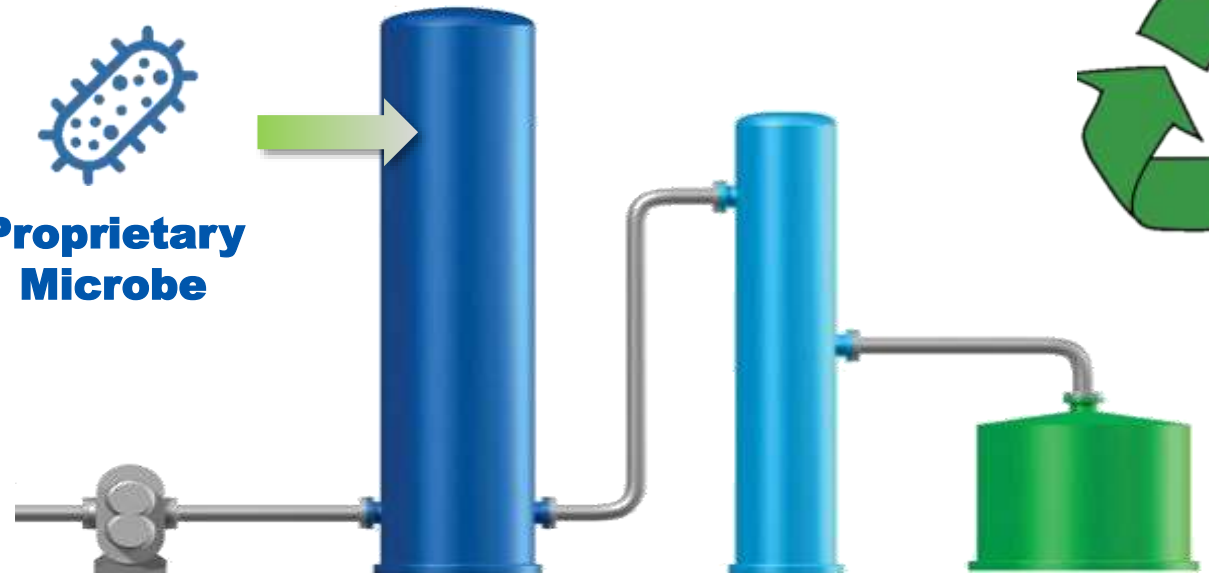
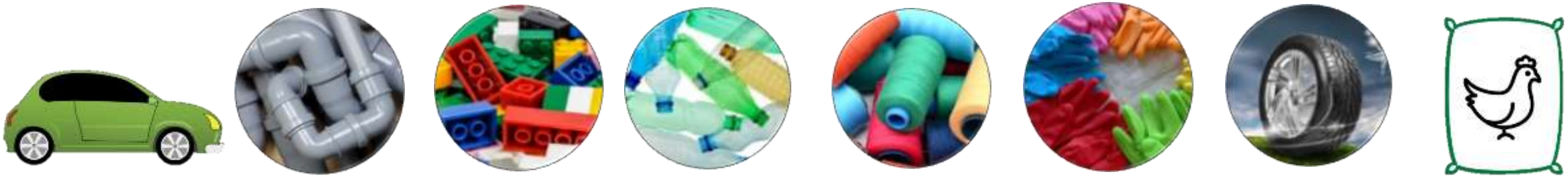
LanzaTech

No such thing as waste

Recycling Carbon

Industrial Off Gas
Biomass, MSW Syngas





LanzaTech

Started Up May 3rd 2018!

首钢朗泽
Shougang LanzaTech

LanzaTech

Status Shougang Commercial Plant

首钢朗泽
Shougang LanzaTech

Inoculator Start-up: **May 3**

All unit operations running
(gas clean up, fermenters, distillation, WWT, biomass recovery)

95% single train design production

100% of design selectivity

100 t/day production
(**35,000** gallons/day)

70% direct water recycle

> 15 million liters produced to date

Compelling Project Economics at 1st Commercial Plant

Production Levels that Enable Profitability

CapEx per Gallon of ~$3.25

Gas BTU Value

Payback Period ~3 Years

It takes Time….It takes Data

LanzaTech

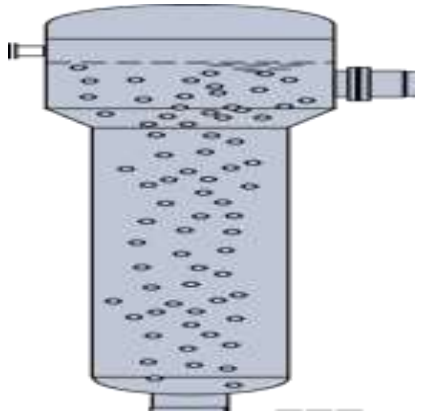
CELEBRATING **13** YEARS

Multiple Demo plants at various scales; 70,000 operating hours

Strain Development → **Lab** → **Pilot** → **Demo** → **Commercial**

Industrial Process Package:

