Going Commercial: The Road to Awesome

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Energy Demand Rising

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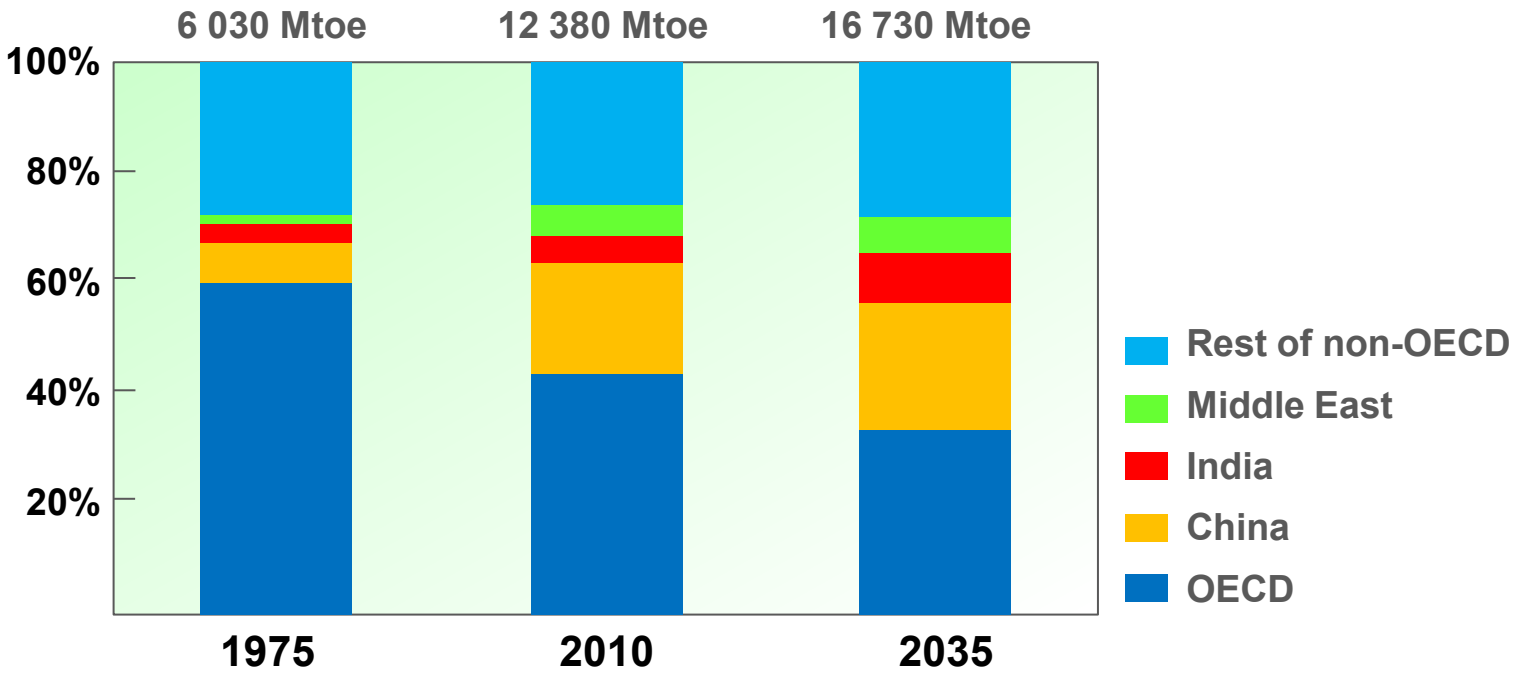
Population growth and climate change put pressure on land, food, water, and ecosystems…

