LanzaTech

CELEBRATING 10 YEARS

Monetizing Biorefinery Residue and Waste Streams

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VP, Government Relations

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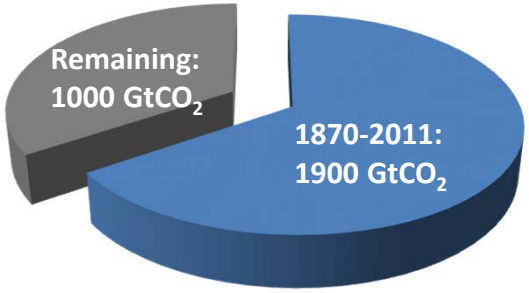
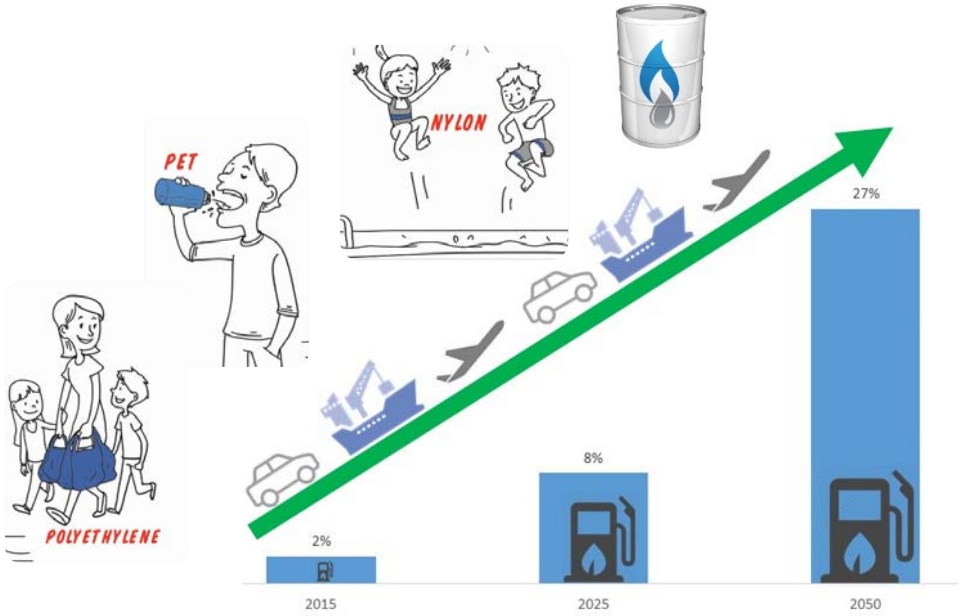
capturing carbon. fueling growth.

