

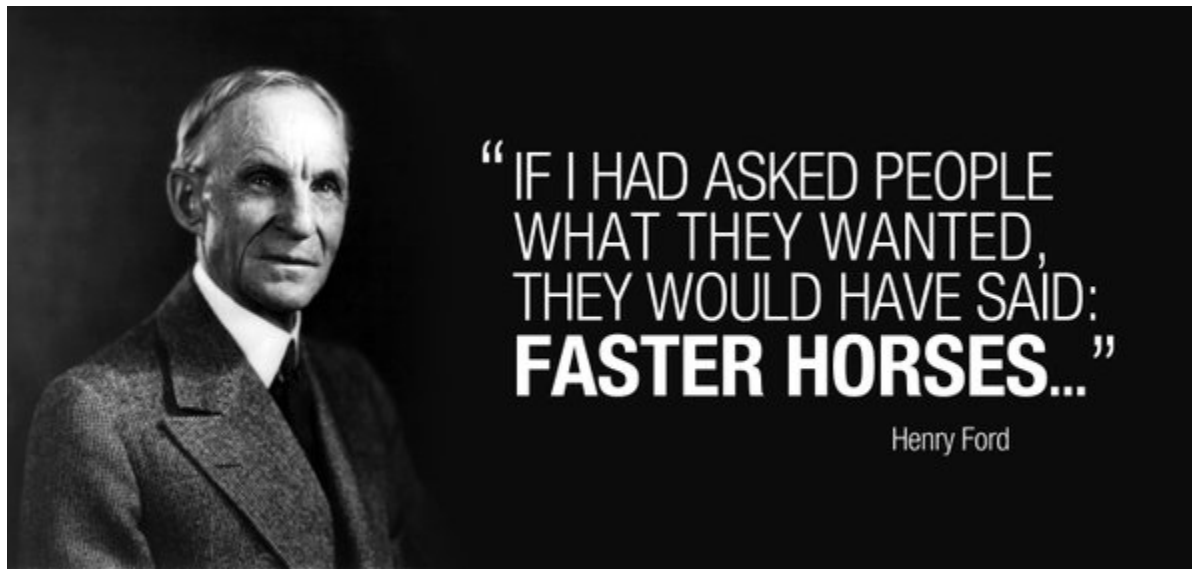


# Innovating for a Carbon Smart Future

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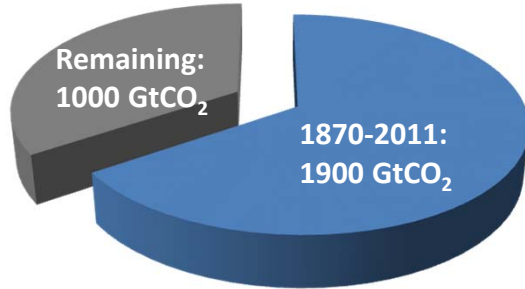


