



LanzaTech

Syngas to Fuels and Chemicals: Closing the Loop

Nov. 7 & 8, 2019

Newark International Airport

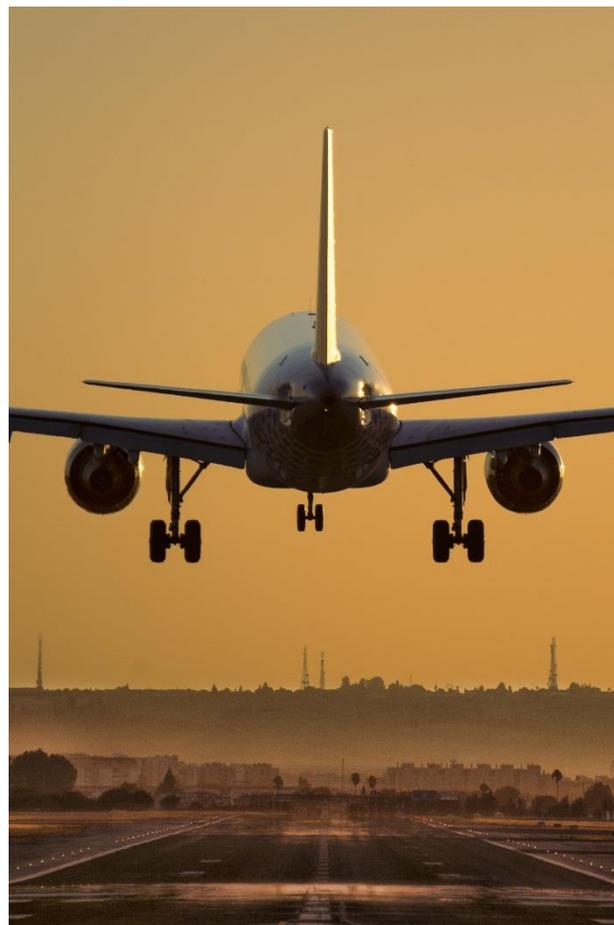
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**Energy can be
Carbon Free**



**(Aviation) Fuel
needs Carbon**

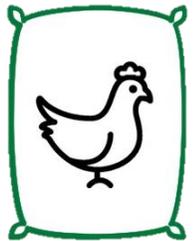
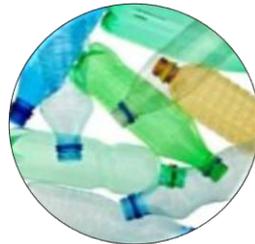
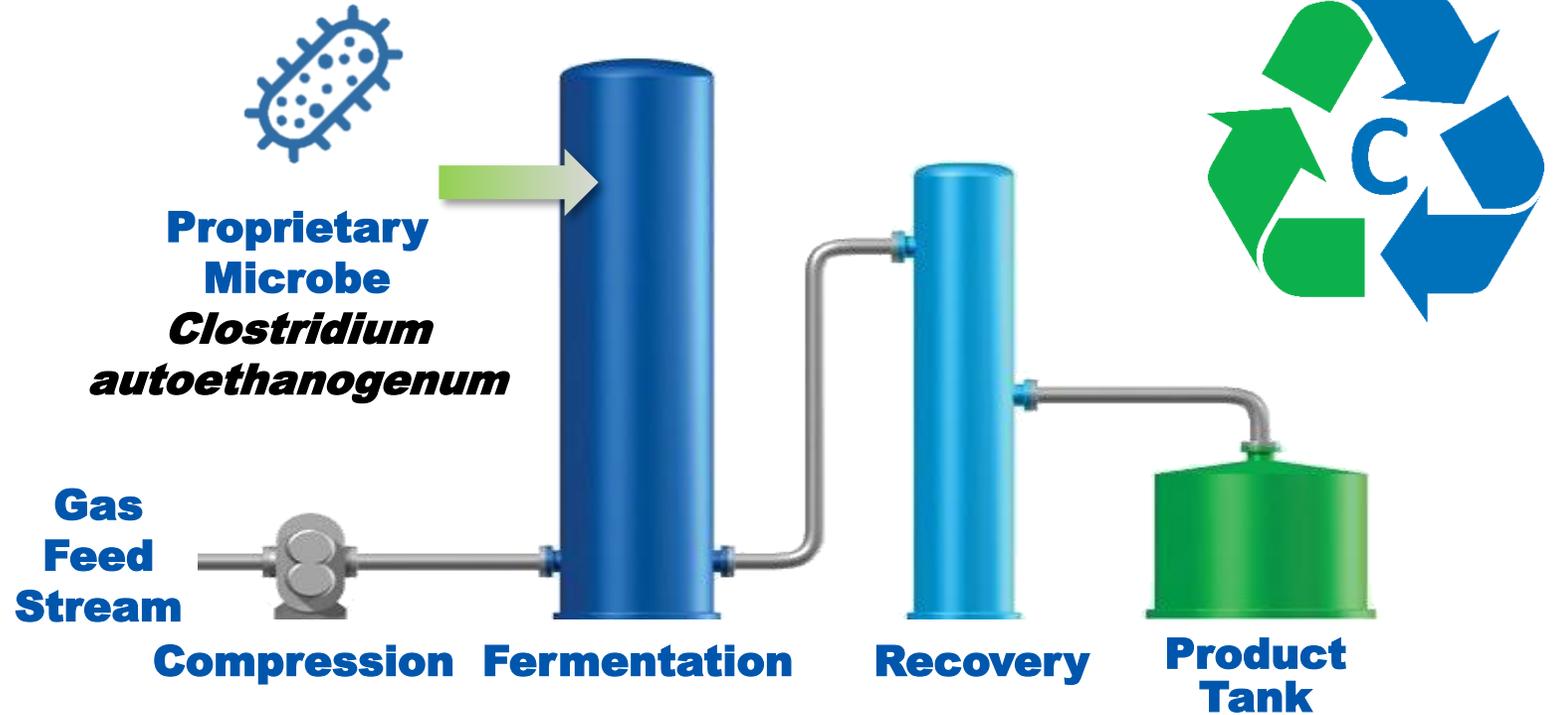


