



# A Few Predictions

1876 “This ‘telephone’ has too many shortcomings to be seriously considered as a means of communication” *Western Union Memo*

1895 “Heavier-than-air flying machines are impossible”  
*Lord Kelvin, President Royal Society*

1920 “The wireless music box (radio) has no imaginable commercial value”  
*David Sarnoffs Associates in response to his urgings for investments in the radio*

1943 “I think there’s a world market for maybe five computers”  
*Thomas Watson, Chairman IBM*

1949 “Computer in the future may weigh no more than 1.5 tons”  
*Popular Mechanics forecasting the relentless march of science*

1977 “There is no reason anyone would want a computer in their home”  
*Ken Olson, President, Chairman and Founder of Digital Equipment*

1981 “640K ought to be enough computer memory for anyone”  
*Bill Gates*



**Predictions are simply extrapolations  
of the past...**

*...innovation expands  
the 'art of the possible'*

**...today's 'unimaginable' is  
tomorrow's 'conventional wisdom.'**







1998: \$12/Watt  
2016: ~ 2.50/Watt

1.9M in Energy Efficiency  
~414,000 Americans  
Renewables  
170,000 Advanced  
Vehicles

2016 new electricity  
generation  
**9564 MW Renewable**  
(wind, hydro, solar)  
**8187 MW Fossil**  
(NG, oil, coal)

**That'll Never Work**

**That'll Never Work**

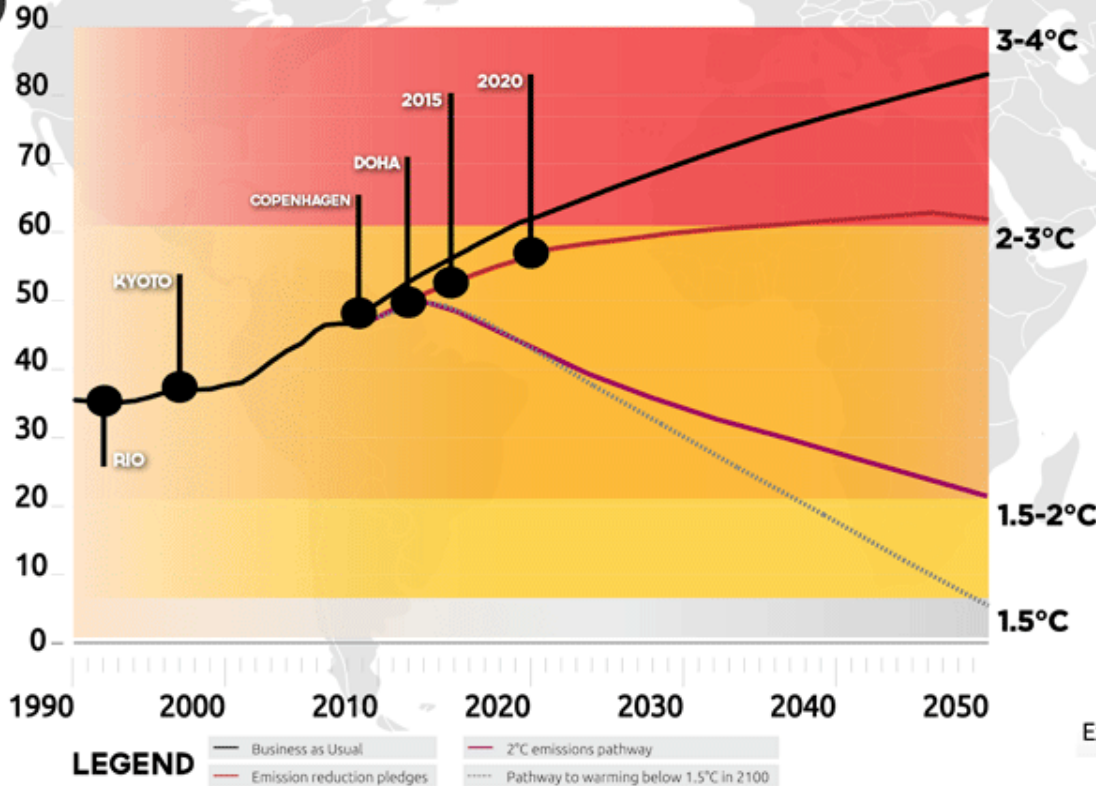


\$2.05/gallon  
At-scale  
Domestically-produced  
2<sup>nd</sup> generation

# STAYING BELOW 2°C: THE CHOICES WE FACE

With current pledges on the table to cut emissions, we are heading to a 3.3°C warming future. No further action before 2020 will limit society's choices. As temperatures rise, so do the impacts.

Global greenhouse gas emissions (GtCO<sub>2</sub>e)