Share of Global Energy Demand



IEA World Energy Outlook 2012

While Carbon Emissions Keep Rising

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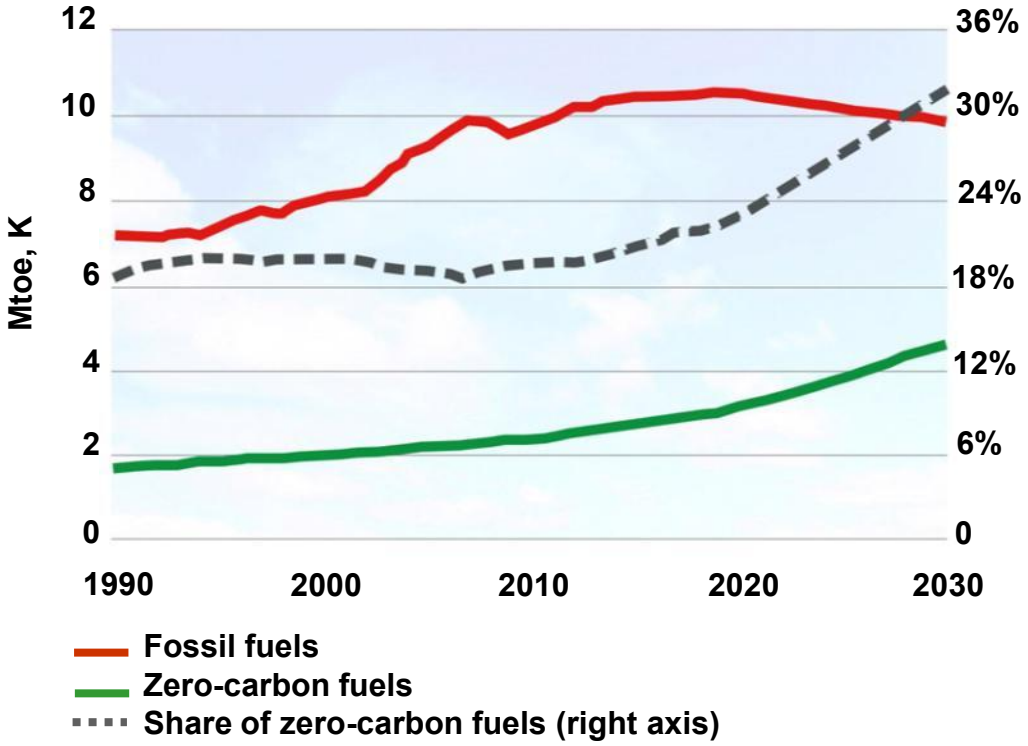
Containing CO_2 growth to safe atmospheric levels (below 450 ppm) requires that zero carbon fuels make up > 30% of the fuel pool. Current Rate: ~8 billion tonnes of CO_2 per year



Source: IEA world Energy Outlook 2011

Data from NOAA* taken at Mauna Loa, Hawaii for May 10, 2013 shows CO_2 levels have exceeded 400 ppm

* National Oceanic and Atmospheric Administration

Despite Large Energy Access Gap

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1.3B people still lack access to basic energy

