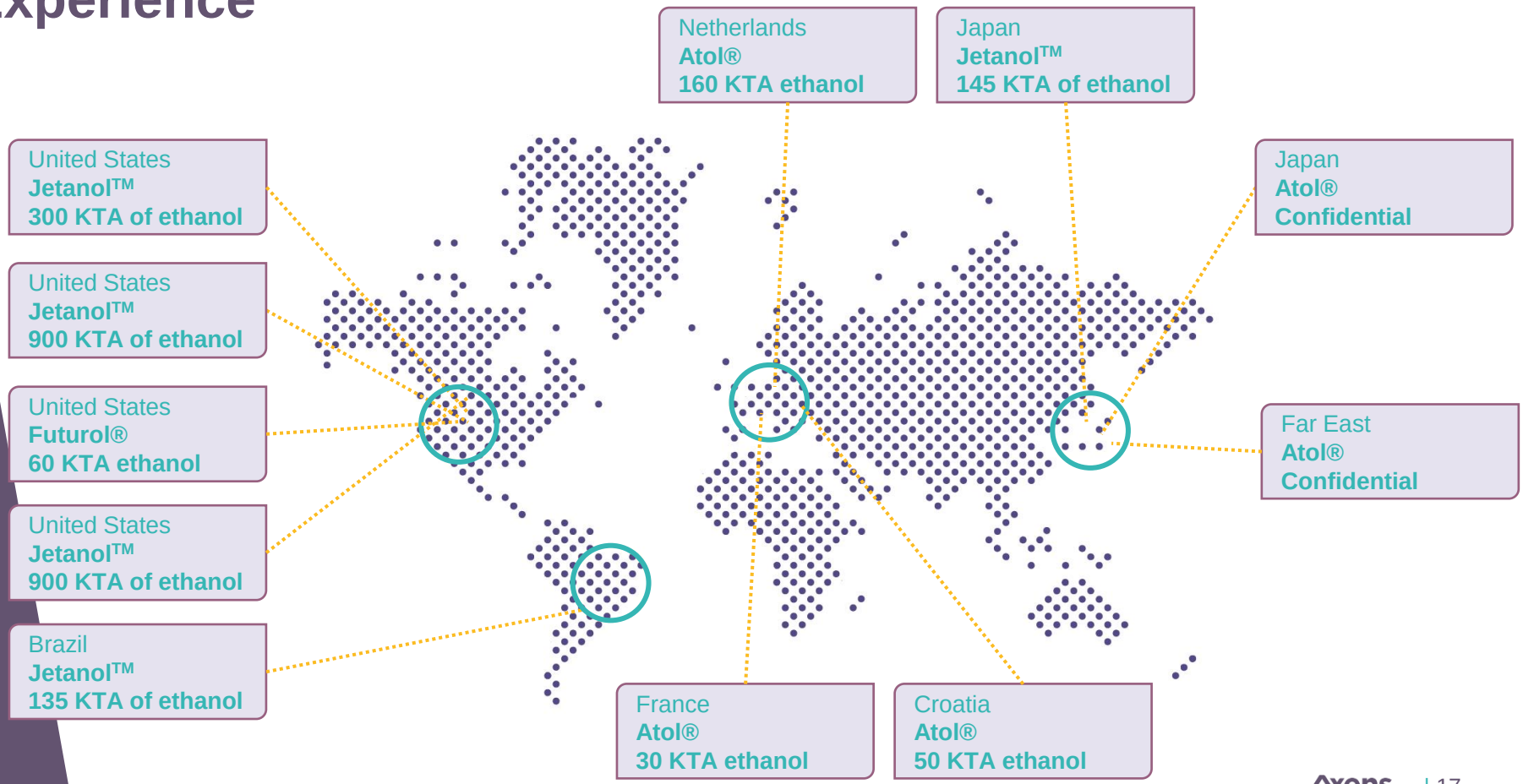
>700 references hydrogenation

- **Technology key features**
  - Products & feedstock flexibility
  - Superior yields → Market leading catalyst
  - High selectivity → easier separation/purification
  - Near zero carbon conversion loss
  - Single point licensor from biomass to biofuels
    - For Catalysts and Process Design Package execution
    - End to end guarantees
- **Products quality**
  - ASTM D7566 compliance
- **Commercial technology**
  - Long track record of references
  - Catalyst already used in the industry
  - 5 references (1 Japan, 3 USA, 1 Brazil)