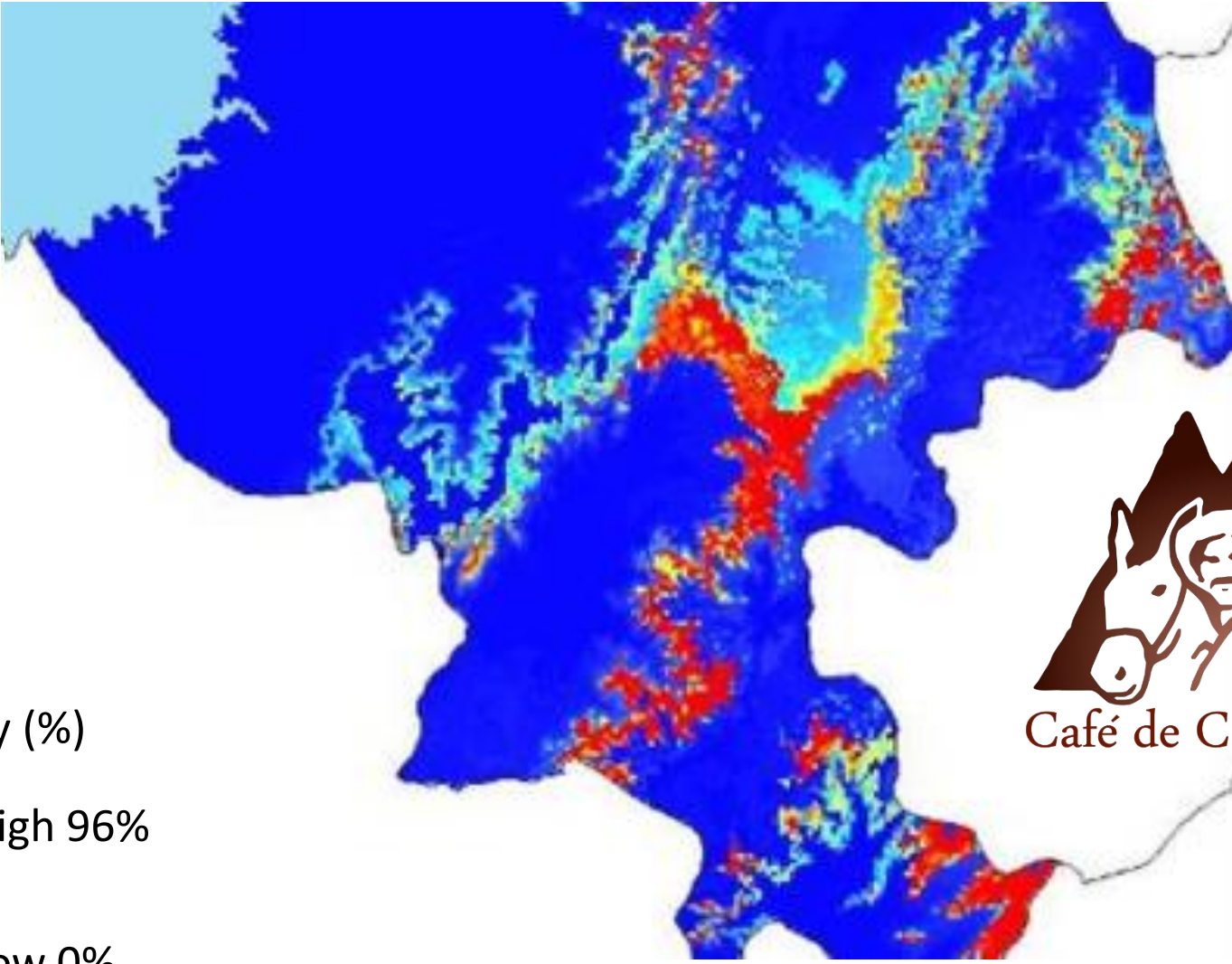
- Adaptation highly questionable
- Unprecedented heat waves
- 20-30% increase extreme precipitation
- Risk of global mass extinctions
- Global crop decline
- Significant Amazon dieback
- Millions risk displacement by sea level rise
- Tipping point for Greenland Ice Sheet
- High risks for regional food security
- Major risk to most coral reefs
- Food production losses
- Extreme heat waves with severe societal impacts

©www.climateactiontracker.org  
Ecofys | Climate Analytics | PIK





# Department's Coffee Growing Regions Colombia



2050

Suitability (%)



High 96%

Low 0%



Source: Jarvis, CIAT (2012)







**Energy can be Carbon Free**





**Aviation Fuel needs Carbon**





**Chemicals for Everyday Products need Carbon**

# Carbon: Problematic When Combusted

## Outdoor Air Pollution Impact

CHINA: 1.2M premature deaths in China in 2010  
Or 25M healthy years of life from the population.

USA: 200,000 early deaths every year  
(Equal to those who die from diabetes each year. )

*The New York Times*, April 1, 2013, sec. World / Asia Pacific,  
quoting from the *Global Burden of Disease Study 2010*, *The Lancet*, December 2012.  
Shindell, D. T. et al. (2016) Climate and health impacts of US emissions reductions consistent with 2C, *Nature Climate Change*, [doi:10.1038/nclimate2935](https://doi.org/10.1038/nclimate2935).



Sources:

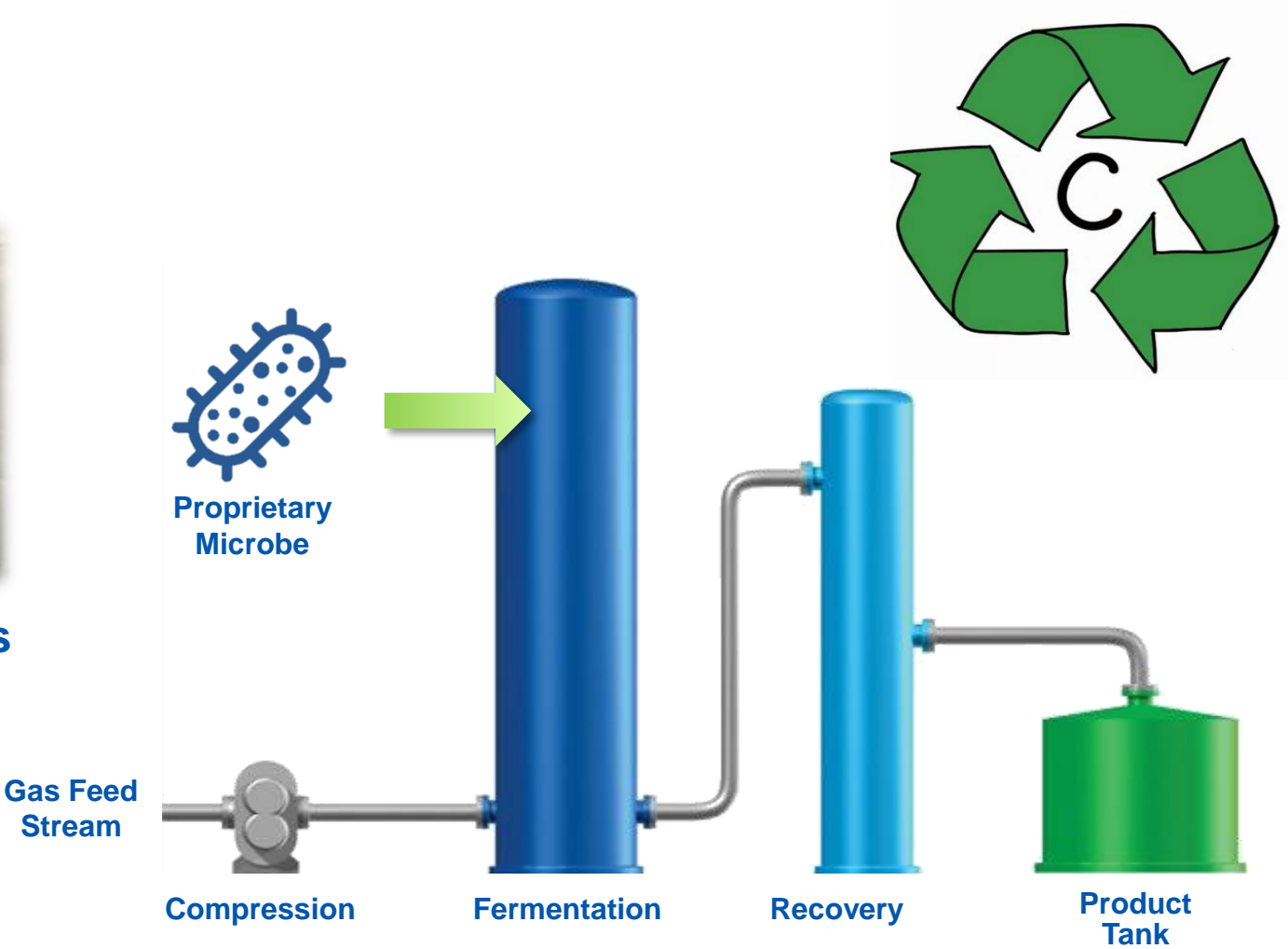




# Recycling Carbon



**Industrial Off Gas**  
✓ Steel  
✓ Refining  
✓ Ferroalloy





LanzaTech



# Commercial Scale Facilities



首钢朗泽

Shougang LanzaTech

**Caofeidian, China**  
**16M gallons/year**  
**2017**



ArcelorMittal



**Gent, Belgium**  
**21M gallons/year**  
**2018**





# Commercial Scale Beyond Steel



IndianOil

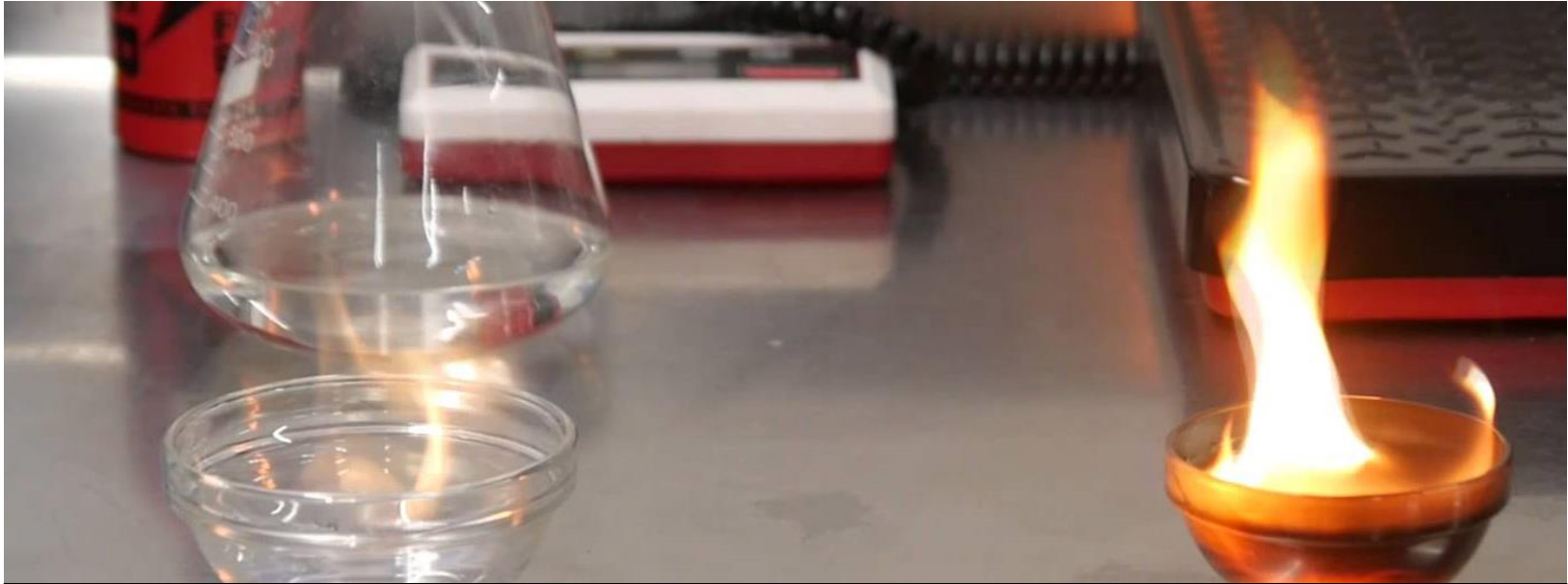
**Haryana, India**  
**13M gallons/year**  
**Refinery offgas**  
**2019**