Industrial Microbe



Bioreactor Design

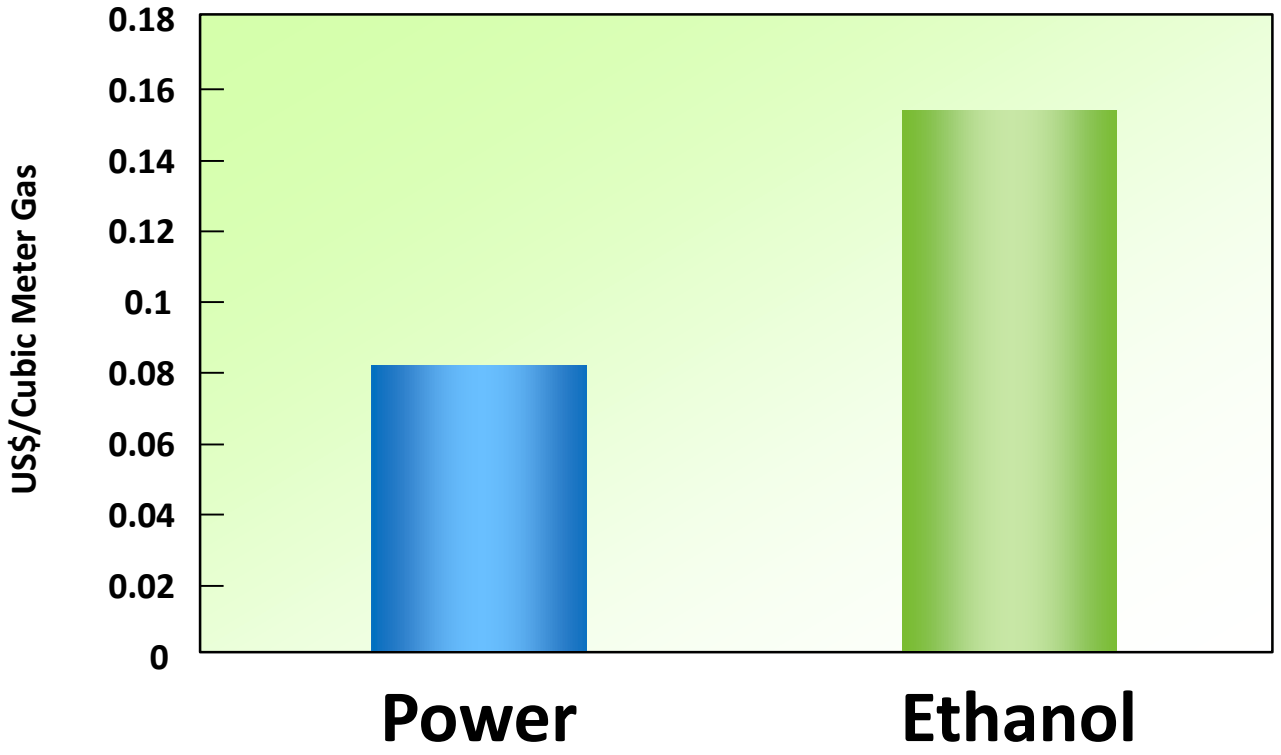
Process Engineering

Process Operation

Support logistics

Enabling global technology deployment

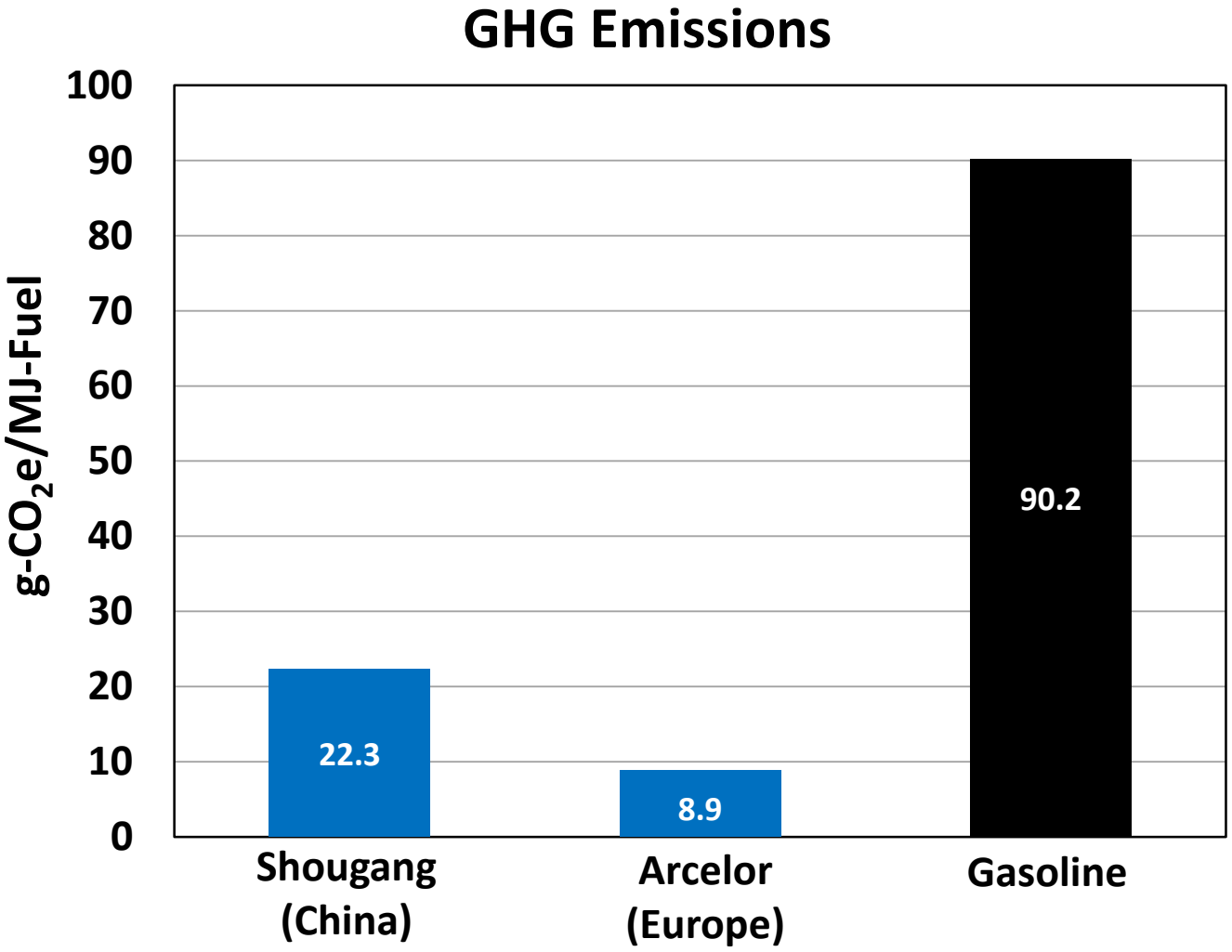
Steel Mill Value Proposition



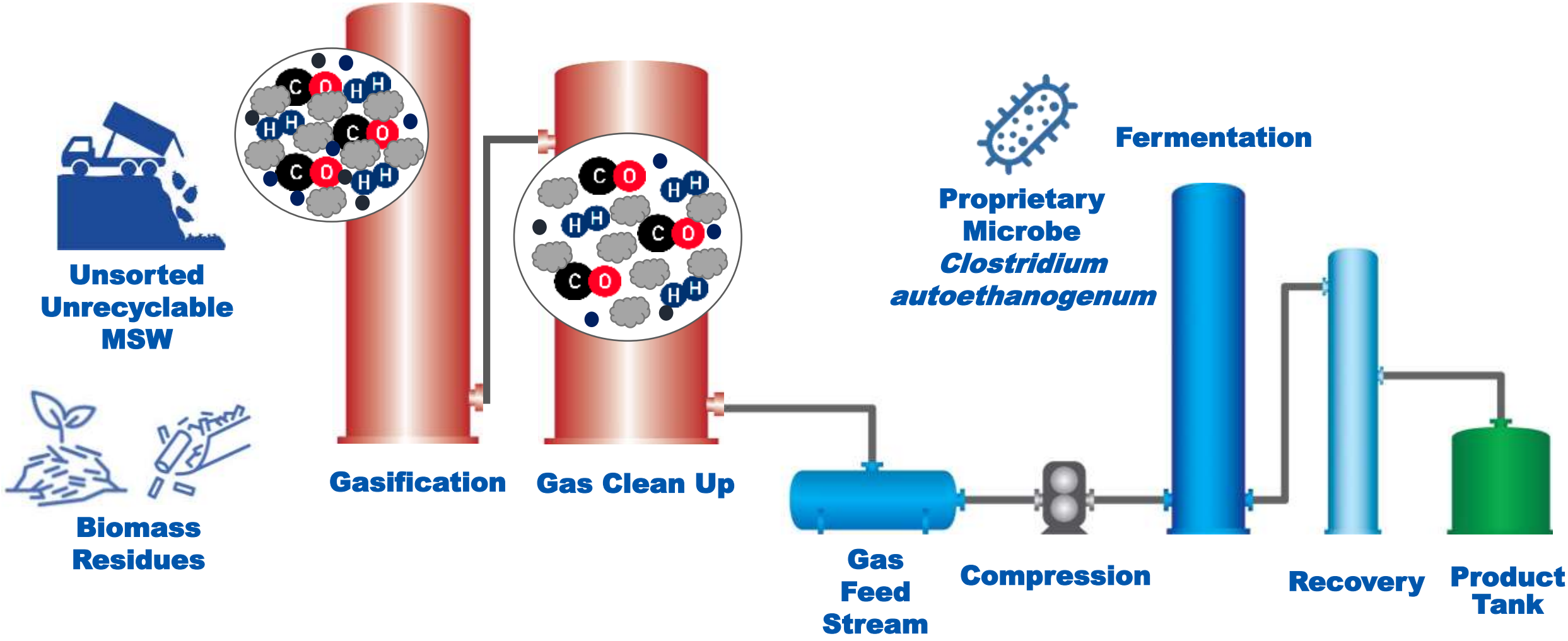
2x More returns from ethanol than from electricity

Environmental Benefits of Our Ethanol Fuels: Waste-Gas Ethanol

- Ethanol produced from **steel mill waste-gas** at our commercial and upcoming facilities.
- LanzaTech ethanol can provide a **75–90% savings** in emissions compared to a fossil gasoline.



Gasification and Fermentation



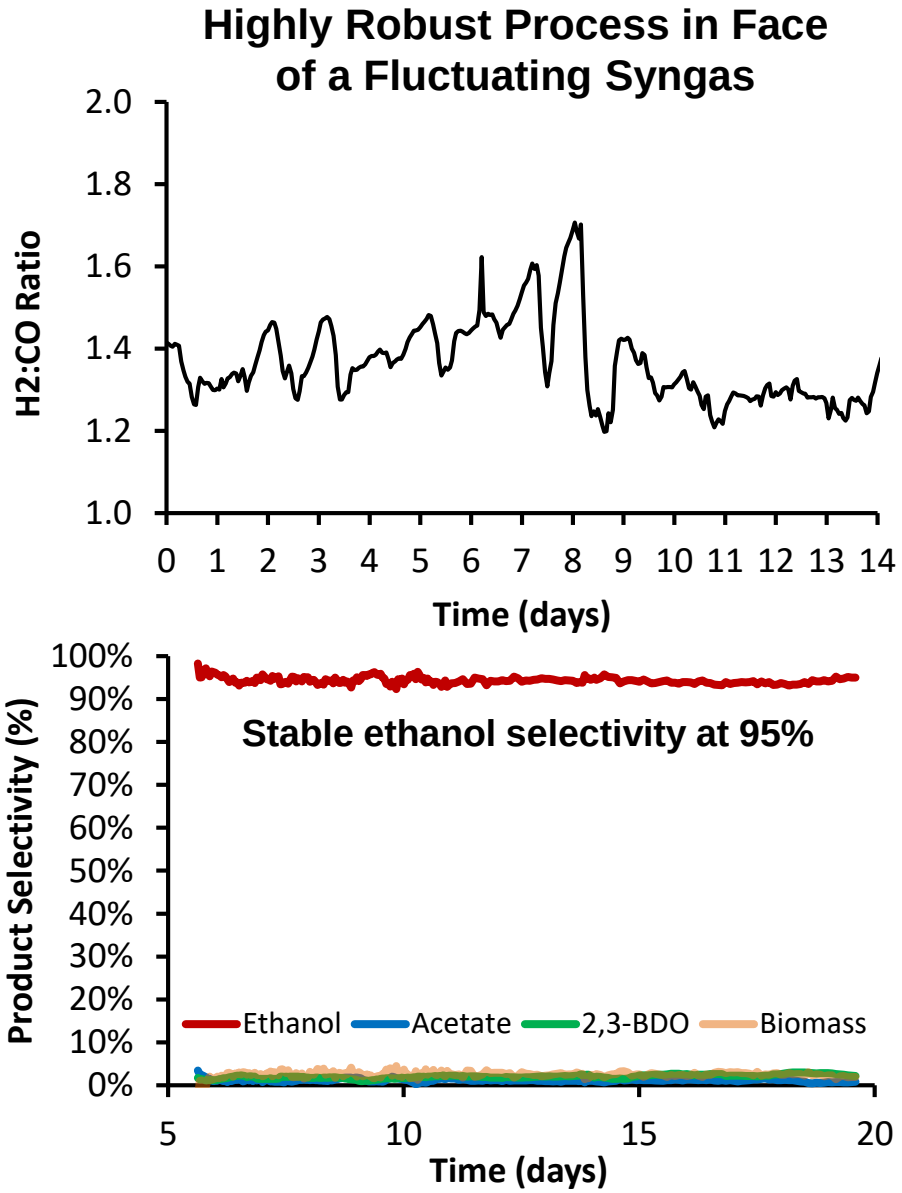
Variety of Feedstocks Successfully Demonstrated with Integrated Gasification Unit