**Chemicals for
Everyday Products
need Carbon**

Recycling Carbon 101



**Industrial Off Gas,
Biomass, MSW Syngas**

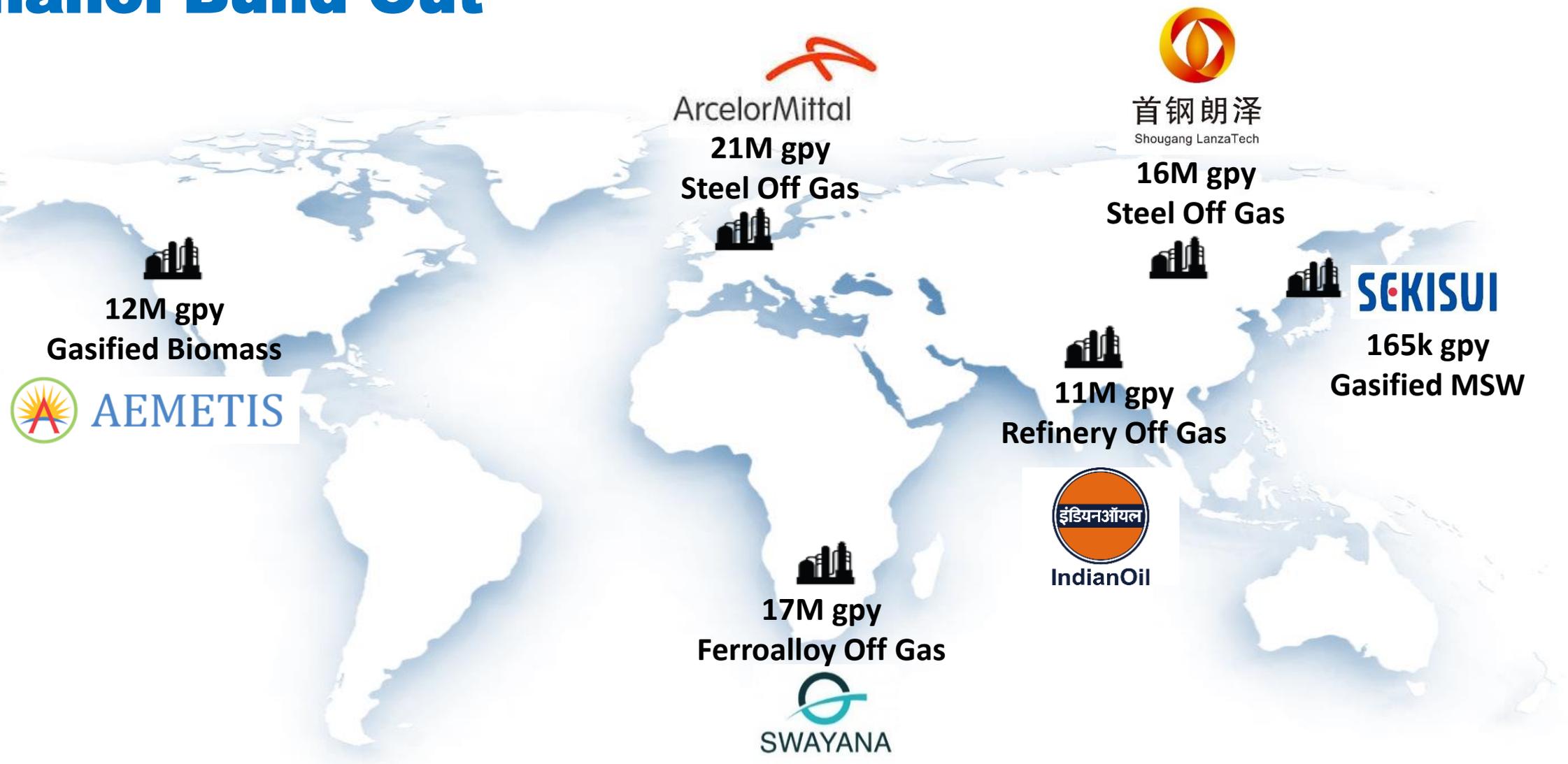


Waste Gas Fermentation is Now Commercial

- **16 million gpy capacity**
- **Started up 2018**
- **10 million gallons ethanol produced to date**



Ethanol Build Out



**Accessing all global carbon waste
= 700M cars off the road!**

Excellent Substrate Building Block of the Future



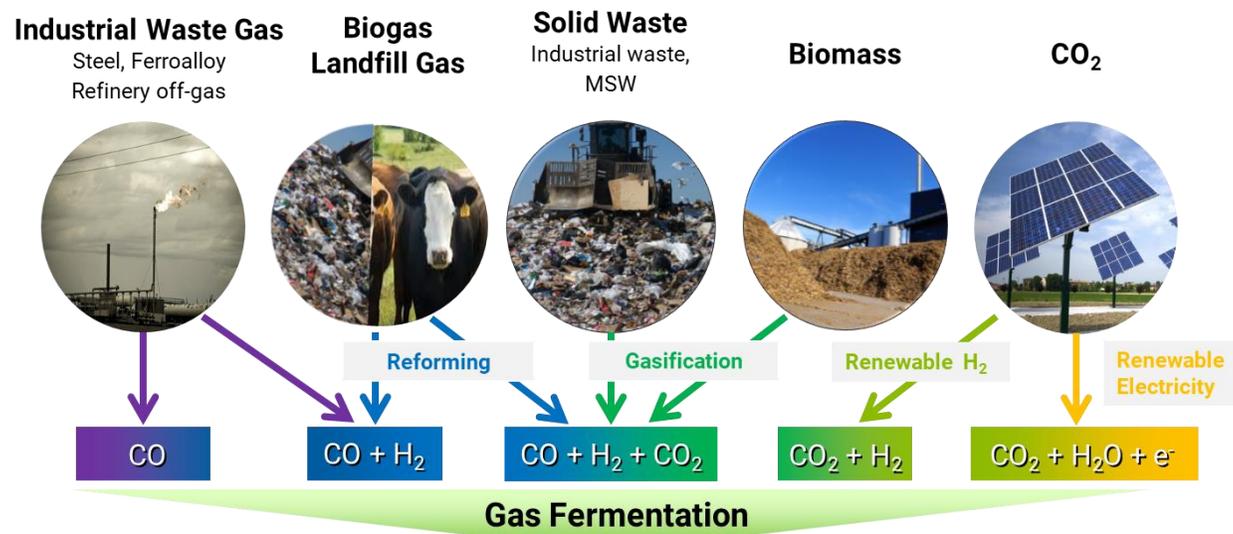
LanzaTech Offers the Optimal Gas Conversion Solution

		H ₂ :CO ratio	
CO	$6 \text{ CO} + 3 \text{ H}_2\text{O} \rightarrow \text{EtOH} + 4 \text{ CO}_2$	0:1	<u>High CO off-gas (e.g. steel)</u> Demonstrated at scale
CO + H ₂	$3 \text{ H}_2 + 3 \text{ CO} \rightarrow \text{EtOH} + \text{CO}_2$	1:1	<u>Syngas (e.g. MSW)</u> Demonstrated at scale
CO + H ₂	$4 \text{ H}_2 + 2 \text{ CO} \rightarrow \text{EtOH} + \text{H}_2\text{O}$	2:1	
CO + H ₂ + CO ₂	$5 \text{ H}_2 + 1 \text{ CO} + 1 \text{ CO}_2 \rightarrow \text{EtOH} + 2 \text{ H}_2\text{O}$	5:1	<u>High H₂ off-gas (e.g. refinery)</u> Demonstrated at pilot, allows CO ₂ fixing in products

- Capable of operating on wide range of H₂:CO ratio in feed gas
- Theoretical maximum 80% HHV conversion to ethanol across stoichiometries. Increased carbon conversion when more H₂ present.