# Solutions We Didn't Know We Needed





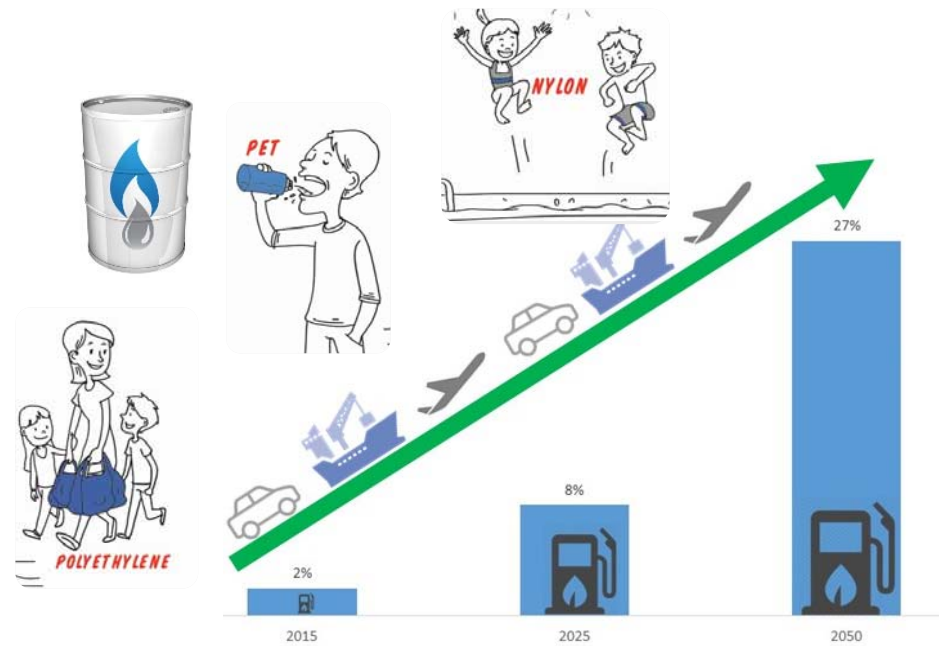
# A Carbon Smart World



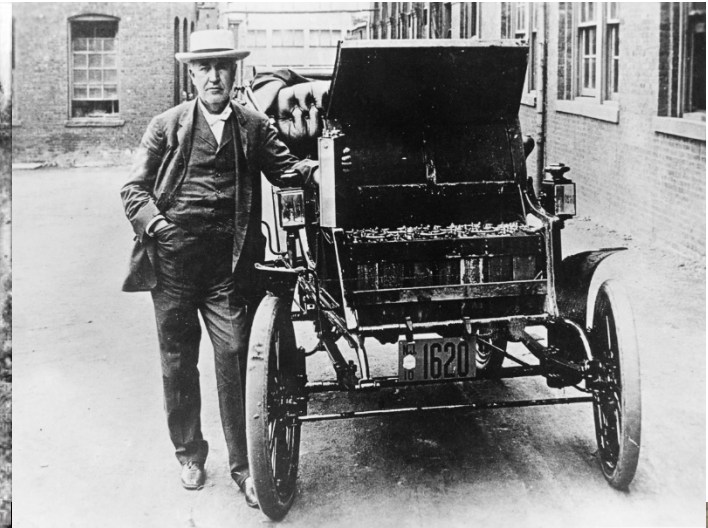
65% of 2° carbon budget: USED



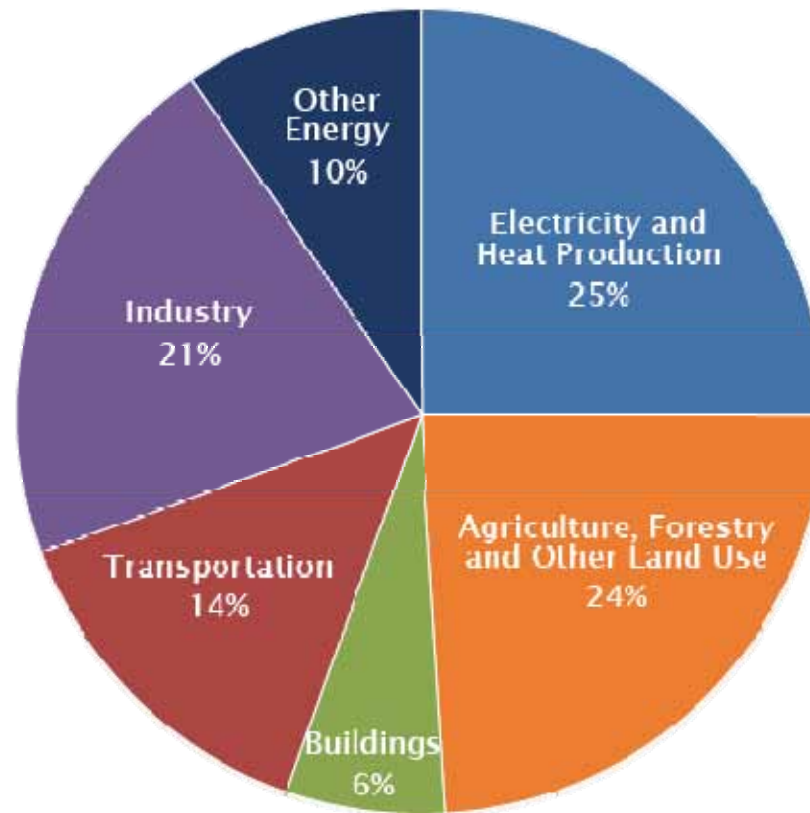
Must stay in the ground



# Evolution of Go...Steam, Electricity and Coal



# The Status Quo is not an Option



**14% of Global CO<sub>2</sub> Emissions come from transportation fuels**





# Advanced Biofuels Taking Off

St. Louis Post Dispatch  
October 17, 2014

ST. LOUIS POST-DISPATCH

## Abengoa opens U.S. cellulosic ethanol plant in Kansas



OCTOBER 17, 2014 11:22 AM • BY JACOB BARKER  
JBARKER@POST-DISPATCH.COM 314-340-8291  
A Spanish company, with U.S. headquarters in Chesterfield, has opened its first cellulosic ethanol plant in Southwest Kansas.  
Abengoa, based in Seville, Spain, announced the opening Friday. The company also operates a conventional ethanol plant in Madison, Ill.