**Modesto, California**  
**8M gallons/year**  
**Biomass Syngas**  
**2018**



# Ethanol-blend Fuels Reduce Particulate Emissions



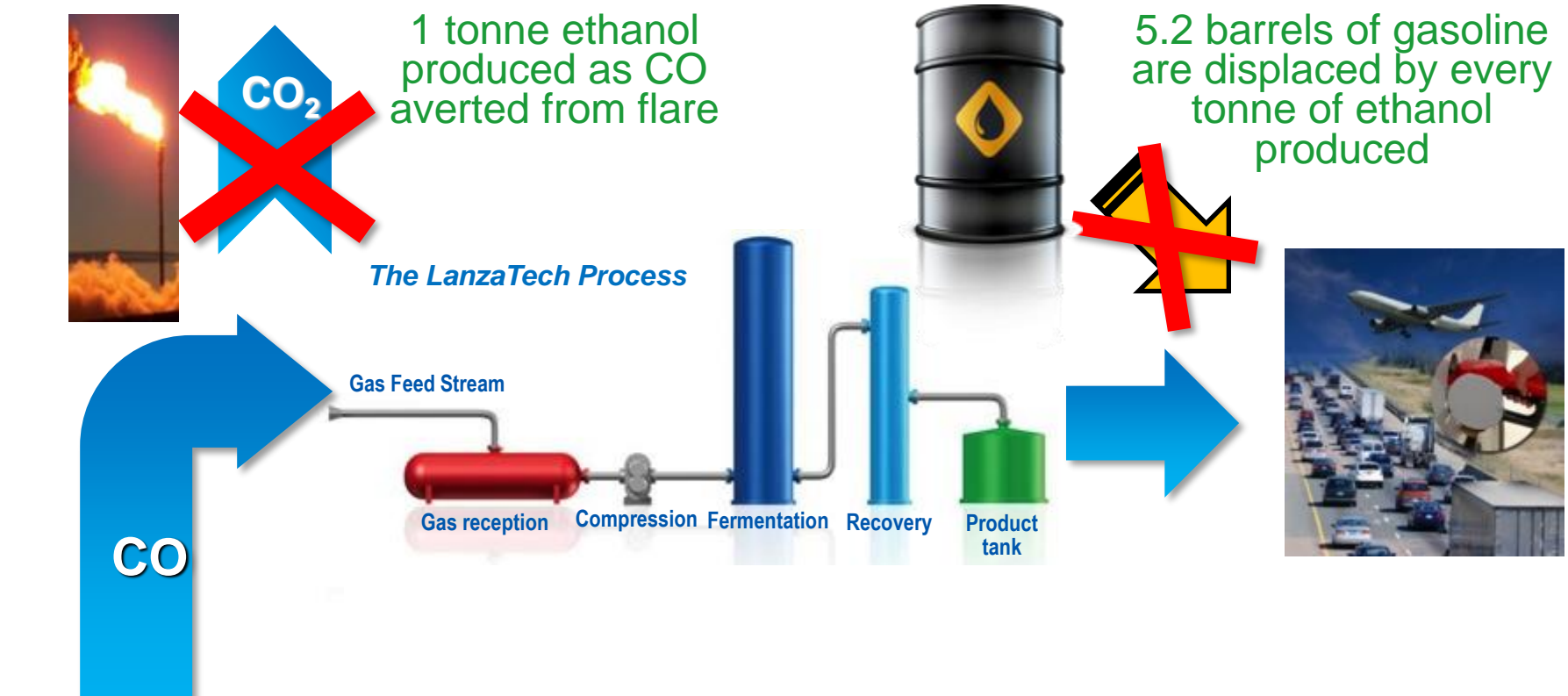
**30-40% reduction PM**  
**E0:E20 fuel blends**

Storey et al., SAE Int. J. Fuels Lubr. 3(2):2010





# Environmental Impact: LanzaTech Example



***Steel mill gases from the Steelanol project can be used to fuel 100,000 cars per year... While saving the emissions of 80,000***