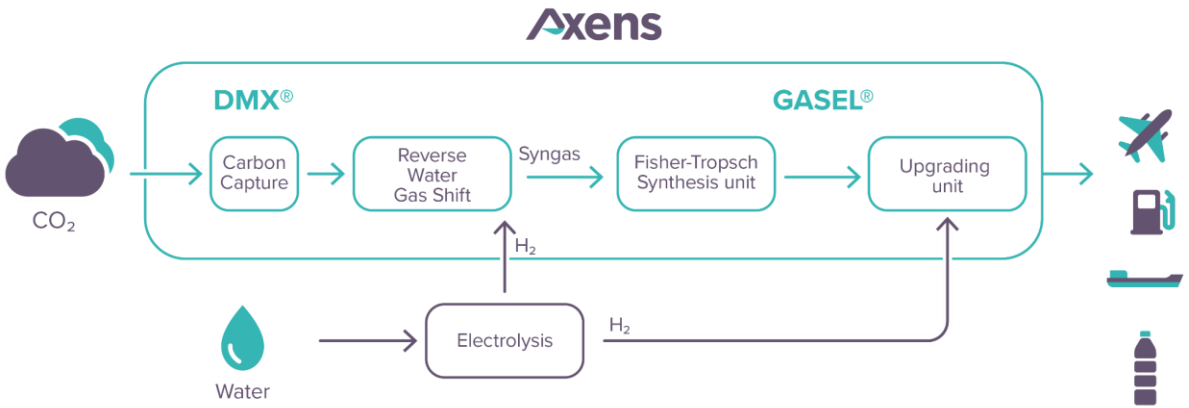
Commercial Experience: Jetanol™

Customer	Project name	Country	Capacity SAF	Feedstock
Gevo	NetZero #1	USA	160 KTA	Corn etOH
Gevo	NetZero #2	USA	490 KTA	Corn etOH
Idemitsu		Japan	80 KTA	Sugarcane etOH
Confidential	NA	USA	490 KTA	Corn etOH
Confidential	NA	Brazil	120 KTA	Sugarcane etOH

Experience

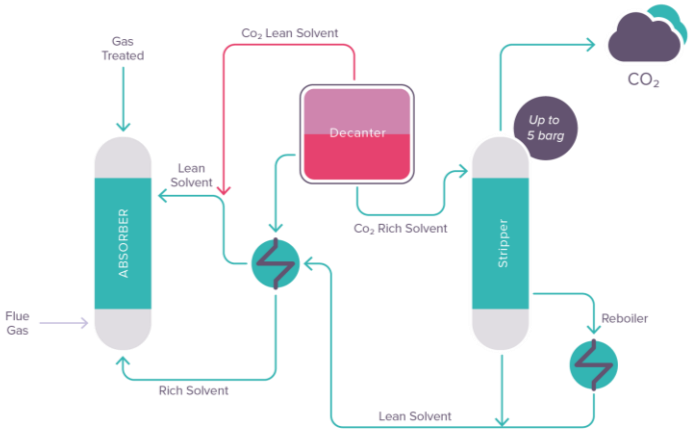

Netherlands
Atol®
160 KTA ethanol
Japan
Jetanol™
145 KTA of ethanol
United States
Jetanol™
300 KTA of ethanol
Japan
Atol®
Confidential
United States
Jetanol™
900 KTA of ethanol
United States
Futurol®
60 KTA ethanol
Far East
Atol®
Confidential
United States
Jetanol™
900 KTA of ethanol
Brazil
Jetanol™
135 KTA of ethanol
France
Atol®
30 KTA ethanol
Croatia
Atol®
50 KTA ethanol

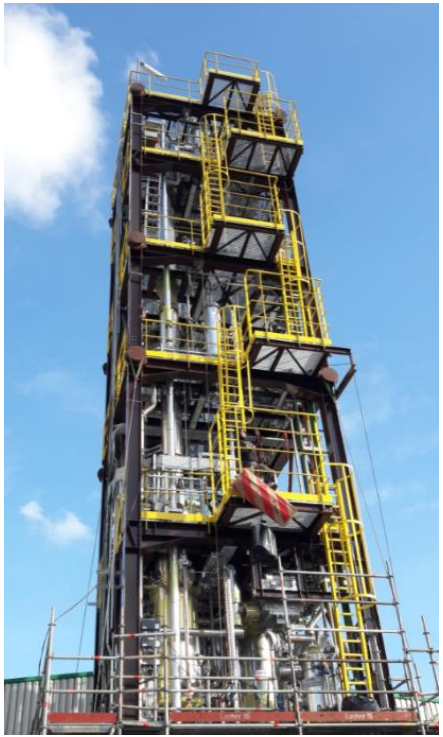
E-Fuels: from CO_2 & H_2 to Low Carbon Fuels



- **Technology key features**
  - End to end Guarantees
  - Optimization between units to maximize projects economics & carbon retention
  - Single point of contact
- **Products quality**
  - Low Carbon/Renewable fuels
  - High quality, aromatic/sulfur free, O_2 free, drop-in fuels
  - Compliance with ASTM D7566 for SAF
- **Technology development**
  - RWGS by 2023
  - Gasel®:
    - 2 references
    - 25 000 hours of operation of FT pre-commercial plant
  - Upgrading > 70 references worldwide for upgrading section