is one of only a handful in the world that produces ethanol from stalks and leaves rather than corn. Almost all U.S. gasoline now  
**Production Begins at Second U.S. Cellulosic Biofuel Facility**  
Posted by Jeremy Martin of Union of Concerned Scientists on October 17, 2014



Like 7 Tweet 34 +1 3 More >



DuPont's Nevada cellulosic biofuels plant is under construction as of August. The core technology an fermenter units can be seen at center, left center, biomass intake; at left, storage tanks; and distillation

agatory for MOU. 100 refinery could start

Industry heads for Kansas to Abengoa's cellulosic ethanol plant in Skopje, Macedonia that MOU to facilitate the market in the Pelagonia  
You don't often hear Kansas and Spain mentioned in the same sentence. Yet today Spanish company Abengoa is bringing another big cellulosic biofuel facility online in Hugoton, a small community in the Southwest corner of the state. This is the second big plant starting up this year, showing that after some predictable yet highly scrutinized delays, the cellulosic fuel industry is finally beginning to establish itself and making critical contributions to oil savings and climate goals.  
It wasn't long ago that cellulosic biofuels were the punchline of a joke: a phantom fuel that could not be economically produced in large volumes. Fast forward to today, and we see headlines like "Advanced Ethanol Makers Are Trying to Give Big Oil a Run for Its Money."

National Geographic  
October 17, 2014

## DuPont, Ethanol Europe Renewables ink pact for cellulosic ethanol in Macedonia

## Beta Renewables, Biochemtex ink deal for commercial-scale cellulosic biofuels project in Slovakia



ergochemica for the construction of 2nd Generation Ethanol plant in Slovak Republic.

Biochemtex and Beta Renewables entered an agreement with Energochemica SE for construction of a 16.5 million gallon (55,000 ton) ethanol plant. The plant, which will be constructed publicly, will also generate power and steam. The plant will immediately and the start-up of the plant is expected in the first half of 2017. The plant will utilize non-food crops and is expected to deliver "cost-competitive" ethanol according to the project sponsors.

Biofuels Digest  
October 6, 2014

Biofuels Digest  
October 16, 2014

## First commercial-scale cellulosic ethanol plant in the U.S. opens for business

EMMETSBURG, IOWA (September 3, 2014) - POET-DSM Advanced Biofuels, LLC, a joint venture of Royal DSM and POET, LLC, today proved its revolutionary technology that converts agricultural residue into renewable fuel at the Grand Opening of its first commercial cellulosic ethanol plant in Emmetsburg, Iowa.  
The plant, named "Project LIBERTY" in honor of the late Willem-Alexander, King of the Netherlands, was formally opened in the presence of His Majesty King Willem-Alexander, King of the Netherlands, Deputy Under Secretary Michael K. Branstad and Lieutenant Governor Tom Ricketts, among other guests.

POET-DSM  
September 3, 2014

## Business Standard

## Beta Renewables and Novozymes open world's first advanced biofuels facility in Italy

The facility to produce 75 million litres of cellulosic ethanol annually from agricultural waste  
BS B2B Bureau | Crescentino, Italy October 09, 2013 Last Updated at 14:47 IST  
Beta Renewables, a major player in cellulosic biofuels and part of the Mossi Ghisolfi Group, and Novozymes, one of the world's leading producer of industrial enzymes, have opened the world's largest advanced biofuels facility in Northern Italy. Situated in fields outside the city of Crescentino, it is the first plant in the world to be designed and built to produce bioethanol from agricultural residues and energy crops at commercial scale using enzymatic conversion.