# Electric Mobility for Road Transport

Transition is underway for road transport



\$35,000 USD  
200miles/charge

**Current LanzaTech Commercial Projects  
Equivalent ~300k EVs on Road/Year**

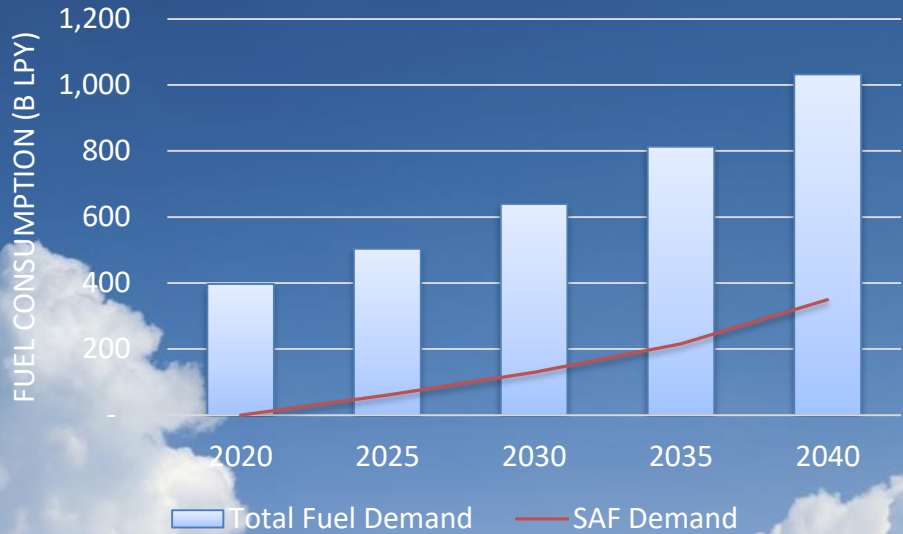






**Aviation Fuel needs Carbon**

# Sustainable Aviation Fuel will Play a Key Role



*SAJF will need to rise to 34% of total jet fuel consumption by 2040 to meet ICAO commitments*

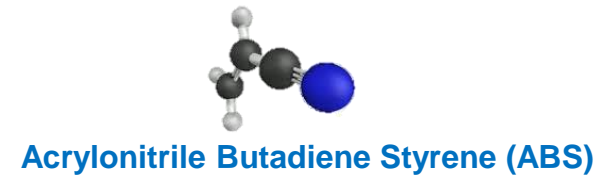
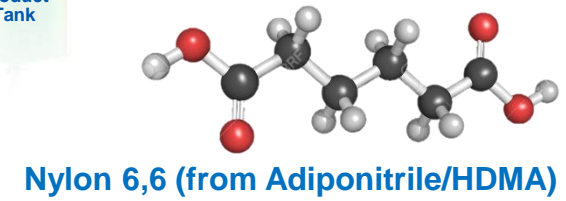
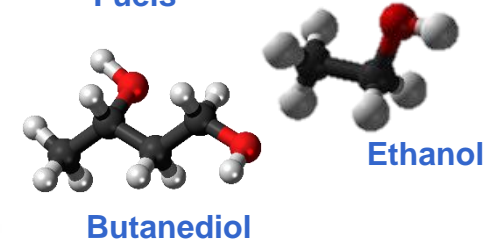
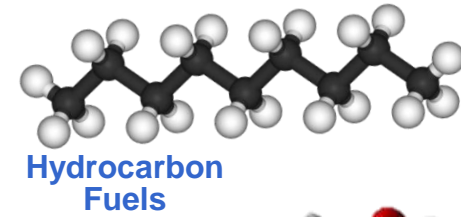
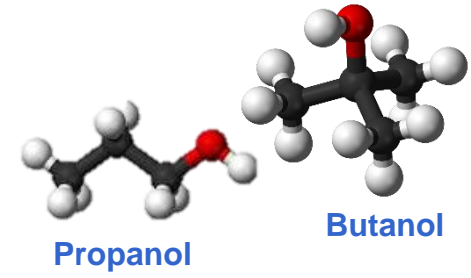
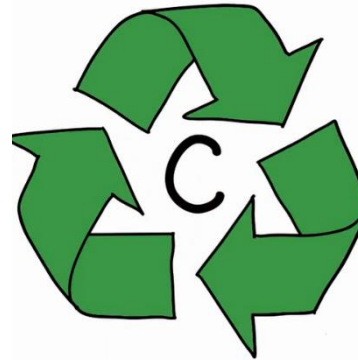
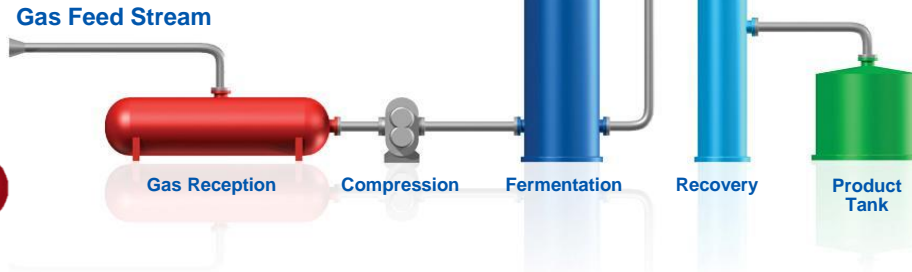
Carbon neutral growth post 2020

50% emissions reduction by 2050: 2005 levels

Limited substitution options for aviation sector



# Building a Technology Platform



# Building Experience...

## Steel (CO)

*Field experience since 2008*

- 4 pilot/demo units; 2 @ 400k lpy capacity
- Over 70,000 combined hours on stream
- Multiple runs exceeding 2000 hours
- 3 commercial projects past basic engineering design; 2 permitted; 1 LLE ordered

ArcelorMittal



CHINA STEEL



首钢朗泽  
Shougang Lanza Tech



BAOSTEEL



BLUESCOPE



## Syngas (CO+H<sub>2</sub>)

*Field experience since 2014*

- MSW Pilot facility in operation
- 2 commercial plants in basic engineering design
- **Over 15,000 combined hours on stream since 2015**



AEMETIS

## Refinery Gas (CO+H<sub>2</sub>+CO<sub>2</sub>)

*Lab and engineering/design experience since 2015*

- Continuous, stable ethanol production from low CO streams in lab
- High CO<sub>2</sub> utilization (>50% of carbon fixed from CO<sub>2</sub>)



IndianOil



LanzaTech  
capturing carbon. fueling growth.