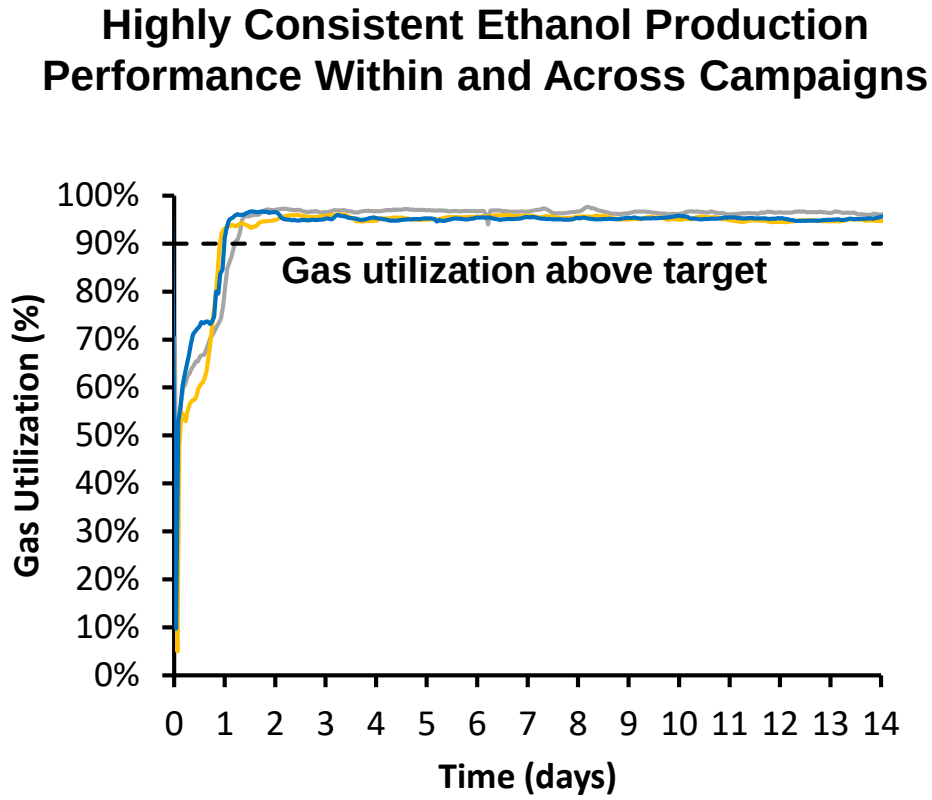
Daniell, Köpke (2012). Commercial Biomass Syngas Fermentation. *Energies*: 5: 5372-5417

SEKISUI

LanzaTech-Sekisui MSW → Ethanol Demonstration 2014-2018

Consistent Performance Through Sequential Campaigns at MSW Pilot Plant





Demonstrated 90% water recycle
→ Low environmental footprint

Deployment Pipeline

IndianOil
- 34K TPA
- 2020

Refining

SWAYANA
- 52K TPA
- 2020

Ferro Alloy

ArcelorMittal
- 62K TPA
- 2020

Steel mill

AEMETIS
- 35K TPA
- 2020

Biomass

SEKISUI
- TBD

MSW

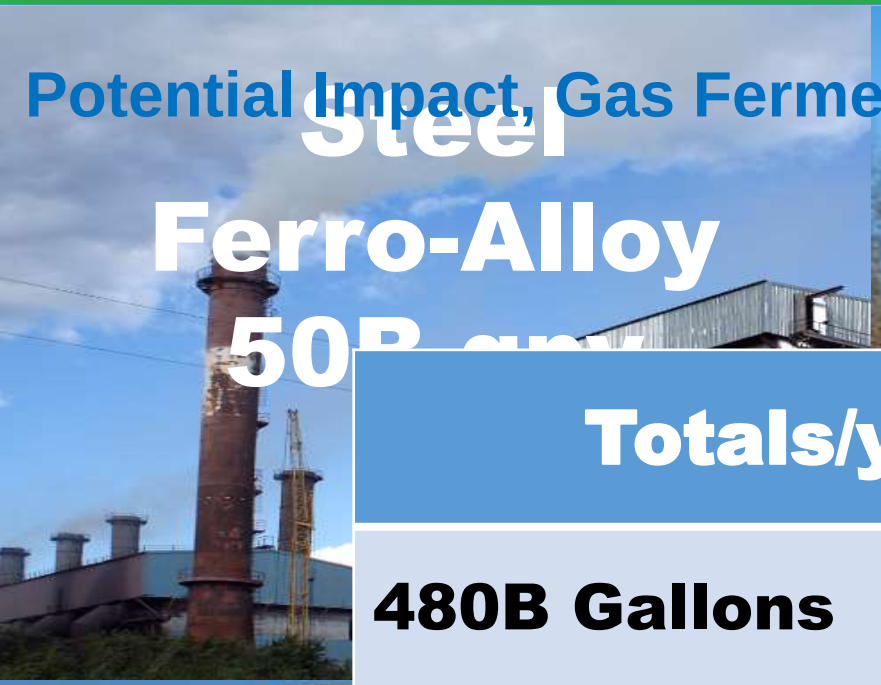
首钢朗泽 Shougang LanzaTech
- 48K TPA
- Operating

Ethanol

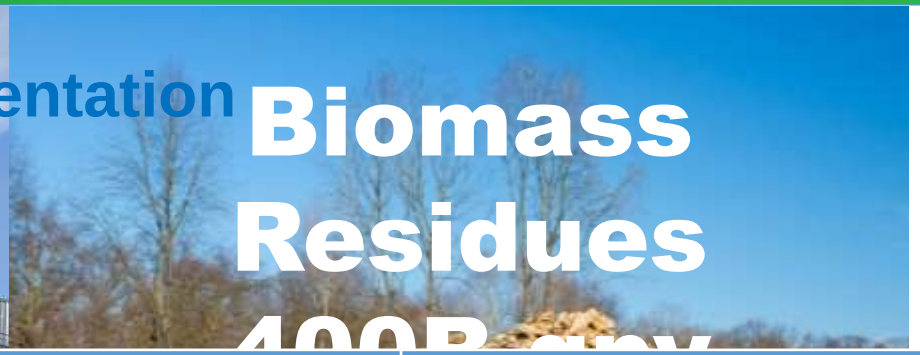
No Carbon Left Behind

LanzaTech

Potential Impact, Gas Fermentation



Steel
Ferro-Alloy
50B gpy



Biomass
Residues
400B gpy

M
26B

Local Input Global Impact

Totals/year	Relative to Today
480B Gallons	~35% of transport fuel
705M Cars off the road	~75% of passenger cars
2.6M mt CO_2	~7% of Global CO_2

ArcelorMittal

IndianOil

METIS

SEKISUI

Significant Global Potential

LanzaTech

Refining

Ferro Alloy

Steel mill

Biomass

MSW

Ethanol

No Carbon Left Behind

LanzaTech

Alcohol-to-Hydrocarbons

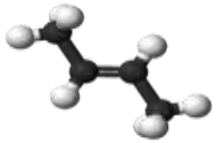
Ethanol → Dehydration → Oligomerization → Hydrogenation → Fractionation → Jet & Diesel