Business Standard  
October 9, 2013



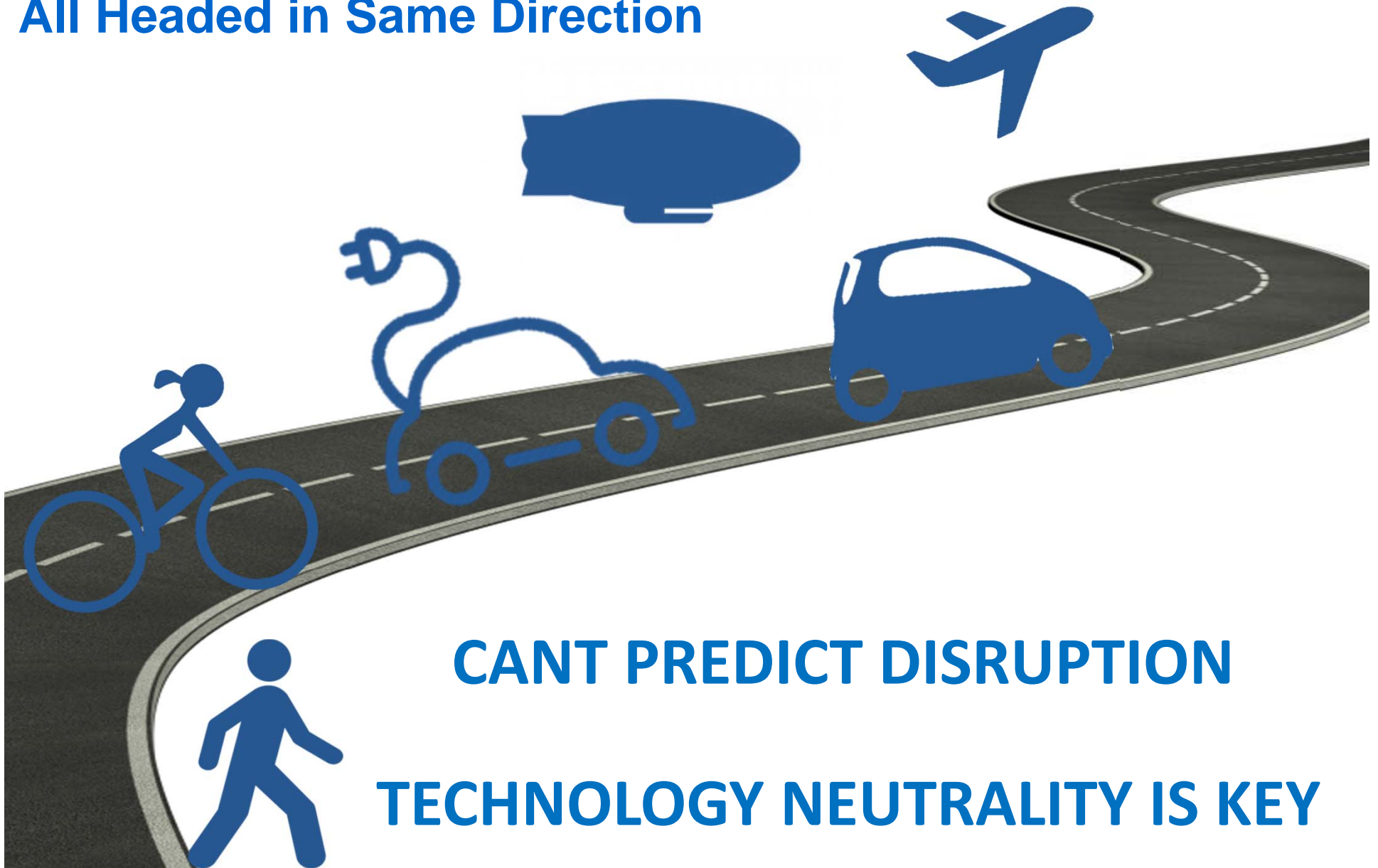
**TODAYS TECHNOLOGIES ARE NOT ENOUGH  
NEW FEEDSTOCKS, NEW APPROACHES ARE NEEDED**