A Carbon Smart World



65% of 2°carbon budget: USED

Must stay in the ground



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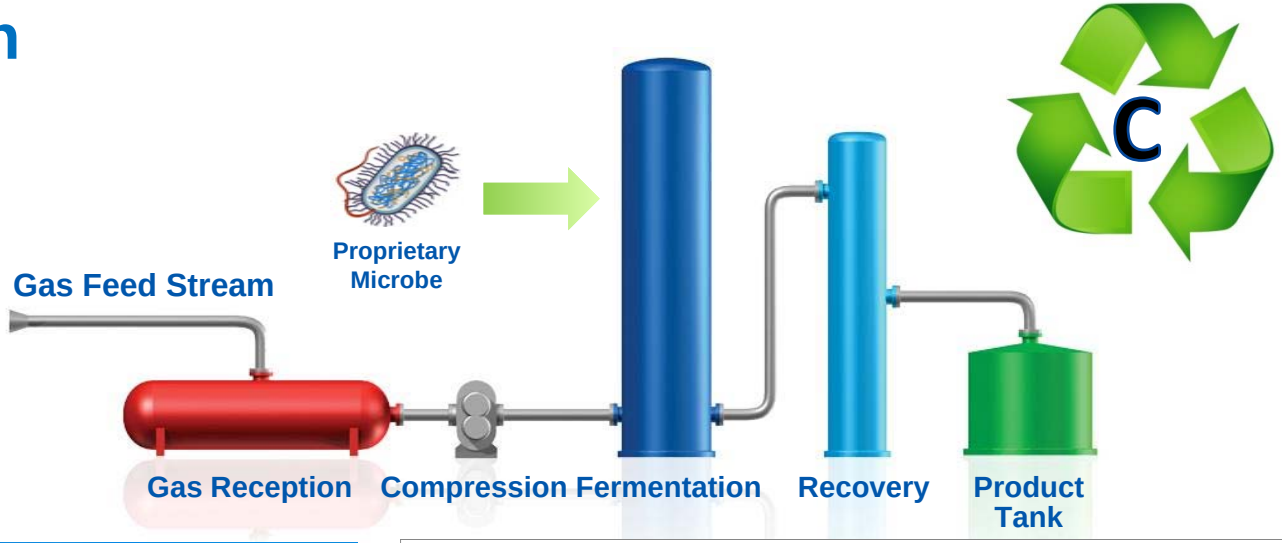
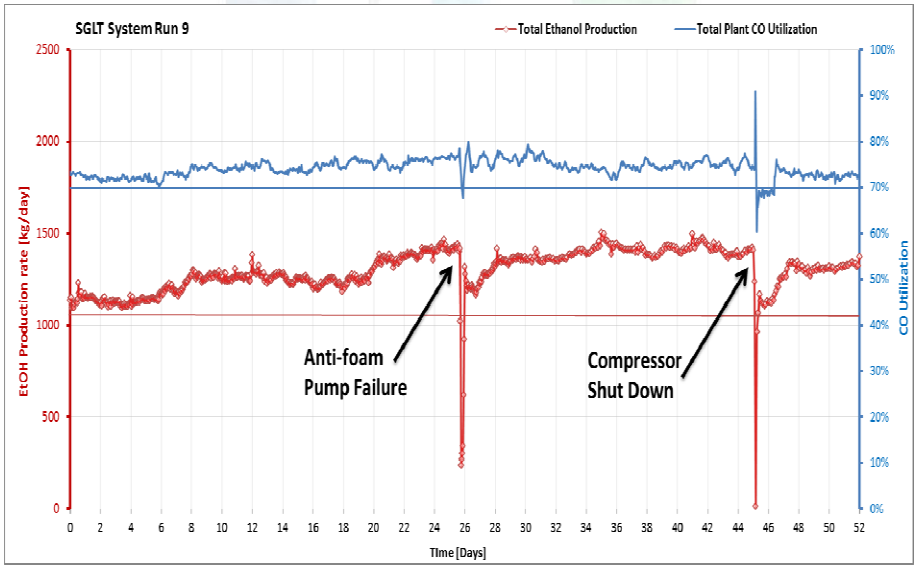
Recycling Carbon

Gas fermentation technology converts C-rich gases to fuels and chemicals





Performance milestones achieved and exceeded for >1000 hours
100K GPY (~400 KL/yr)

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From Demonstration to Commercial

50,000+ combined hours on stream
Multiple runs exceeding 2000 hours

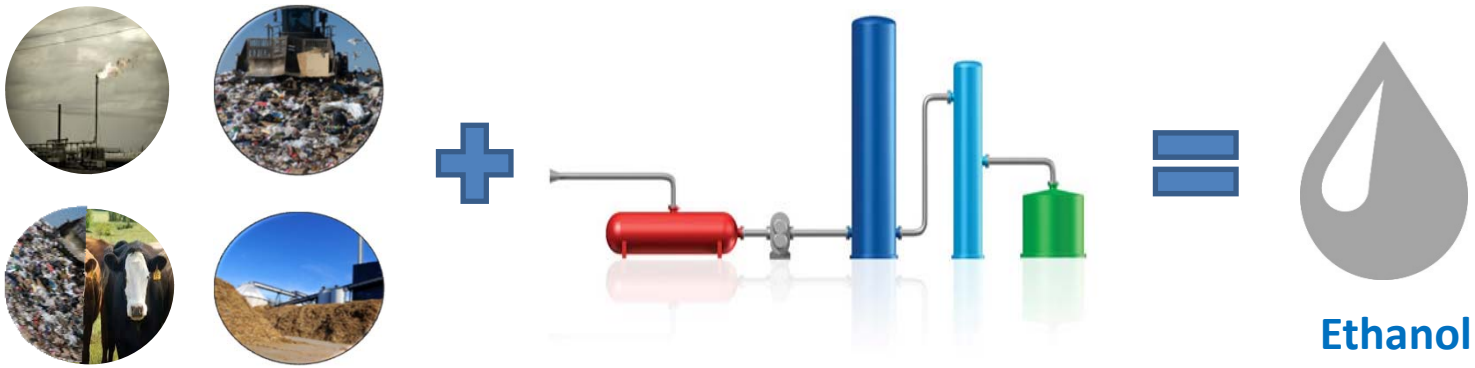
BAOSTEEL CHINASTEEL 首钢集团 SHOUGANG GROUP WBT OSO LCY