The LanzaTech Process

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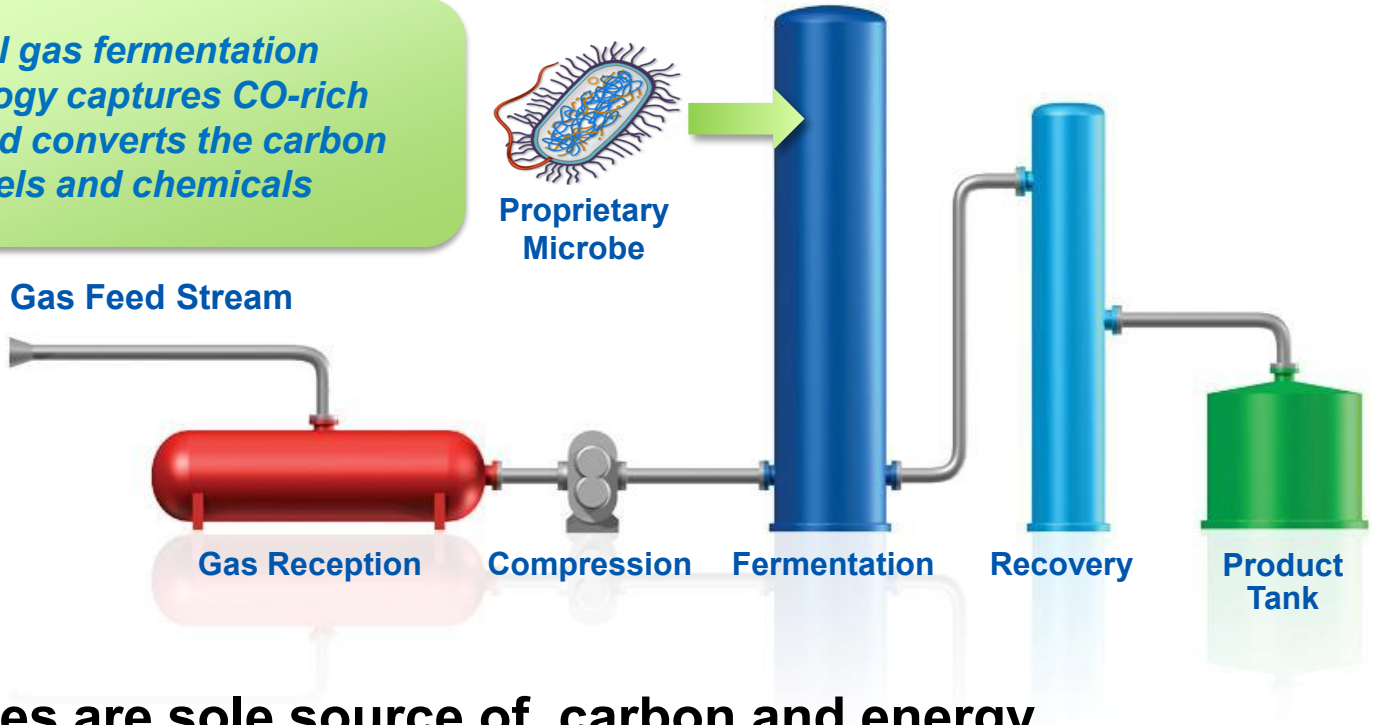
Novel gas fermentation technology captures CO-rich gases and converts the carbon to fuels and chemicals



- **Gases are sole source of carbon and energy**
- **Production of fuels and chemicals**
- **Potential to make material impact on the future energy pool (>100s of billions of gallons per year)**
- **Biofuel/chem, carbon capture and energy efficiency solution**

No impact on water, food, land or biodiversity

LanzaTech-BaoSteel Demonstration Plant

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BAOSTEEL

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Distillation

Bioreactor

Gas Handling

Ethanol Storage

WWT

Fast Path to Commercialization

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SMOG

- Two Demonstration facilities in China 100,000 gallon/year ethanol capacity
  - ✓ Exceeded all production and performance milestones
  - ✓ Commercial facility approved for construction 2014
- Demonstration facility in Taiwan 12,000 gallon/year ethanol capacity
- China commercial facility in design; financing completed

SynGas

- MSW Mobile Lab in Japan demonstrated operation with a syngas stream
- MSW Demonstration facility in Japan 6,000 gallon/year ethanol capacity Q4 2014
- Integrated syngas to Butadiene Demonstration facility Q1 2015 in Korea