# Stoichiometry of Ethanol Production with Different Gas Compositions

CO:H<sub>2</sub> ratio

CO



1:0

**Steel Mill Gas**  
Demonstrated at scale

CO + H<sub>2</sub>



1:1

**Syngas (e.g. MSW)**  
Demonstrated at scale

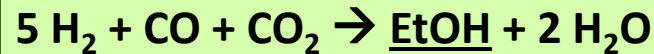
CO + H<sub>2</sub>



1:2

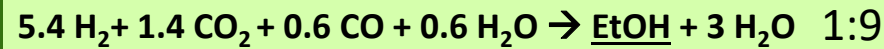
**High H<sub>2</sub> Syngas**  
Demonstrated at pilot, allows  
CO<sub>2</sub> fixing in products

CO + H<sub>2</sub> + CO<sub>2</sub>



1:5

CO + H<sub>2</sub> + CO<sub>2</sub>



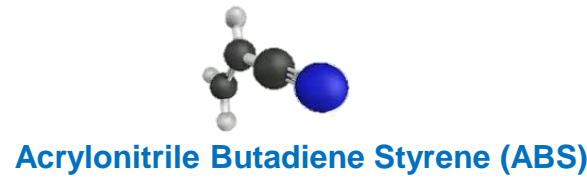
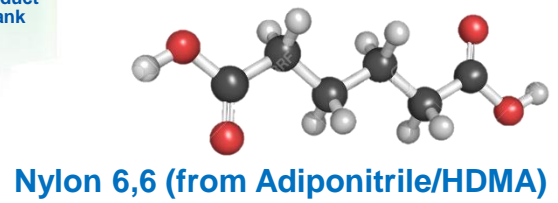
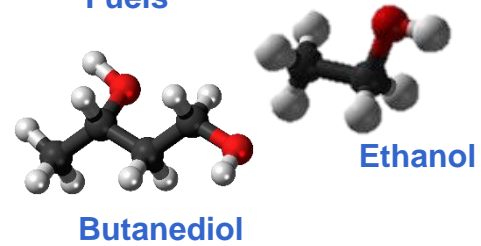
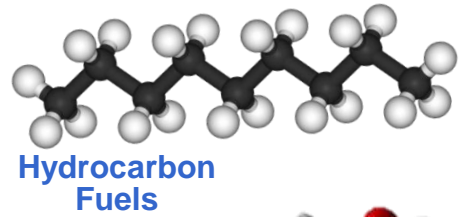
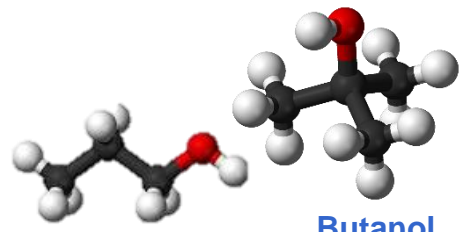
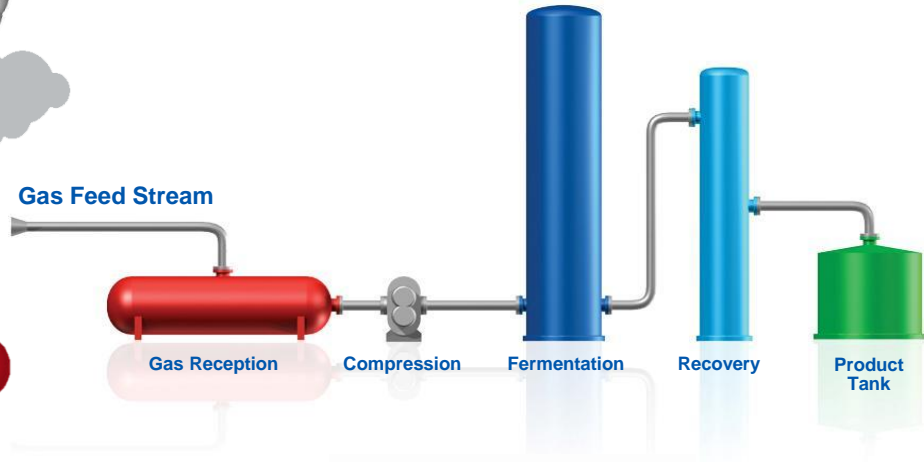
1:9