Commercial Scale Q2 2018

Ton (gallons) Lanzanol per year

ArcelorMittal	64k (21M)
CHINASTEEL	20k (6.7M)
首钢集团 SHOUGANG GROUP	46k (15M)

From Waste to Wing



Ethanol

Dehydration → Oligomerization → Hydrogenation → Fractionation → ATJ-SPK

首钢朗泽 Shougang LanzaTech

virgin atlantic

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

BOEING

HSBC

Pacific Northwest NATIONAL LABORATORY

GE

Co-Products, By-Products, Residues and Wastes

- **Biorefinery co-products and by-products**
  - Intentional or unintentional, high relative value
- **Biorefinery <u>residues</u> and wastes**
  - Unavoidable outcome of primary process(s), low value or liability
- **Gas, liquid or solid streams**
  - Fermentation CO_2 or pyrolysis off gas ($CO/CO_2/H_2$)
  - Waste water and waste water sludge
  - Lignin, algal, bacterial biomass residues

http://animalscience.tamu.edu/2012/08/29/study-focuses-on-feeding-beef-cattle-algae-co-products/

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Maximizing Contributions from Residues

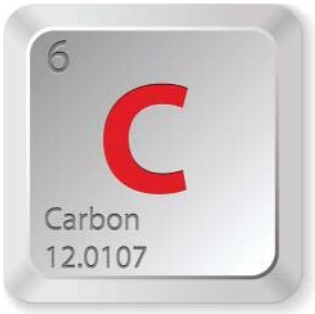
Energy
can be Carbon free

Wind:

Solar:

Hydro:

Liquid Fuels
& Chemicals …
+ Food & Feed
must contain



Efficiency
Recycle C

Prioritize carbon re-use where it is truly needed

Value proposition

Transform energy intensive processes and capture storable liquid fuel

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Today

Waste water treatment plant

Pretreatment

Treatments
1° settling clarifier
2° aerobic/activated sludge

Digester

Sludge Dewatering

to landfill or cover

FOG Skim

Grit Removal

Primary

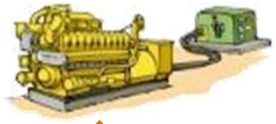
Secondary

Anaerobic Digestion

Press

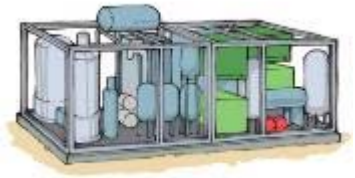
Transport and Tipping Fees

CH_4/CO_2



What could be

85% carbon converted to usable energy



CH_4/CO_2

21 BOE/day

Courtesy John Holladay, Pacific Northwest National Laboratory

Issues and Considerations

- **Economics**
  - Returns vs additional CAPEX and OPEX
  - Avoided disposal or compliance costs
- **Quantity/capacity**
  - Effective utilization at scale of primary product
- **Market**
  - Alignment of production capacity with potential market
  - Technologies and markets outside core
- **Logistics**
  - Infrastructure and complexity - capture, conversion, and transport
  - Requirements or opportunities for co-location
- **Approvals**
  - Additional permitting
  - Specifications and regulatory approvals for end use (fuel, chemical, feed)