Scaling Up LanzaTech's Technology

Strain Development → Lab → 50 X → Pilot → 32 X → Demo → 25 X → Commercial

2005 2008 2012 2014

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

Waste Carbon as a Resource for Product Synthesis

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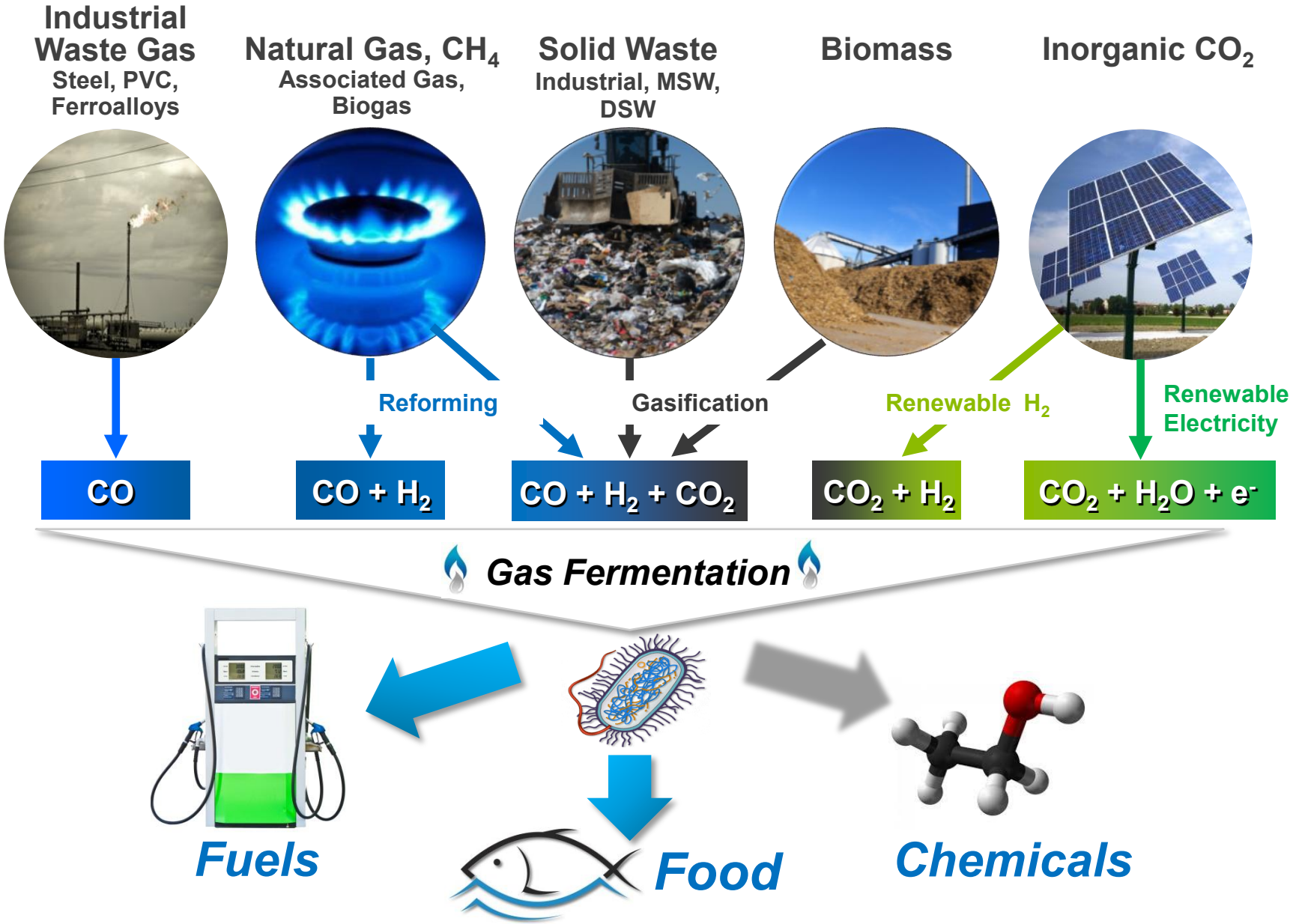

Butadiene: Key Chemical Intermediate

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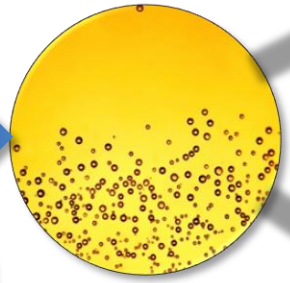
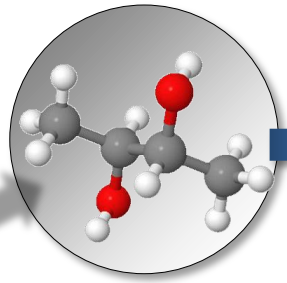
Industrial Waste
Biomass
NG
Coal
MSW/DSW



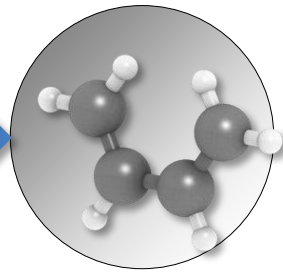
Syngas



2,3-BDO

Ethanol

Advanced Biofuel



Butadiene

Global Market Size:
~11 million tons, ~$22 billion

Styrene Butadiene Rubber (SBR)

Global Market Size:
~4.9 million tons, ~$13 billion

Polybutadiene Rubber (BR)

Global Market Size:
~3 million tons, ~$8 billion

Acrylonitrile Butadiene Styrene (ABS) Resins

Global Market Size:
~8 million tons, ~$16 billion

Nylon 6,6
(from Adiponitrile/HDMA)

Global Market Size:
~1.8 million tons, ~$6.9 billion

INVISTA™

SK innovation

1 organism, 20 products…so far!