Pacific Northwest NATIONAL LABORATORY

Ethanol

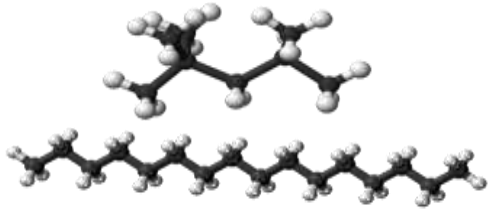
$-H_2O$

Ethylene



C_4- C_{24} Olefins

$+ H_2$



Paraffins and IsoParaffins

U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

DARPA DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

FEDERAL AVIATION ADMINISTRATION

BOEING

RSB
www.rsb.org

virgin atlantic

HSBC

Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons

LanzaTech

ASTM INTERNATIONAL

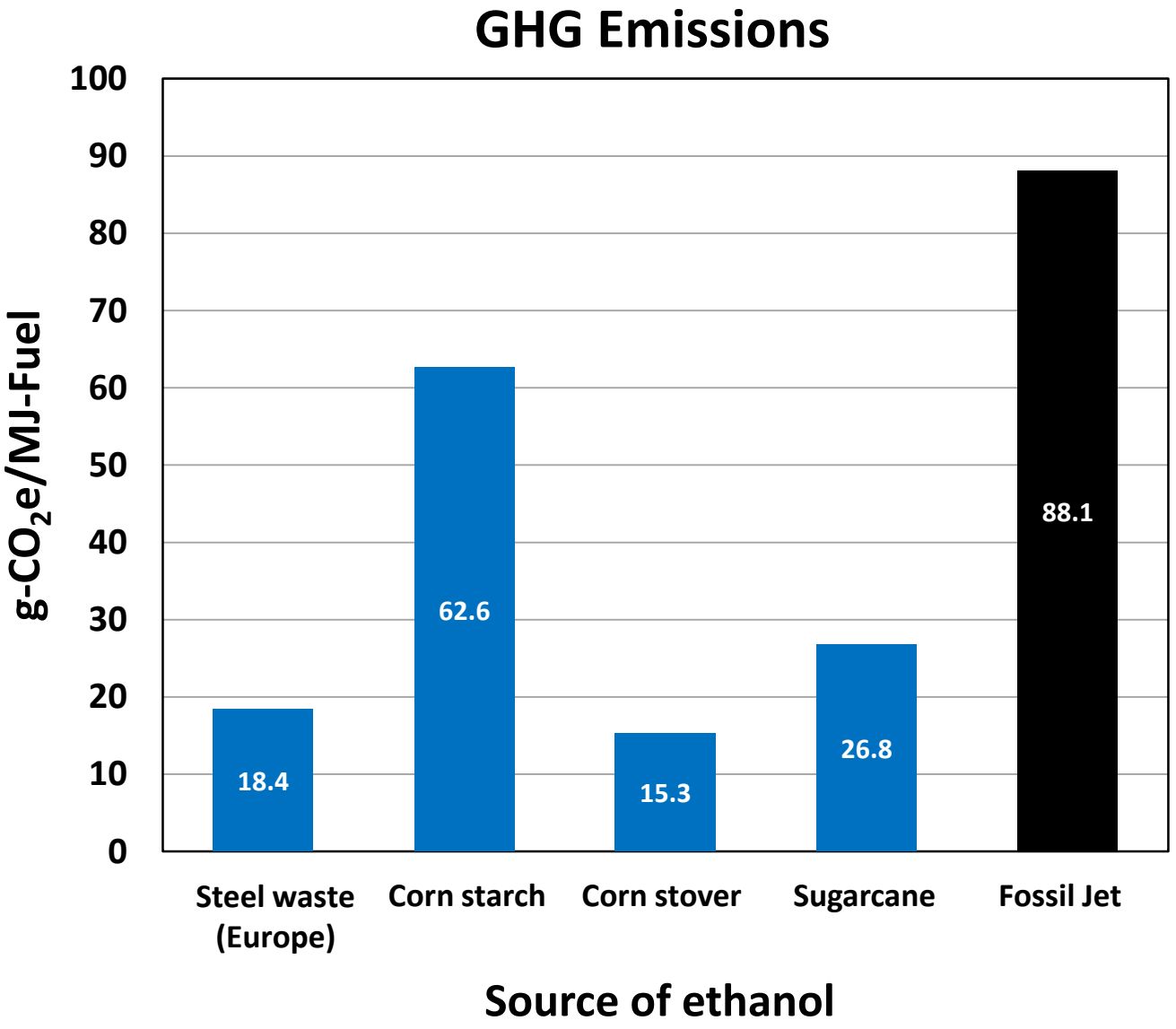
On April 1, 2018 ASTM Intl. Revised D7566 ATJ SPK Annex A5

- **Added Ethanol as a feedstock**
- **Increased final blend ratio to max 50 %**

October 3, 2018

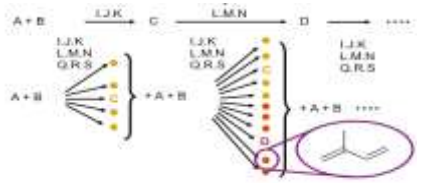
Environmental Benefits of LanzaJet

- SPK can be produced from any ethanol source. Steel waste gas ethanol is from Arcelor Mittal project (Ghent).
- LanzaJet can provide a **29–83% savings** in emissions compared to a fossil jet fuel.



Complete Synthetic Biology Platform Developed

Knowledgebase & Pathway Discovery



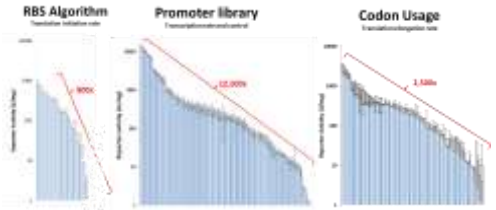
Northwestern CENTER FOR SYNTHETIC BIOLOGY

U.S. DEPARTMENT OF ENERGY

BioCAD

teselagen BIOTECHNOLOGY

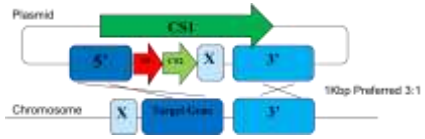
Validated Part Libraries & Algorithms



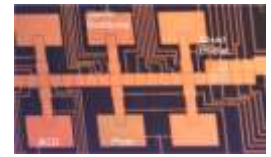
- *Control across several log units*

Advanced Genetic Toolbox

- *CRISPR Multiplexing*
- *Proprietary Homologous Recombination Tool*



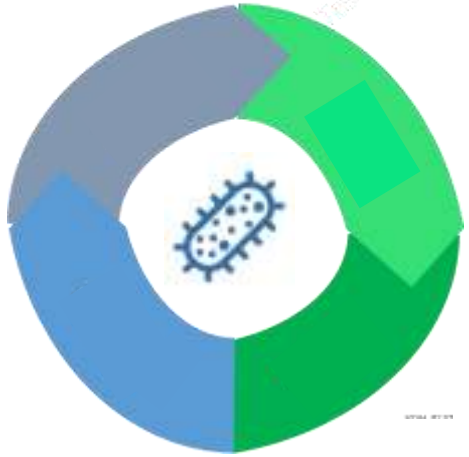
Microfluidics strain construction



- *Reduced footprint*
- *>10x time savings*
- *>1000x reagent cost savings*

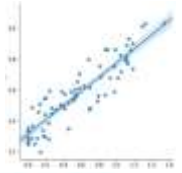
JBEI Joint BioEnergy Institute

U.S. DEPARTMENT OF ENERGY



Automated strain evolution

Modelling & Machine Learning



teselagen BIOTECHNOLOGY

Agile BioFoundry

Argonne NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY

Multi-Omics

OAK RIDGE National Laboratory

The University Of Queensland AUSTRALIA

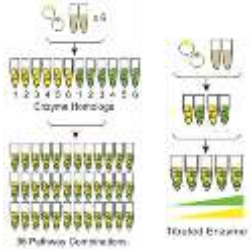
U.S. DEPARTMENT OF ENERGY

Anaerobic Biofoundry

- *Automated HT screening*
- *Anaerobic conditions*
- *In context of gases*

U.S. DEPARTMENT OF ENERGY

Cell-free prototyping



- *>20x time savings*
- *>10x cost savings*
- *>100x higher throughput*

Northwestern CENTER FOR SYNTHETIC BIOLOGY

U.S. DEPARTMENT OF ENERGY

No Carbon Left Behind

LanzaTech

Making Materials:

Refining

Ferro Alloy

Steel Mill

Biomass

MSW

Fixing Carbon + Adding Value

Acrylic Glass

Rubber

Packaging

Building Materials

Toys

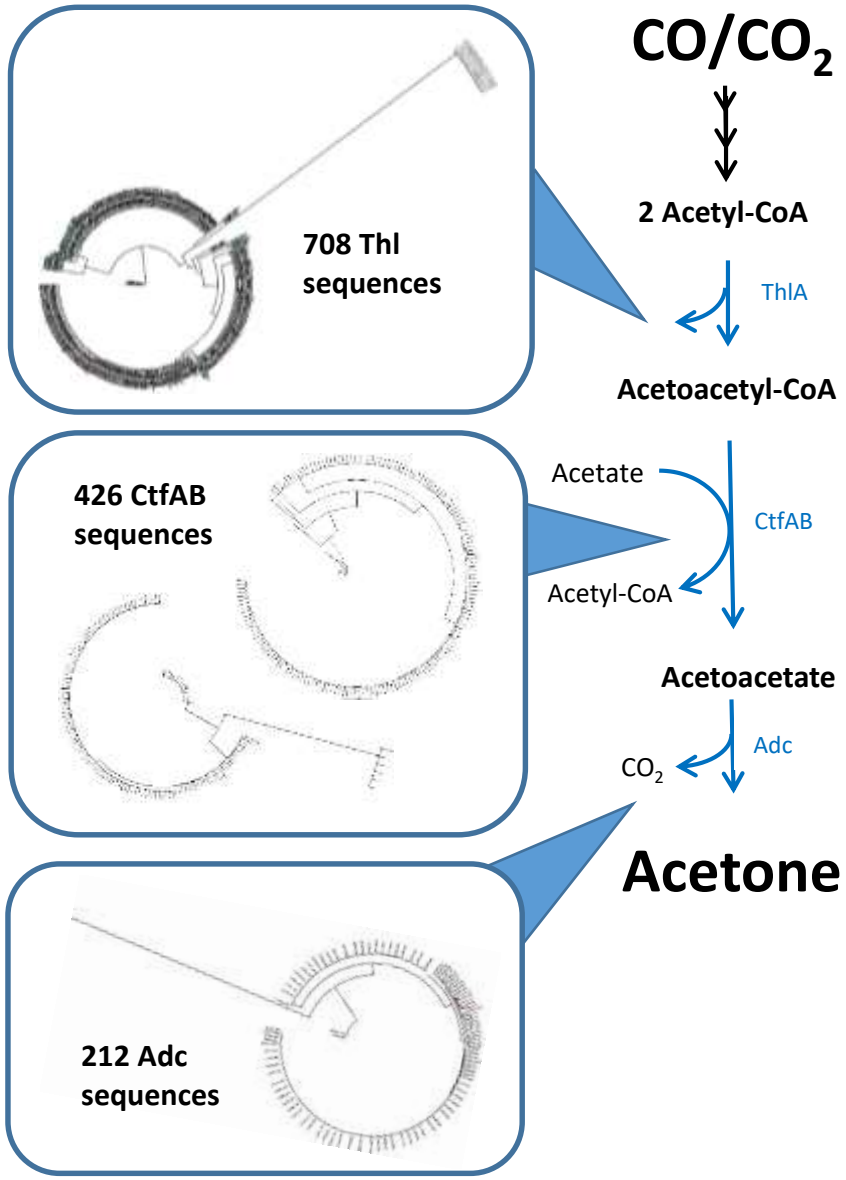
LanzaTech

Demonstrated Range of Chemistries and Functional Groups to Date

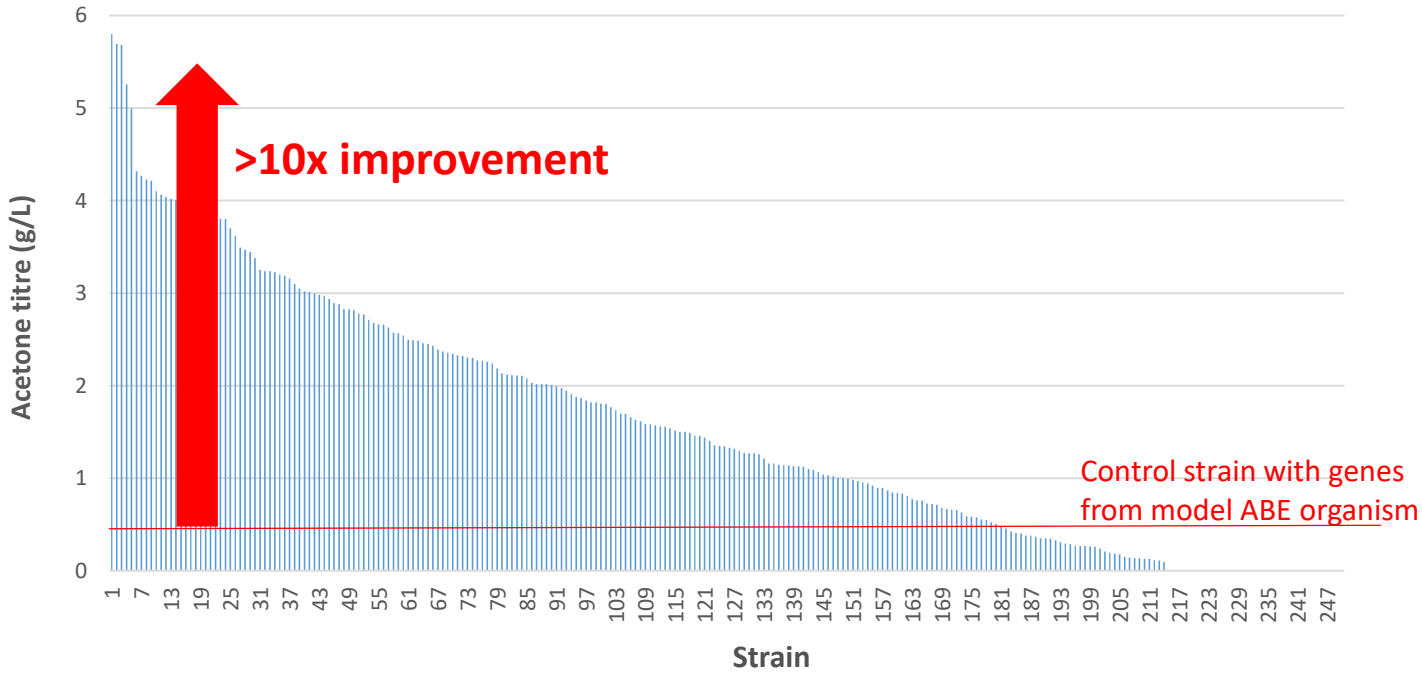
	Acids						Alcohols		Diols			Aromatics	Dienes	Esters	Ketones	Terpenes
	Carboxylic	Dicarboxylic	Hydroxy	Dihydroxy	Keto	Amino	Linear	Branched	1,2-	1,3-	2,3-					
C2	Acetic						Ethanol		MEG							
C3			Lactic	3-HP		ALA	n-propanol	IPA	1,2-PDO (R,S,mix)	1,3-PDO (R,S,mix)					Acetone	
C4	Butyric		2-HB, 3-HB, 4-HB (R,S,mix)	2-HIBA	2-EM		n-butanol	2-butanol		1,3-BDO (R,S,mix)	2,3-BDO (RR,meso,mix)		IBUT		MEK Acetoin	
C5	Succinic		Citramalic		Ketoglutaric	VAL							Isoprene			
C6+			C6-C14 Hydroxyacids	PHB	Mevalonic	C6-C14 Alkylmalates	LEU ILE	linear branched C6-C14 alcohols				Phenyl ethanol PHB Salicylic			FAEE FABE	Farnesene

Direct production from gas demonstrated for wide range of functional classes, including control over stereochemistry