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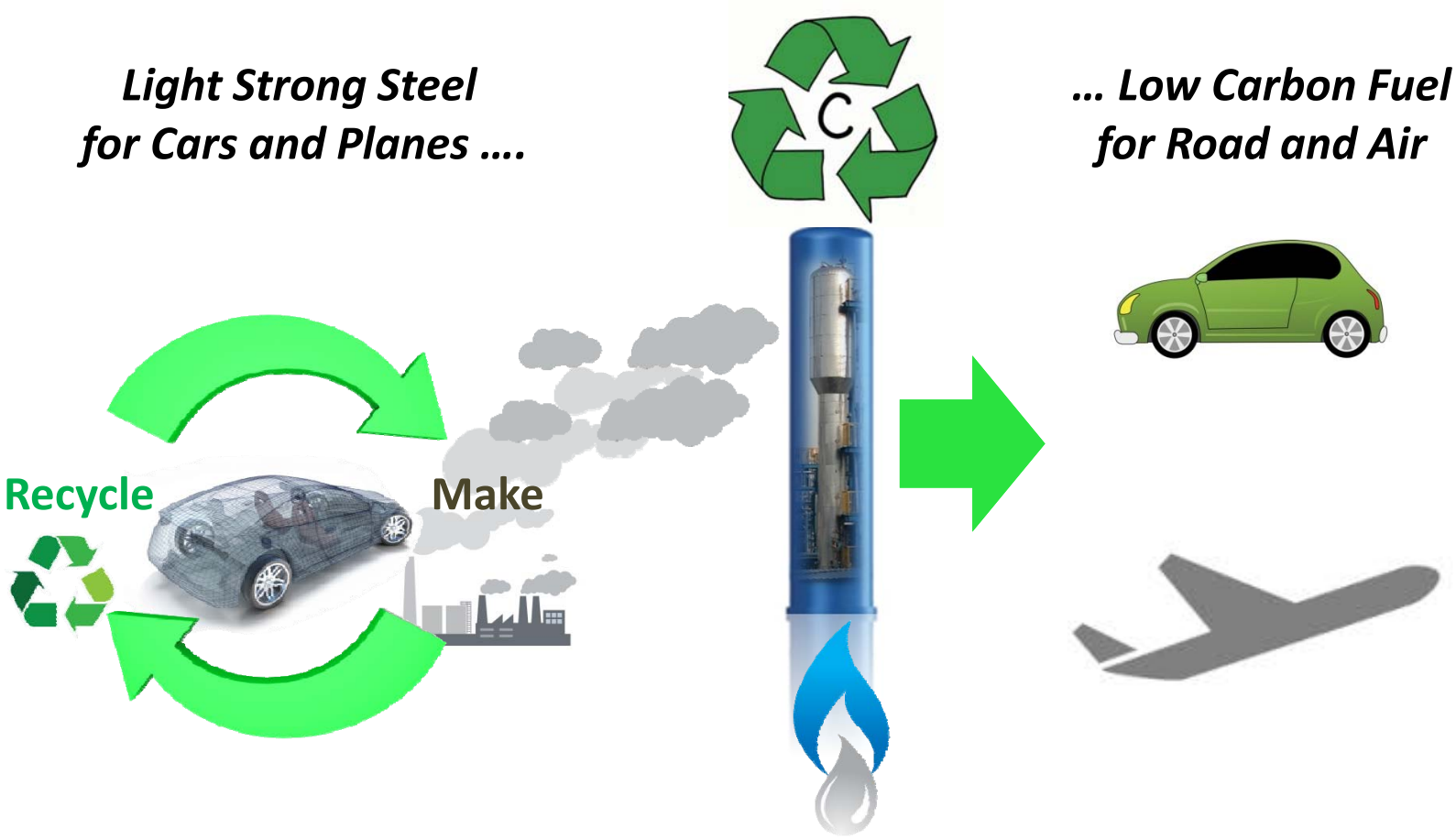
Embrace the Circular Economy

Light Strong Steel for Cars and Planes ….

… Low Carbon Fuel for Road and Air



Steel, Refining, Gas Processing, Petrochemical, FerroAlloy, …and Biorefineries

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