Target feedstocks include:

- Steel and Ferro-alloy off-gas
- Syngas from biomass or MSW
- Syngas from electrolysis
- Pyrolysis gas
- Refinery off-gas



- Gas fermentation yields 2x more value than producing power

A Robust, Flexible Upstream Technology is Necessary for Optimal Efficiency

Process	Global Deployment	Energy Efficiency	Air Quality
Incineration	✓		
Gasification		✓	✓

- Unsorted, non-recyclable MSW represents a significant resource for making fuels and chemicals
- The hybrid gasification + gas fermentation pathway offers an efficient, flexible MSW conversion route
 - Gasification accommodates the enormous breadth of materials present in MSW
 - Microbes used in gas fermentation tolerate wide variations in gas composition and contaminants
- Both technologies have been proven at scale, with MSW gasification operating commercially where appropriate market drivers exist, such as Japan.
- LanzaTech has demonstrated the robustness of this hybrid pathway through several years of operating experience with unsorted, post-recycling MSW.
- Gasification produces solid byproducts, some of which are pozzolanic materials (but feedstock dependent).



SEKISUI

Japan

**Unsorted MSW Syngas
Demonstration Scale**

2013-2019

Carbon Recycling: Converting MSW to Ethanol

2013

Proof of concept

2014

Pilot commissioned near Tokyo

- ✓ 15 tonne/year
- ✓ Slip stream of commercial, non-plasma gasifier operated to produce syngas for electricity production
- ✓ Reactor design leverages LanzaTech steel-mill experience

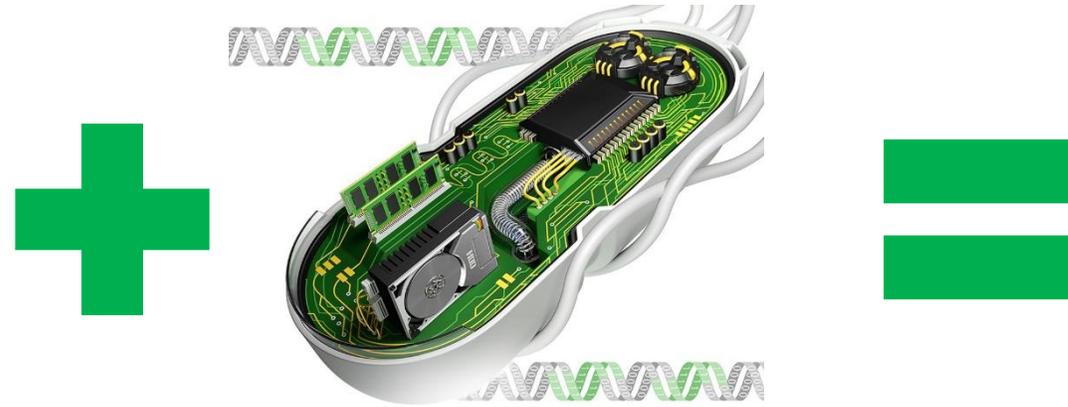


Successful demonstration of continuous ethanol from unsorted, non-recyclable, non-compostable, MSW-derived syngas

Direct Production of Chemicals from Recycled Carbon Pollution



Direct Production Reduces Costs & Footprint



- ✓ Same reactor
- ✓ Same operating conditions
- ✓ Same feedstock

DISRUPTION =

- 1) Rapid reaction to market fluctuations
- 2) Feedstock ≠ Commodity

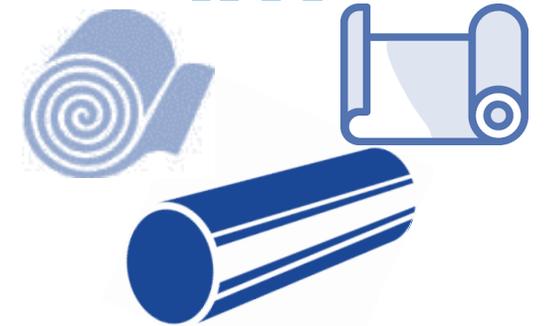
MEG



Acetone



IPA





Enabling a Circular Economy