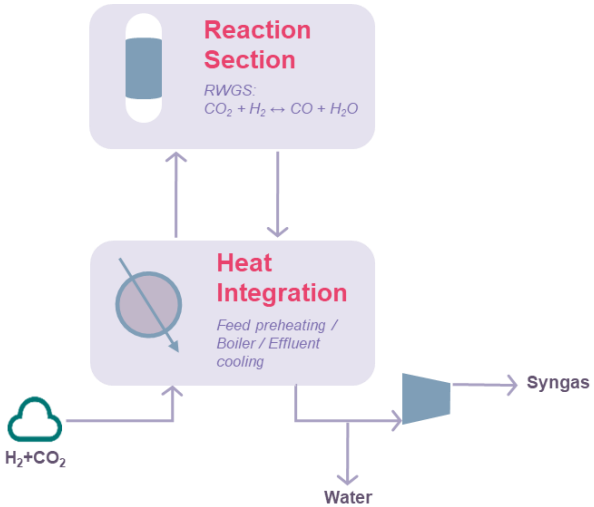
E-Fuels: DMX™ from Flue Gases to CO_2

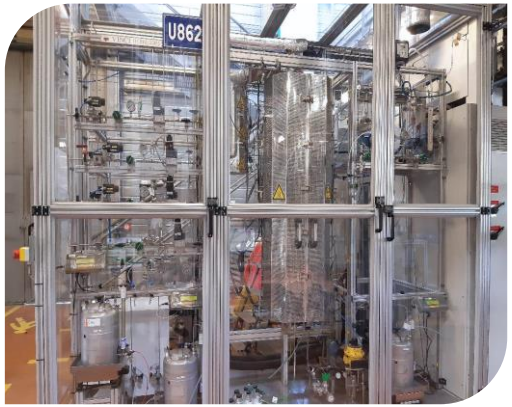




- **Technology key features**
  - CO_2 up to 5 bar g recovery
  - Proprietary solvent
  - Demixing capability
  - Adaptable to high capacities (4 times MEA)
  - Thermally stable
  - Low sensitive to oxygen
  - TRL 4-5
- **References**
  - ArcelorMittal - 3D Project - Dunkirk
  - IFPEN Pilot - Solaize
- **Technology development**
  - Pilot started-up (September 2022)
  - Target end 2023

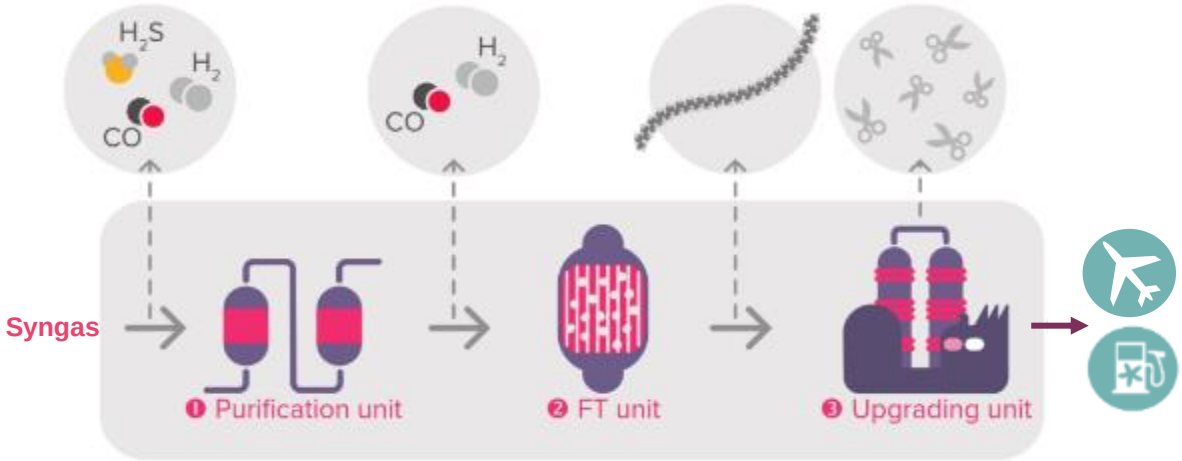
E-Fuels: Reverse Water Gas Shift from CO_2 to CO





- **Technology key features**
  - Simple Process scheme
  - Fast-track development
  - Industrial ready catalyst
  - Optimized conversion & CO selectivity
  - TRL 6-7
- **Technology development**
  - RWGS by 2023

E-Fuels: Gasel® from Syngas to drop-in HC Fuels



- **Technology key features**
  - Flexible Feed Slate: **Power to Liquid**, Gas to Liquid, Biomass to Liquid
  - Innovative reactor technology to maintain product quality and high availability
  - Mild operation to maximize middle distillate, easier operation
- **Commercial technology**
  - 2 references
  - 25 000 hours of operation of FT pre-commercial plant
  - > 70 references worldwide for upgrading section

Pre-commercial plant

FT Demo Unit- Sanazzaro

Upgrading Pilot Plant

Gasel®

Let’s Make Your Transition Together

Large range of **solutions** for the **decarbonization** of **plastics/chemicals** and **fuels**

De-risked technologies built on **long-standing experience** and dedicated pre-commercial programs

Unique partner to provide **taylor-made** bio-based technologies that fit your project

Axens
Powering integrated solutions

axens.net

Thank you

Axens.net
a new digital journey