**INNOVATION = OPPORTUNITY**



# All Headed in Same Direction



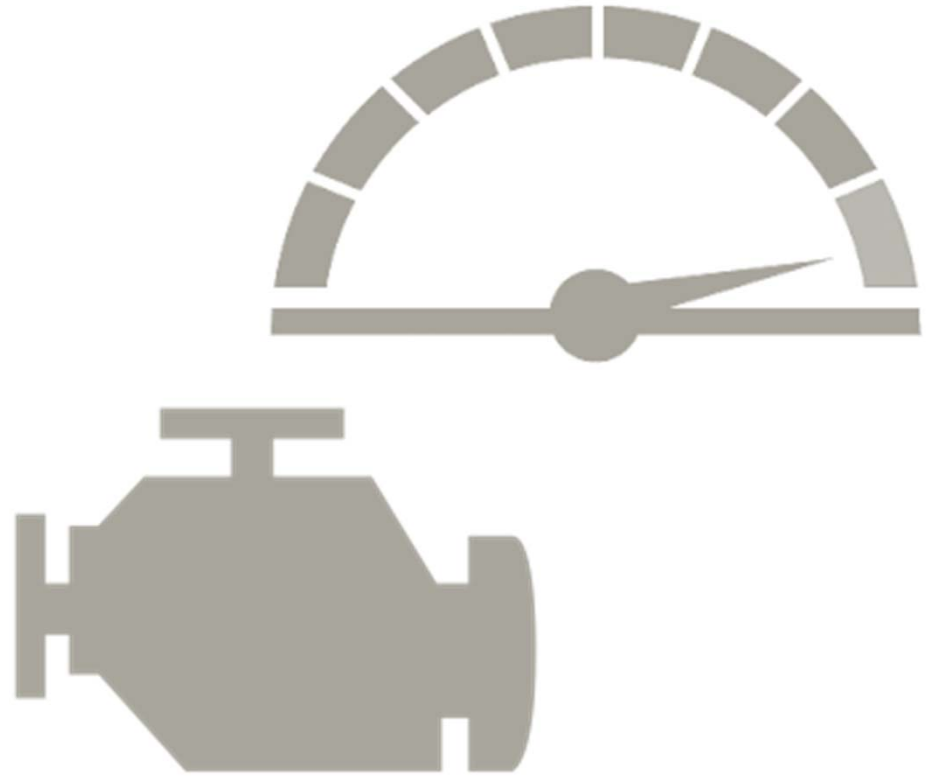
**CANT PREDICT DISRUPTION**

**TECHNOLOGY NEUTRALITY IS KEY**





# Standards Must be Performance Based



**ENGINE TECHNOLOGIES ARE CHANGING**



# LanzaTech: Earliest Known Biomass

1. Reduced atmosphere