Gas to Acetone: Strain Development

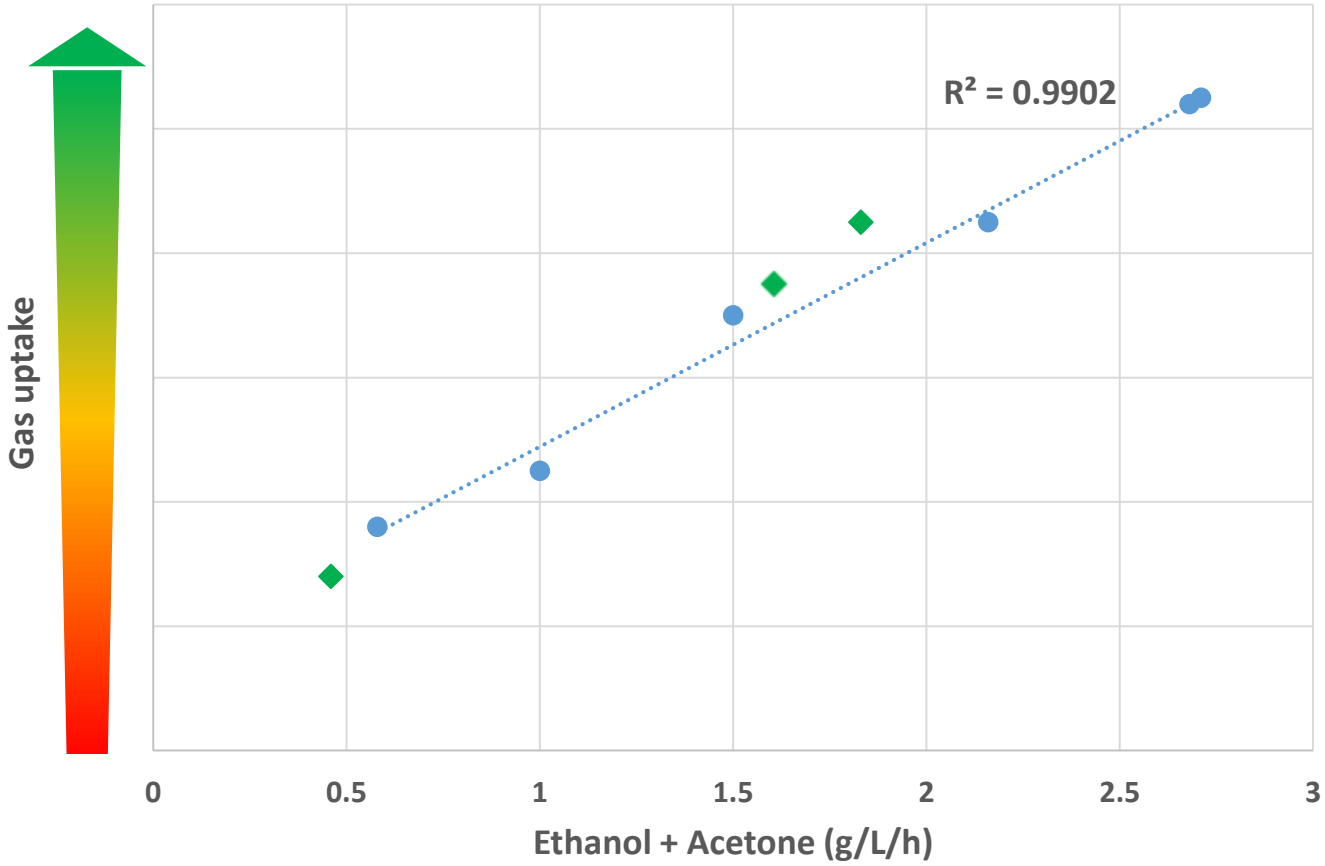


- No organism known that produces acetone from gaseous feedstocks
- Microbial acetone production through ABE well known
- LanzaTech owns a collections of >400 industrial ABE strains
- Rapid prototyping of identified genes through LanzaTech's advanced genetic engineering platform improved acetone production from gas by >10x



Waste Gas To Acetone: Scale Up

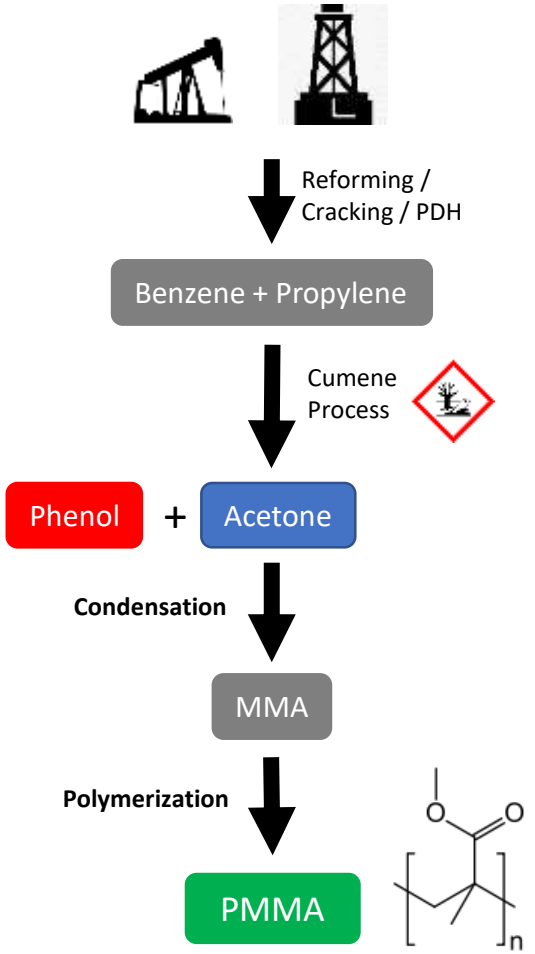
- A continuous process has been developed and successfully scaled up
- High correlation between lab and pilot process



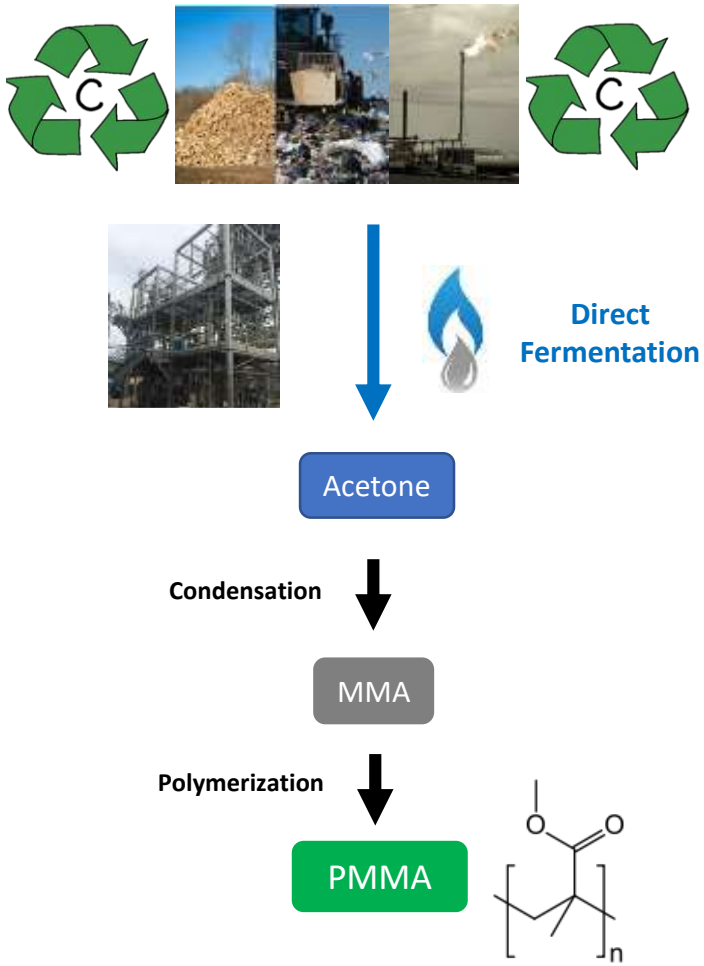
- 1.5L Lab CSTR

- >80L Pilot Reactor

Waste Gas to Acetone



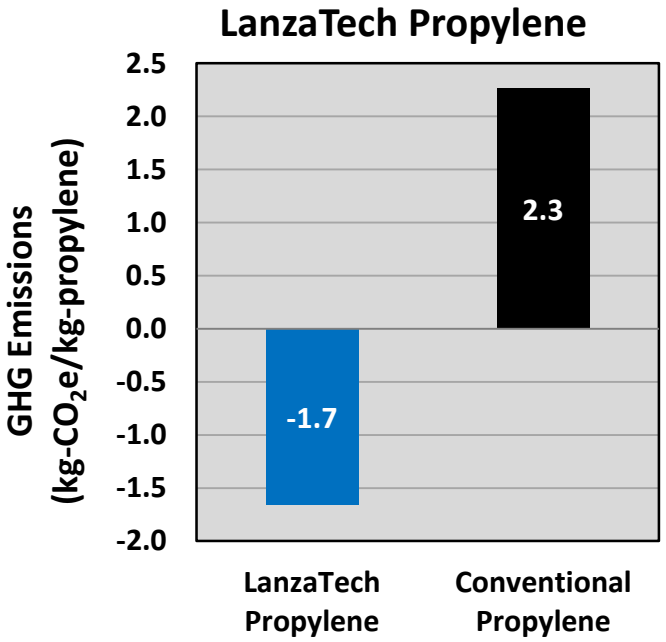
- Fresh fossil resources as starting material
  (Coal use has additional negative social & environmental impacts)
- High energy (Reforming/Cracking) demand
- Waste management (Cumene process produces 1 mol waste per 1 mol product)
- Supply dependent on phenol production (predicted to decline)

