Circular economy through C1 fermentation
The LanzaTech process is driving innovation

- **Process** *recycles* waste carbon into fuels and chemicals
- **Process** brings underutilized carbon into the fuel pool via *industrial symbiosis*
- Potential to make *material* impact on the future energy pool (>100s of billions of gallons per year)
Waste carbon streams as a Resource

Industrial Waste Gas
Steel, PVC, Ferroalloys
~ 1.4B MTA (Steel only)

Biogas
LFG, Methane
~184.2T M³

Solid Waste
Industrial, MSW, DSW
>2B MTA

Biomass
>1.3B MTA (US Alone)

CO₂

Reforming
Gasification

Renewable H₂

Renewable Electricity

CO
CO + H₂
CO + H₂ + CO₂
CO₂ + H₂

Gas Fermentation

✓ Available
✓ High Volume/Low Intrinsic Value
✓ Most Point Sourced
✓ Non-Food

Source:
2010 global production; 2012 proven gas reserves data (IEA, UNEP, IndexMundi, US DOE Billion Ton Update)
The natural LanzaTech gas fermenting microbe can make both ethanol and 2,3-butaneediol.
Ready Now: Scale-up of the LanzaTech technology

Commercial Scale-up Factor Less Than What Has Been Proven at Demo Scale
CSC Board Approval

Public Announcements  [Link: http://www.chinatimes.com/newspapers]

China Steel Invest 7000 MM TWD  Launch Two Projects
2015 -03-28  Economic Daily News

CSC board meeting held yesterday (27) has approved two investment project. It will spend 5600 MM TWD to overhaul No. 2 blast furnace of the third train; **meanwhile** investment 1400 MM TWD to erect a 100,000 ton per annum ethanol plant.

CSC states, trans-invested to WBT using LanzaTech (USA) fermentation technology, built an ethanol demonstration plant, in accordance with actual operation result, all indices were way exceed the targets, approve this technology worth for commercialization, will begin commercial plant at the year end.

Per the decision of CSC board, it will use the land near Xiao Gang Zhong Lin Road purchased from LCY to build the plant. The investment amount 1400 MM TWD. Starts production after estimated 2~3 years later. Per understanding, the plant will be in two phases, it will erect a 100,000 MT per annum production line, main application is gasoline additives and industrial ethanol.

**Project Execution Time-lines:**
- **Project K.O.**  –  May, 2015
- **JV Establishment**  –  June, 2015
- **Construction start**  –  Q4’15
ArcelorMittal Gent

- Electricity generation with LanzaTech
  - First of a kind project in EU Q2 2017
  - Aggressive deployment across EU post Gent
  - Power from renewables not carbon

- €300M investment in electricity from CO in Gent

- Fully integrated flagship mill

- Carbon recycling with LanzaTech
  - 120,000 tons/annum CO$_2$ reduction
  - 300,000 tons/annum CO2 captured for future reuse
  - 60k MTA ethanol capacity
  - Adding value to CO

ArcelorMittal supports a carbon smart future
Steel Mill Value Proposition

LanzaTech business case:

- Providing 2x More returns from fuel than from electricity
LanzaTech Ethanol Life Cycle Assessment
Third Party Study – EU Basis

LanzaTech ethanol achieves a **76.6% reduction** in greenhouse gas emissions over baseline fossil fuel

Key Assumptions:

- Cradle-to-pump lifecycle of ethanol
- EU’s Renewal Energy Directive methodology
- BOF gas considered as waste gas by steel industry and as residue by RSB.
- GHG emissions for LanzaTech ethanol from steel mill waste gas (BOF)

Fossil fuel comparator emissions (83.8 gCO2eq/MJ) from EU’s FQD
Broader Environmental Impact

LanzaTech Process emits ~40% less NO\textsubscript{x} and ~80% fewer particulates than electricity generation per MJ energy recovered

LanzaTech Process emits 33% less CO\textsubscript{2} than electricity generation per MJ energy recovered

Carbon is Only Part of the Story
Project overview
LanzaTech has a two year partnership with a major Asian chemical company to convert live-feeds of syngas produced from municipal solid waste (MSW) into ethanol.

*LanzaTech has designed, installed, and operates a pilot plant producing ethanol at a MSW processing facility.*
Continuous stable ethanol production from MSW

- Continuous with live feeds of MSW Syngas proven
- Operation at commercial ethanol production rates and yields
- Gas utilization efficiency exceeds 90%
- All gas contaminant and variability issues understood and overcome.

LanzaTech is the only company to demonstrate continuous fuel production from MSW syngas.
Downstream Conversion - Hydrocarbon Fuels Process

Key Enabler: Price and Availability of Alcohol
**Downstream Conversion – 2,3-BDO to Butadiene**

Köppe and Havill, Catalyst Review 27: 7-12 (2014)

**Butadiene Product Markets**

- **Styrene Butadiene Rubber (SBR)**
  - US $13 billion/yr

- **Polybutadiene Rubber (BR)**
  - US $8 billion/yr

- **Acrylonitrile Butadiene Styrene (ABS)**
  - US $16 billion/yr

- **Nylon 6,6 (from Adiponitrile/HDMA)**
  - US $7 billion/yr
What do you want to make today?

- Fermentation systems remain identical
- Product recovery may in some cases need modification

**Paradigm Shift:** chemical production plants that rapidly react to market conditions
1 Organism, over 25 products so far...

- **Discovery**
  - Isoprene
  - Biodiesel
  - 2-Butanol
  - MEK
  - Succinate
  - Lactate

- **Pilot/Demo**
  - 2,3-Butanediol

- **Physiology**
  - Control flux to single product
  - Product tolerance
  - Vitamin biosynthesis
Recycle to Reduce Pressure on Reserves

Keep it in the Ground!

A 2-degree carbon budget will require countries to leave 80% of coal, 50% of gas and 33% of global oil in the ground.

Organization for Economic Growth and Development, Nature
Reducing Carbon: use all strategies

**Re-using**
Atmospheric Carbon

- Starch-based
- Sugar-based
- Oil-based
- Cellulose-based

(Todays approach)

**Recycling**
Waste Carbon

- Industry Waste
- Municipal Waste
- Agricultural Waste
- Biogas

(Gas fermentation)

**Reducing**
Carbon footprint

*Carbon Reduction through Re-use and Recycling*
Questions?