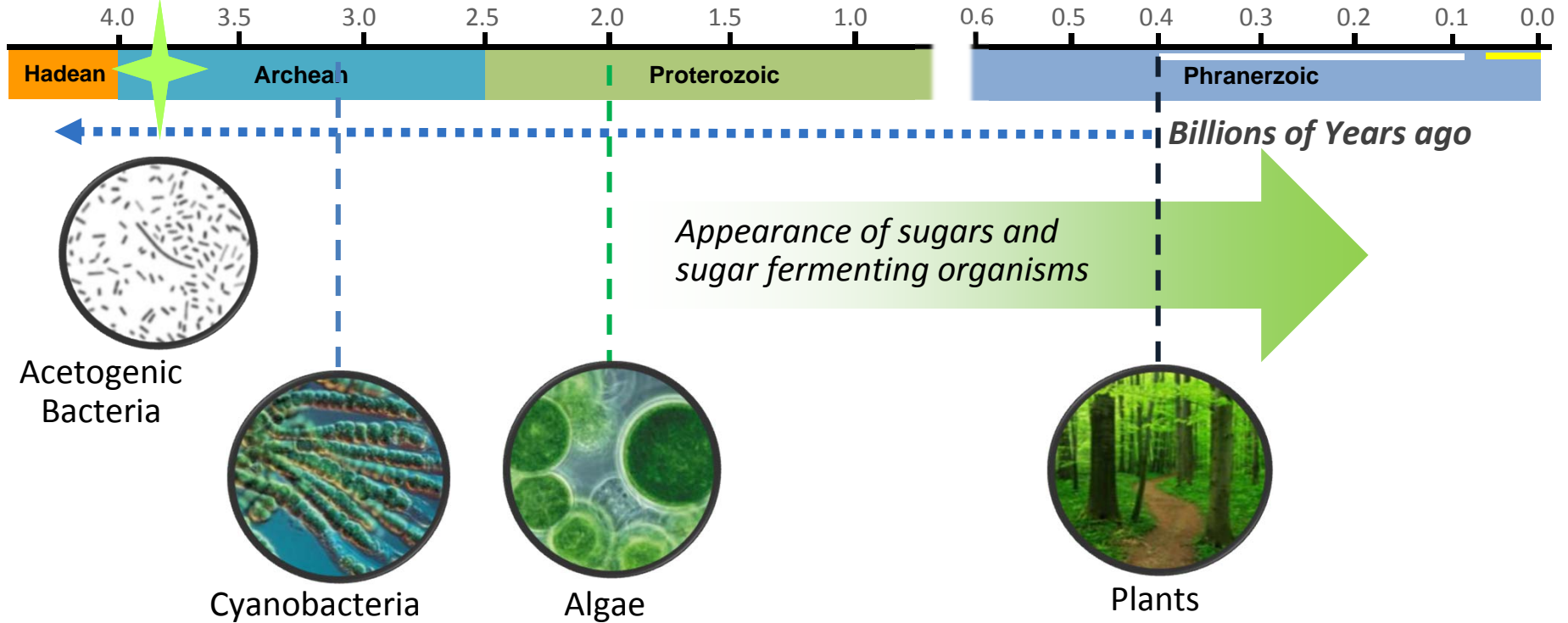
2. CO<sub>2</sub>-rich atmosphere

3. O<sub>2</sub>-rich atmosphere

- Hydrogen
- Carbon monoxide
- Carbon dioxide
- Methane

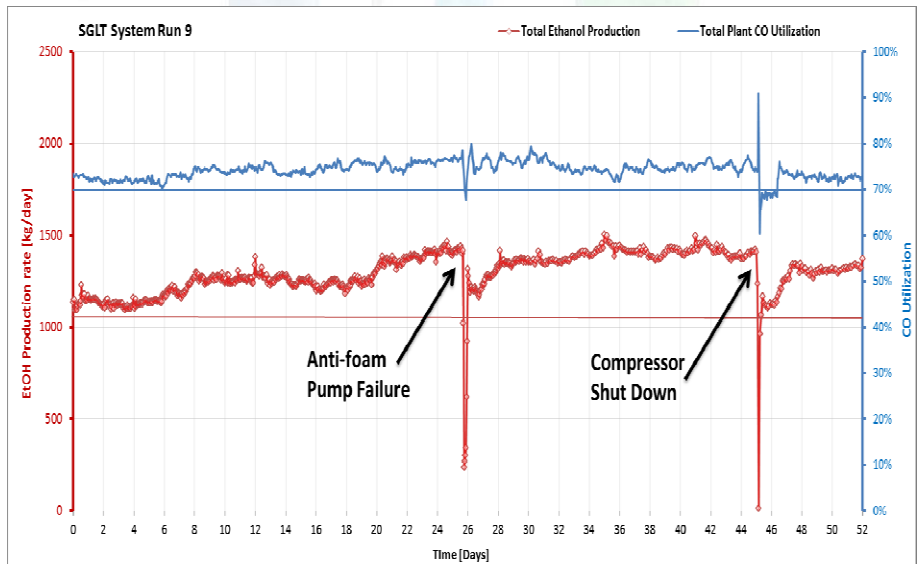
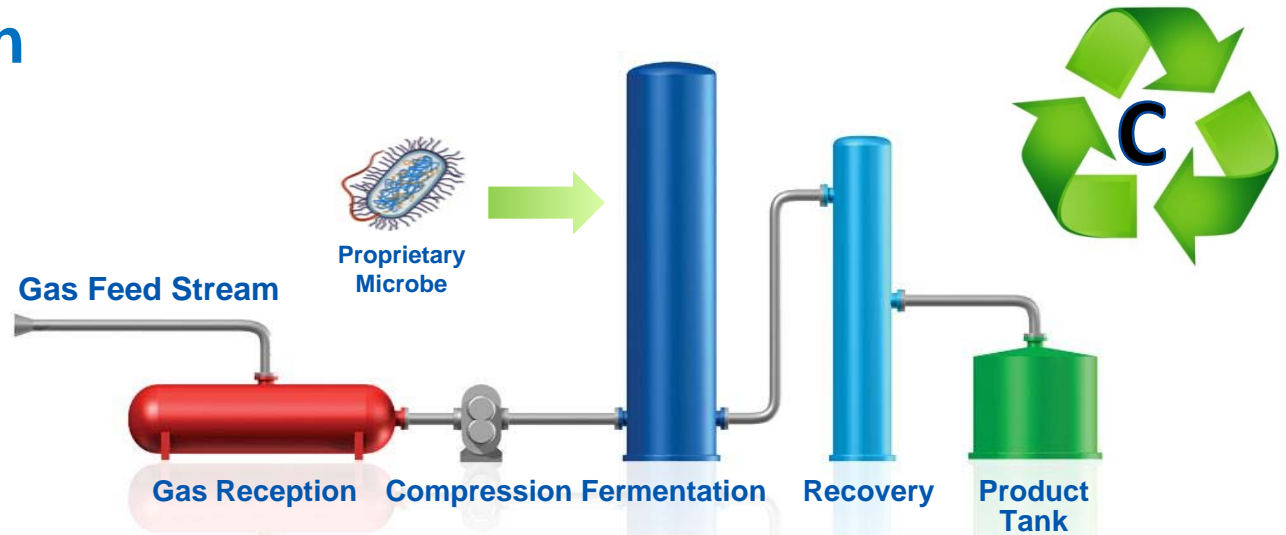
Carbon Dioxide