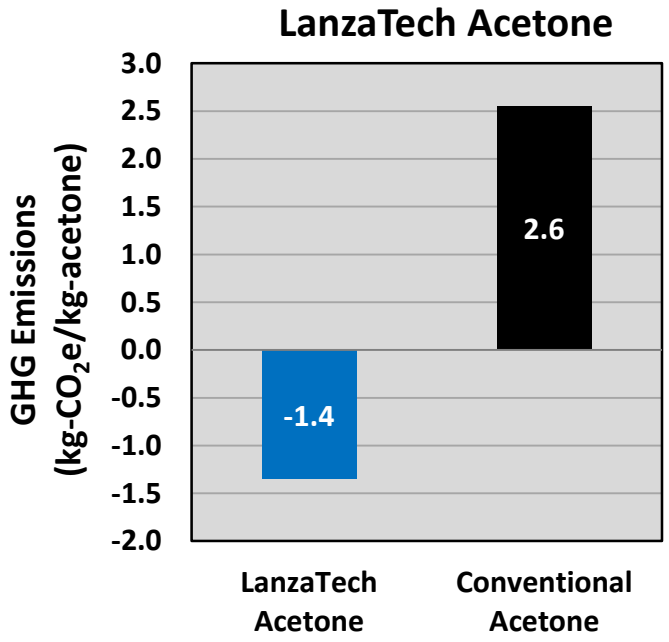


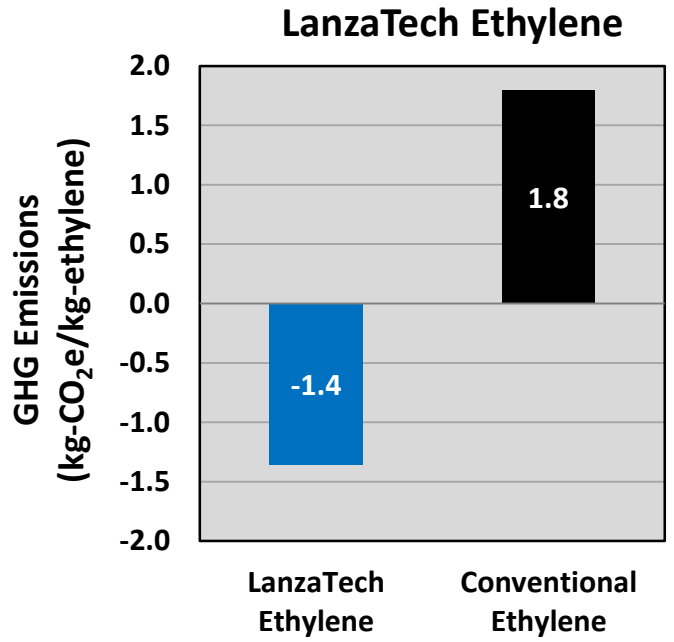
- Waste and residue feedstocks
- Independent of phenol production
- Reduced GHGs and water
- 150% GHG savings for acetone

Environmental Benefits of LanzaTech Chemicals from waste

- All chemicals are produced from gas fermentation of steel making waste-gases. There are produced directly (direct acetone) or through multiple steps (ethanol -> ethylene, isopropanol -> propylene)
- Our chemicals can provide substantial GHG emissions savings over chemicals produced by fossil routes.







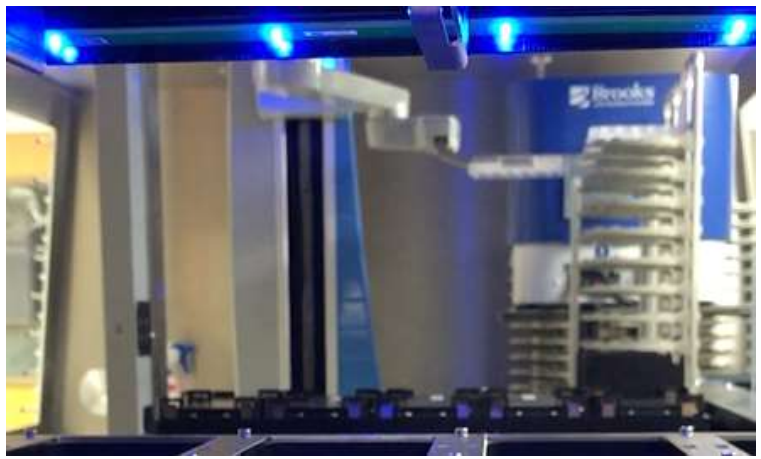
Clostridium Biofoundry (cBioFab)

- **World-first biofoundry that works in context of anaerobic organisms and toxic and flammable gases**

Fully automated workflows include: Assembly of pathways, Cell-free prototyping of pathways, Generation and banking of strains, Screening of strains

Fully integrated operations include: Microfluidics (plasmid assembly, electroporation), Colony picking, Advanced robotics, Automated incubators, HT readers and analytics

Modular design allows for seamless expansion: Current capacity >4,000 strains per cycle; Expandable to >16,000 strains per cycle and module



Microbe 1.0

✓Ethanol

Microbe 2.0

✓new product molecule

✓Same reactor

✓Same operating conditions

✓Same feedstock

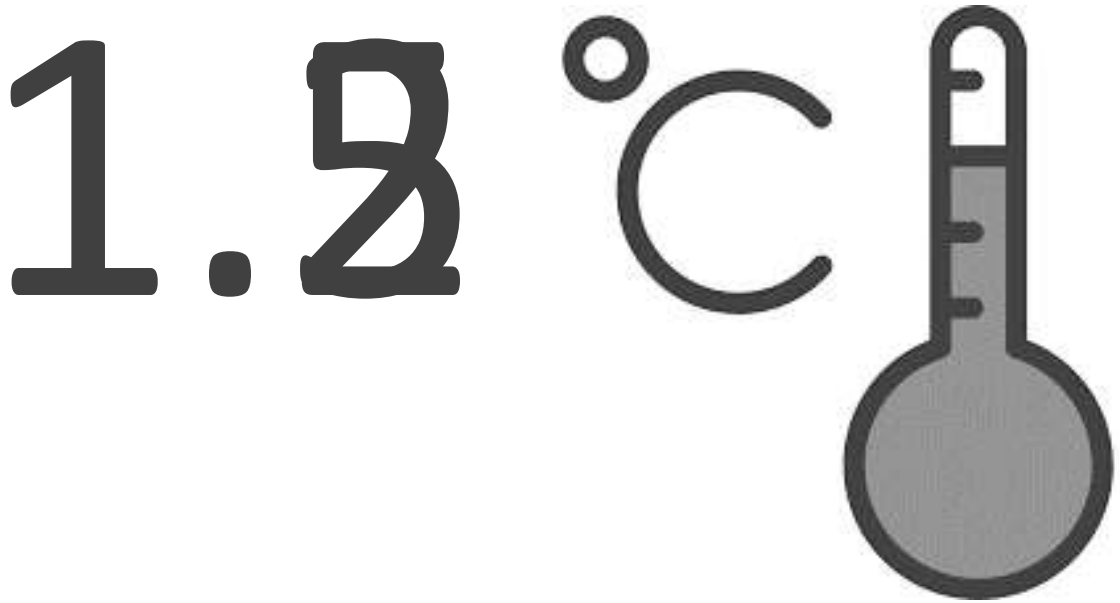
DISRUPTION = 1) Rapid Reaction to Market Fluctuations 2) Feedstock ≠ Commodity

Enabling the Circular Economy

Light Strong Steel for Planes….

LanzaTech

The World is Debating



The Time for Debate is Over!

New Categories of Weather

AMERICA

National Weather Service Adds New Colors So It Can Map Harvey's Rains

August 28, 2017 · 1:50 PM ET

BILL CHAPPELL

HIGHEST NOCTURNAL TEMPERATURE IN HISTORY RECORDED IN KHASAB: GÉOCLIMAT

Share 30 Like 30 Tweet

MUSCATDAILY.COM

By Zain al Tauqi
July 10, 2017

MUSCAT - French weather data compiling and analysis site Géoclimat claims that the highest ever nocturnal temperature recorded globally was on the night of June 16-17 in Khasab, as the temperature did not drop below 44.2°C.

"The temperature didn't drop below 44.2°C during the night of June 1

THE TIMES OF INDIA
CITY

Rajasthan's Phalodi sizzles at 51°C, highest ever temperature in country

BBC Sign in Menu

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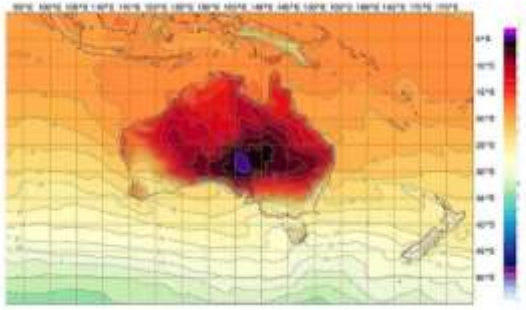
US & Canada

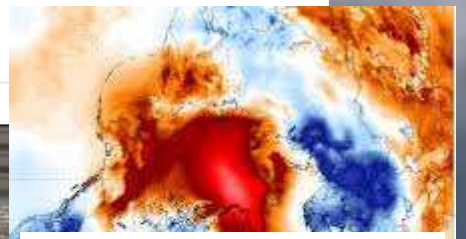
Phoenix flights cancelled because it's too hot for planes

20 June 2017

It's So Hot in Australia That They Added New Colors to the Weather Map

This deep purple is a brand-new shade that the Australian bureau of meteorology was forced to add to its heat index because their country is, you know, kind of on fire.





January 2018:
Arctic 45 degrees above Normal

Floods in drought season: is this the future for parts of India?