Primarily **Acetate** production

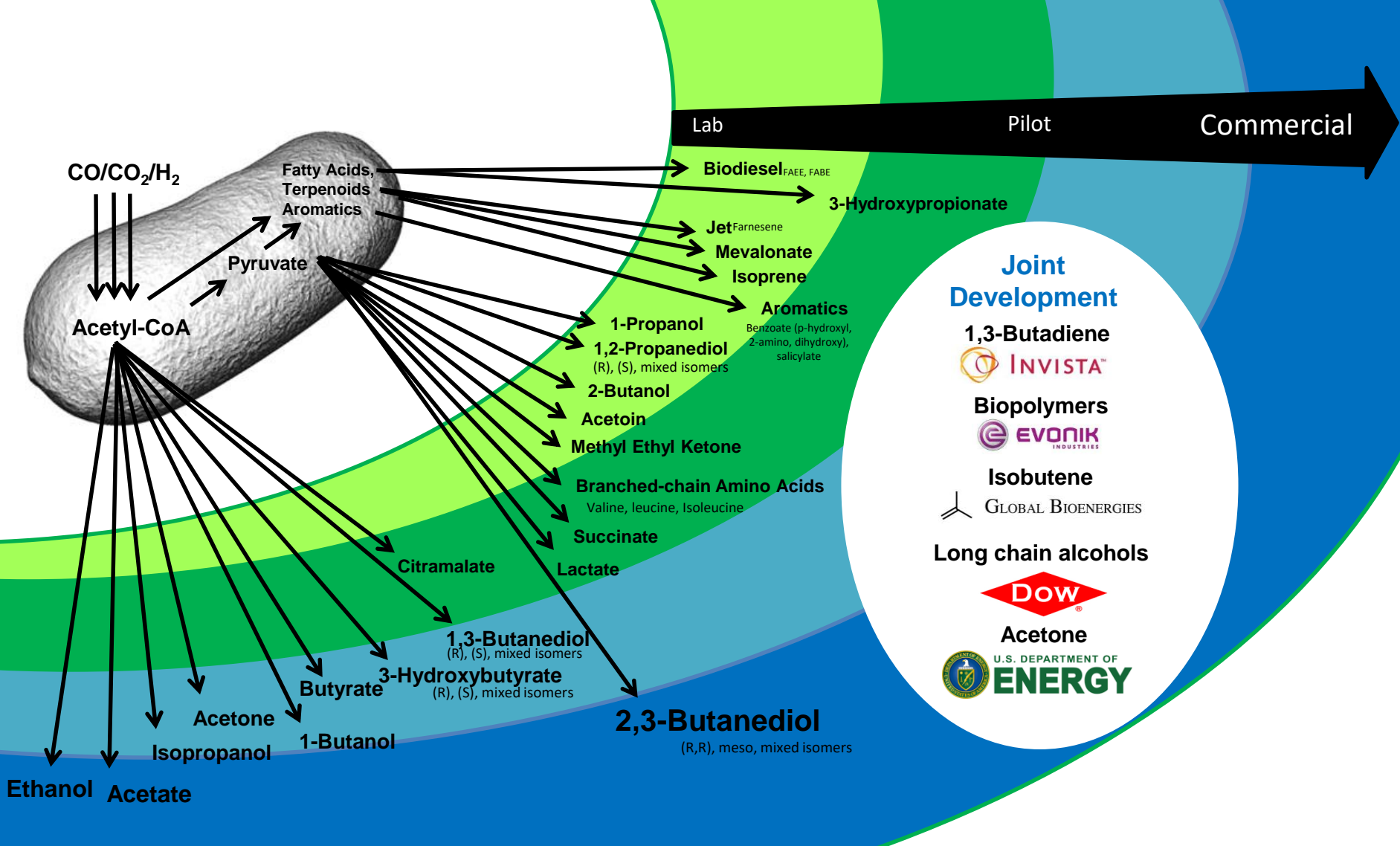
CO<sub>2</sub> + H<sub>2</sub>



# Building a Technology Platform





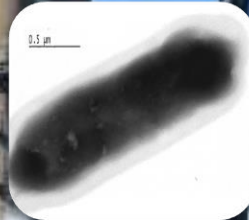


**Demonstrated Over 30 New Products Directly from Gas**



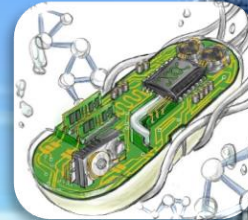


Microbe 1.0



✓ Ethanol

Microbe 2.0

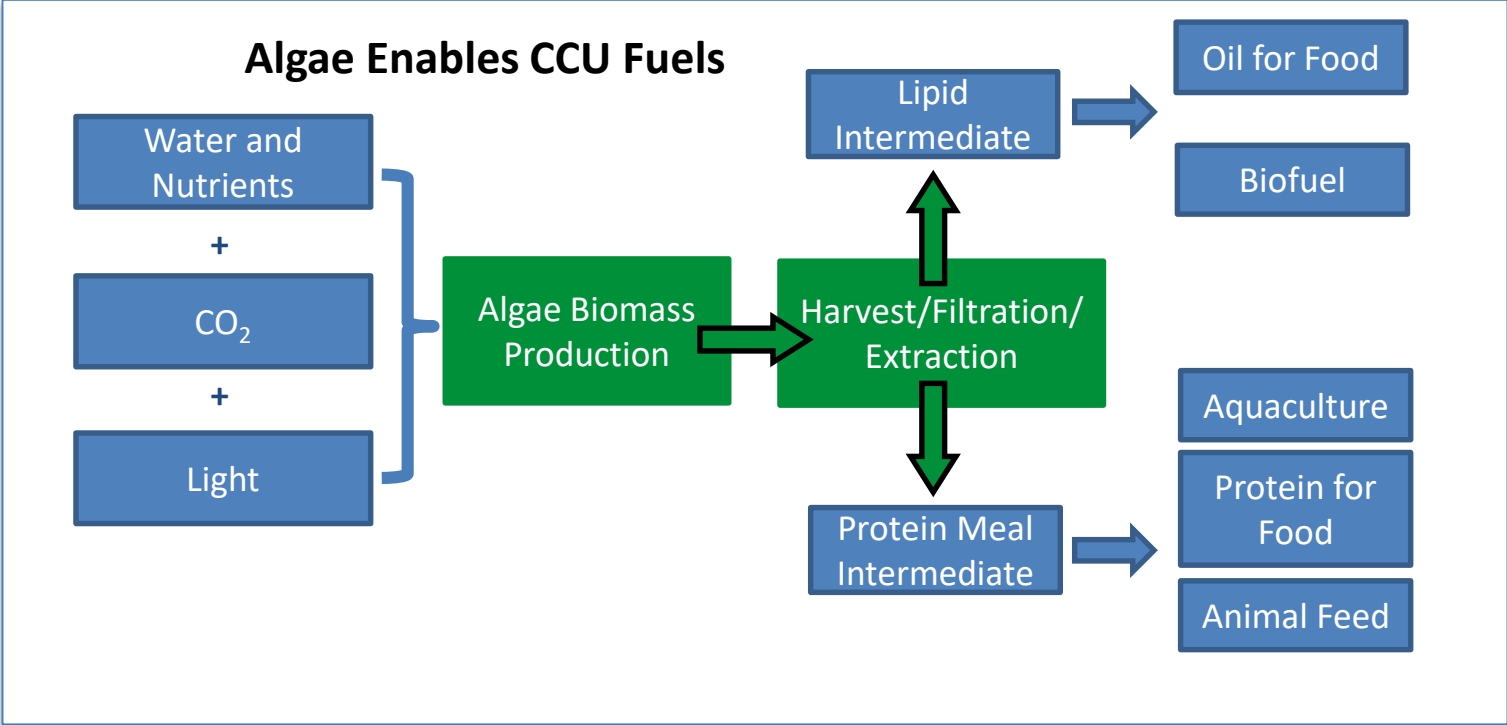


✓ new product molecule

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

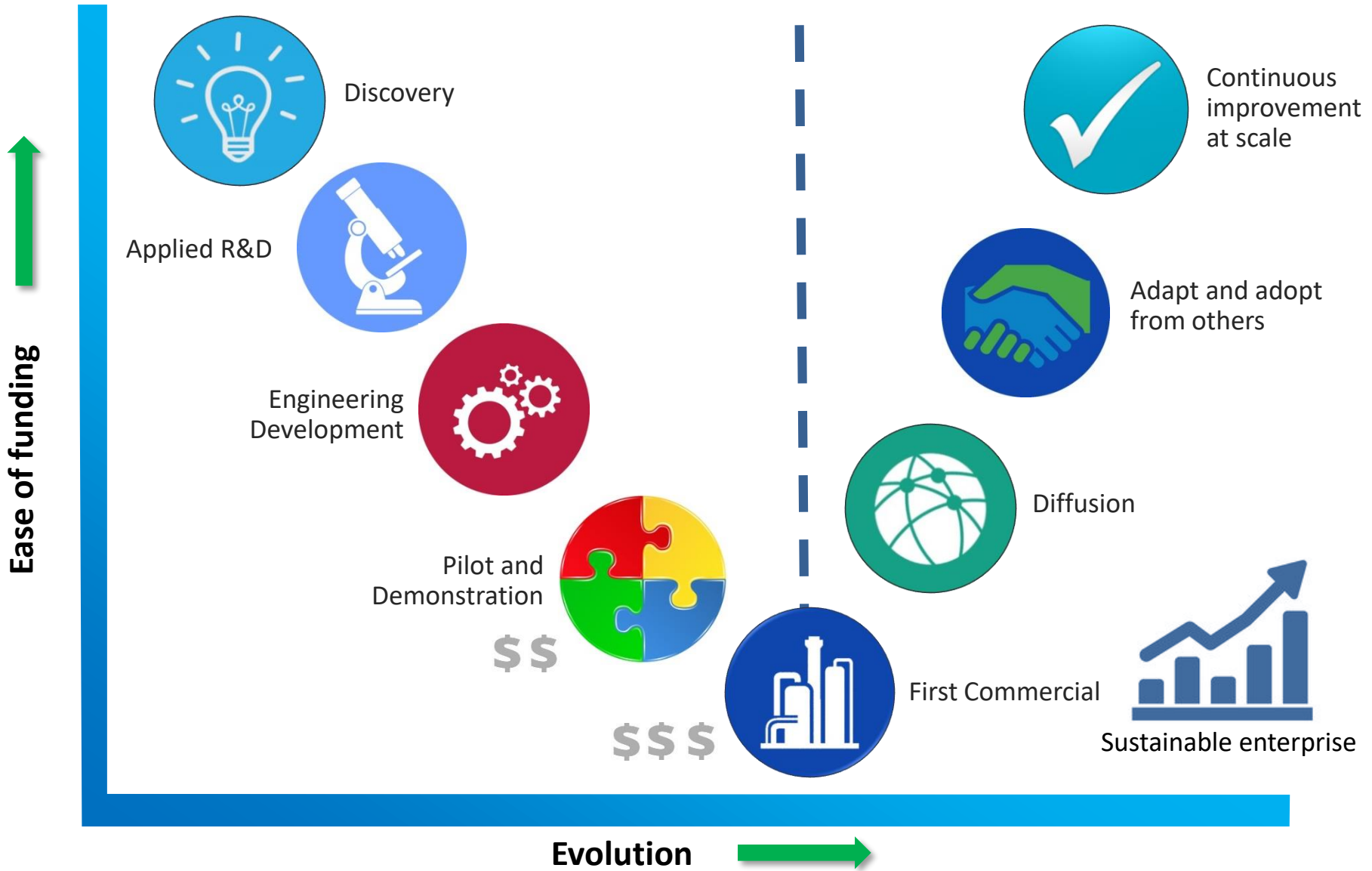
**DISRUPTION = 1) Rapid Reaction to Market Fluctuations 2) Feedstock ≠ Commodity**

# Carbon: Opportunities Today





# Crossing the Valley of Death



**“I run in the darkness long before  
I ever dance under the lights”**

*-Muhammad Ali*





**CO<sub>2</sub>**

**Carbon  
(CCU)**



**Liquid Fuels**



**Polyethylene**



**PET**



**Nylon**



**CO<sub>2</sub>**

**Carbon  
(CCS)**

**CO<sub>2</sub>**

**CO<sub>2</sub>**

**CO<sub>2</sub>**

**Capturing Carbon. Generating Revenue. Reducing Emissions.  
NOW**