Oxygen



# Recycling Carbon

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

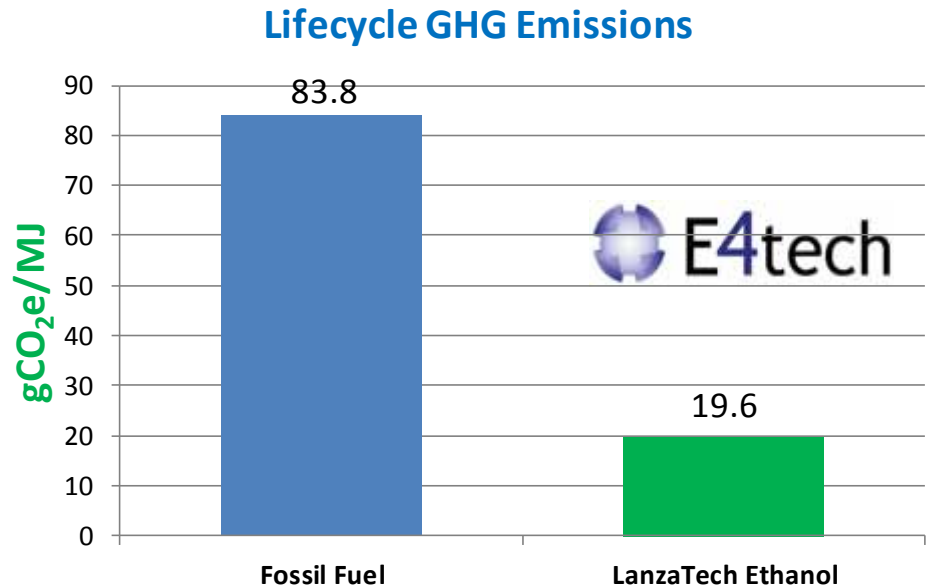


Performance milestones achieved and exceeded for >1000 hours  
100K GPY (~400 KL/yr)





# Recycling Gases: Environmental, Economic, Social Benefit



## Additional 3<sup>rd</sup> Party Life Cycle Analyses (LCA)

- Michigan Tech University
- Roundtable on Sustainable Biomaterials (RSB)
- Ecofys
- Tsinghua University

*50-70% GHG Reduction over Petroleum Gasoline*



Water Recycle



No Land Biodiversity



Provides new revenue stream from waste materials



Provides energy security from sustainable, regional resources



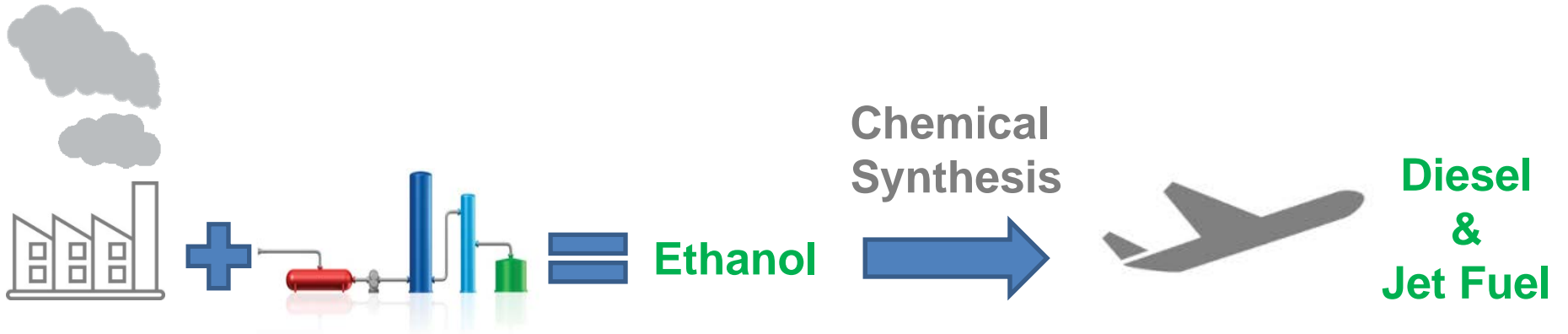
Provides affordable options to meet growing demand



Provides economic development that creates “green jobs”



# From Mill to Wing



HSBC 

virgin atlantic 

 **BOEING**

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



  
Pacific Northwest  
NATIONAL  
LABORATORY



**LanzaTech**   
capturing carbon. fueling growth.

# Great Progress on Certification for Flight

## Certification

“Less than a decade ago, the prospect of flying commercial aircraft on sustainable aviation fuels (SAF) seemed unrealistic due to the associated technical and safety challenges, the developments have been impressive!” IATA Roadmap