Raghu Karnad

Mumbai, Assam and other regions are used to extreme weather, but the recent flooding was not 'normal'. The powers that be must adjust, and fast

The Guardian

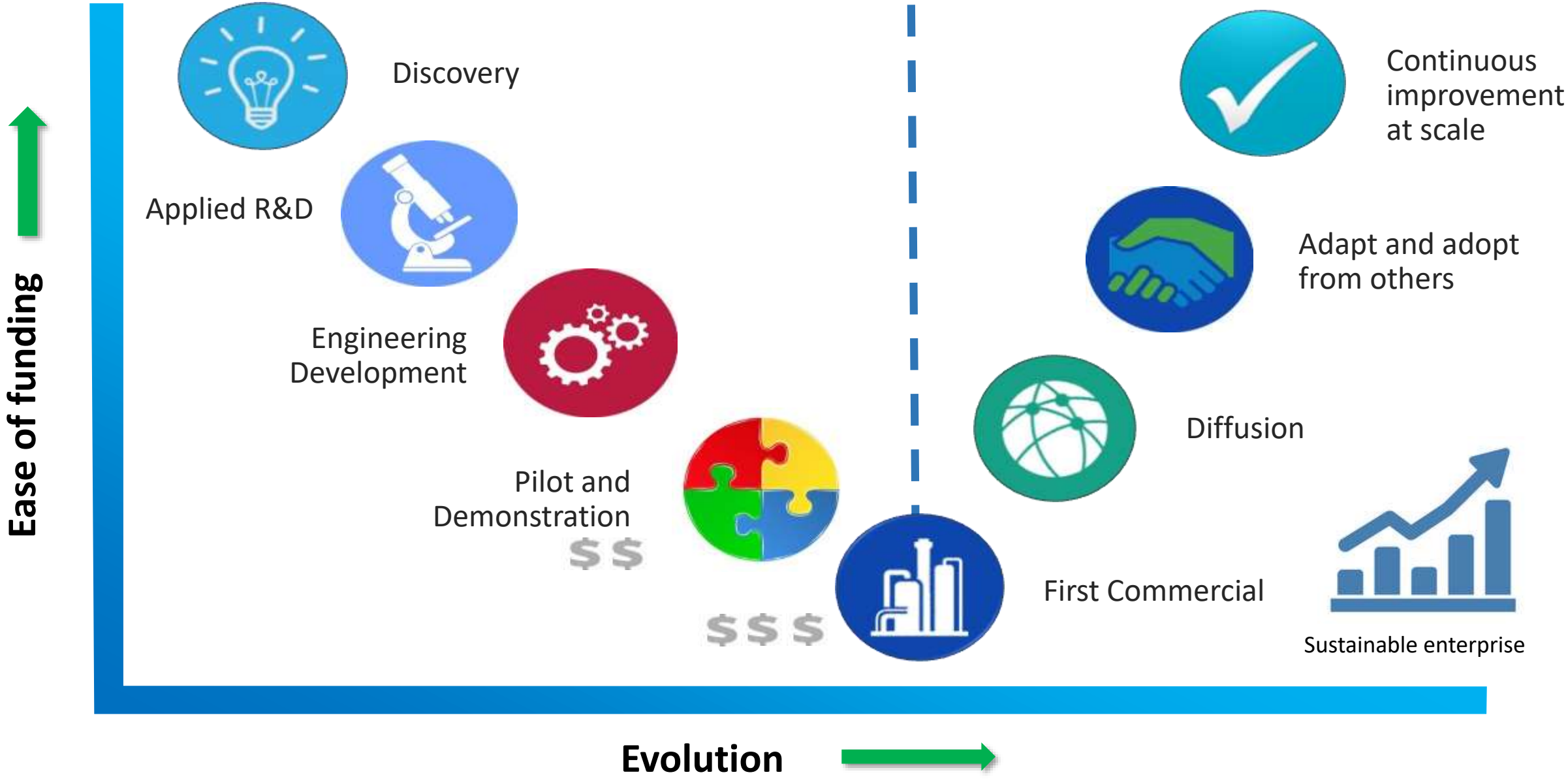
Decreases in global beer supply due to extreme drought and heat!

Wei Xie, et. al. *Nature Plants* (2018)

"Future climate and pricing conditions could put beer out of reach for hundreds of millions of people around the world,"

Prof Steven Davis; University of California, Irvine.

Crossing the Valley of Death



LanzaTech

It Takes…

Data

首钢朗泽
Shougang LanzaTech

BAOSTEEL

SEKISUI

WBT

Multiple Demo plants at various scales

70,000 operating hours

Time

LanzaTech

CELEBRATING
13 YEARS

Lab Pilot Demo

Commercial

Money

>$250M

khosla ventures

K1W1
K One W One Ltd.

CICC 中国国际金融有限公司
CHINA INTERNATIONAL CAPITAL CORPORATION LIMITED

MITSUI & CO.

इंडियनऑयल
IndianOil

QIMING VENTURE PARTNERS

NEW ZEALAND SUPERANNUATION FUND

BAOSTEEL

PETRONAS

SIEMENS

BASF
We create chemistry

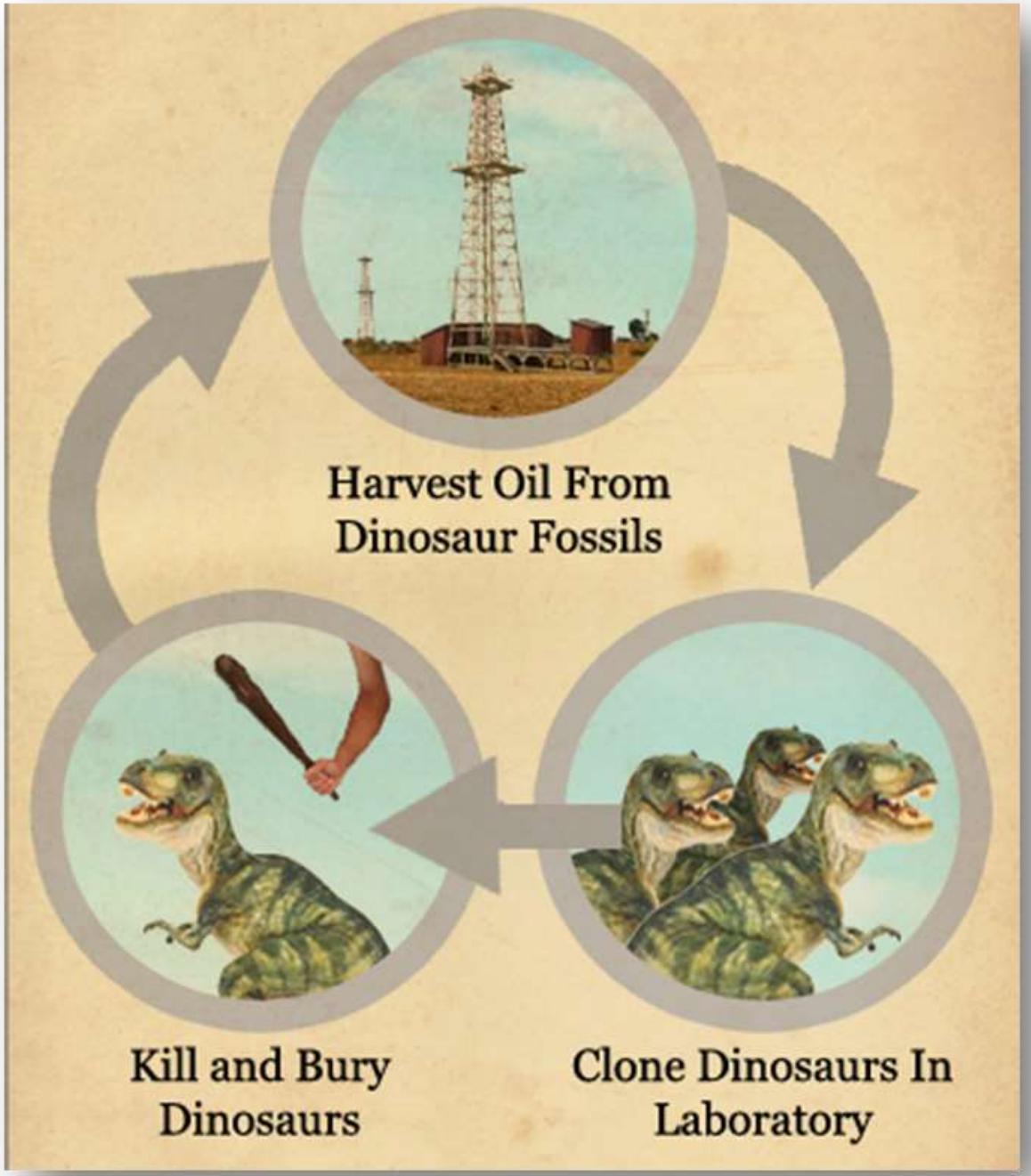
CITIC CAPITAL 中信資本

MLS Capital

SBCVC

SUNCOR ENERGY

Questions?


Harvest Oil From
Dinosaur Fossils
Kill and Bury
Dinosaurs
Clone Dinosaurs In
Laboratory