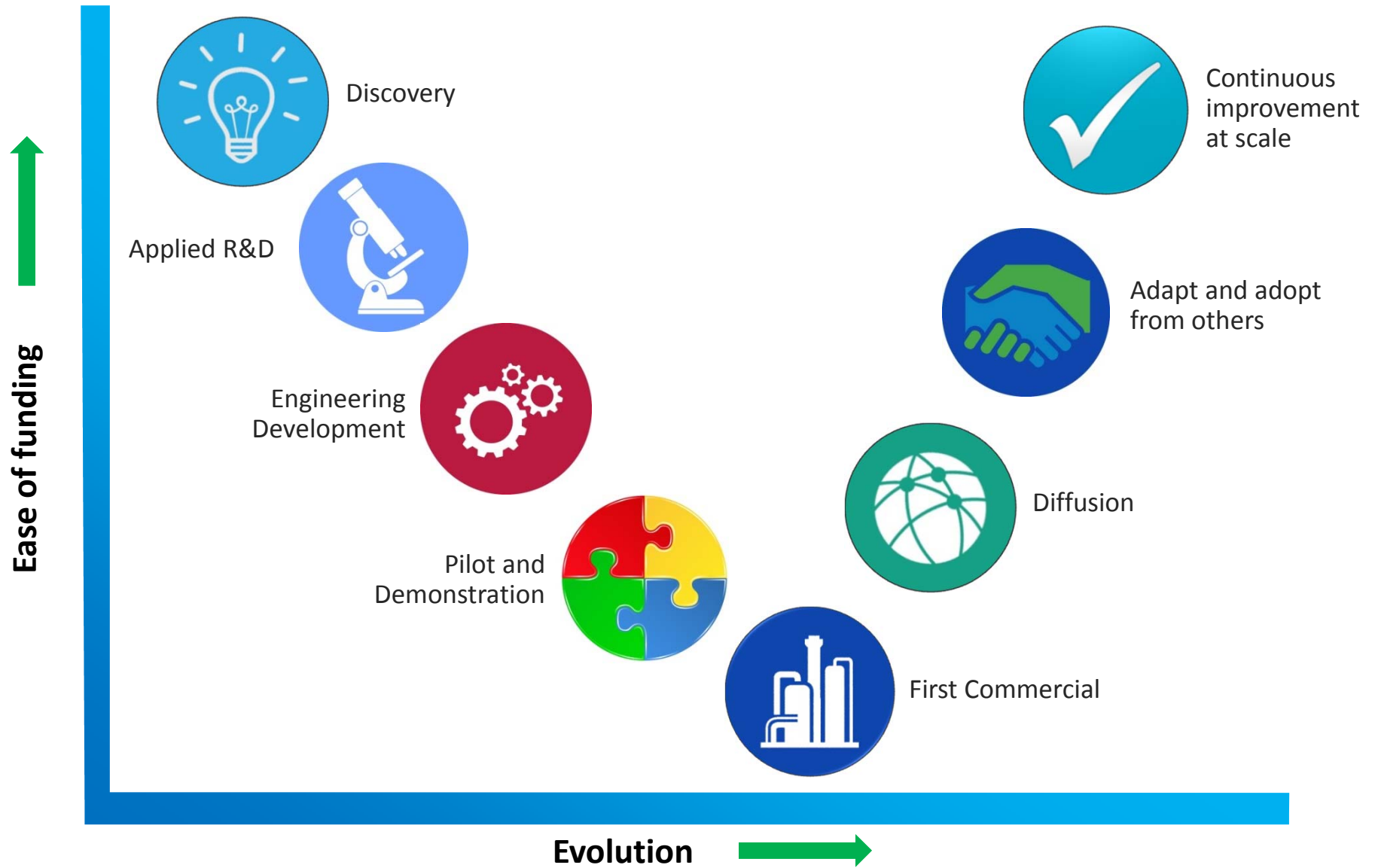
| Type                                       | ASTM approval | When |
|--|---------------|------|
| Fischer Tropsch (FT) ( <i>or BtL</i> )     | Max 50% blend | 2009 |
| Hydrotreated Esters and Fatty Acids (HEFA) | Max 50% blend | 2011 |
| Renewable Synthesized Iso-Paraffinic (SIP) | Max 10% blend | 2014 |
| Butanol to Jet Fuel (ATJ)                  | Max 30% blend | 2016 |

*Pipeline: Green Diesel, Ethanol to Jet (EtJ), pyrolysis and catalytic cracking (Hydroprocessed Depolymerized Cellulosic Jet), catalytic hydrothermolysis and catalytic conversion of sugars.*





# Getting a New Process to Scale



# From Demonstration to Commercial



Commercial Scale  
Q2 2018



Ton (gallons) per year

|   |                        |            |
|---|------------------------|------------|
|   | ArcelorMittal          | 64k (21M)  |
|  | CHINASTEEL             | 20k (6.7M) |
|  | 首钢集团<br>SHOUGANG GROUP | 46k (15M)  |

40,000 combined hours on stream  
Multiple runs exceeding 2000 hours



# What Is Our Intent?



## CARBON REDUCTION