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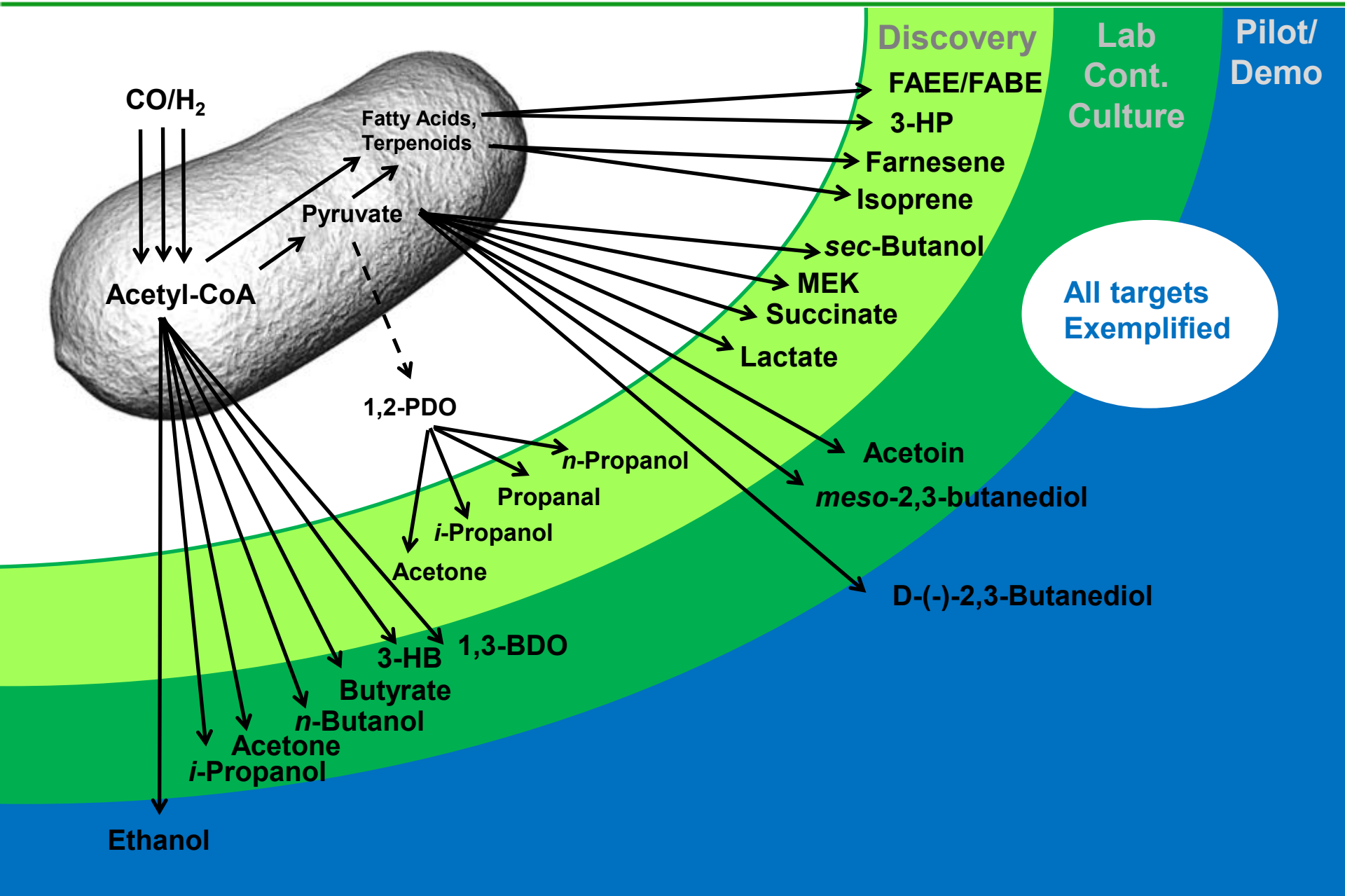

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Output: Diverse Products in Large Markets

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~1.7M bpd

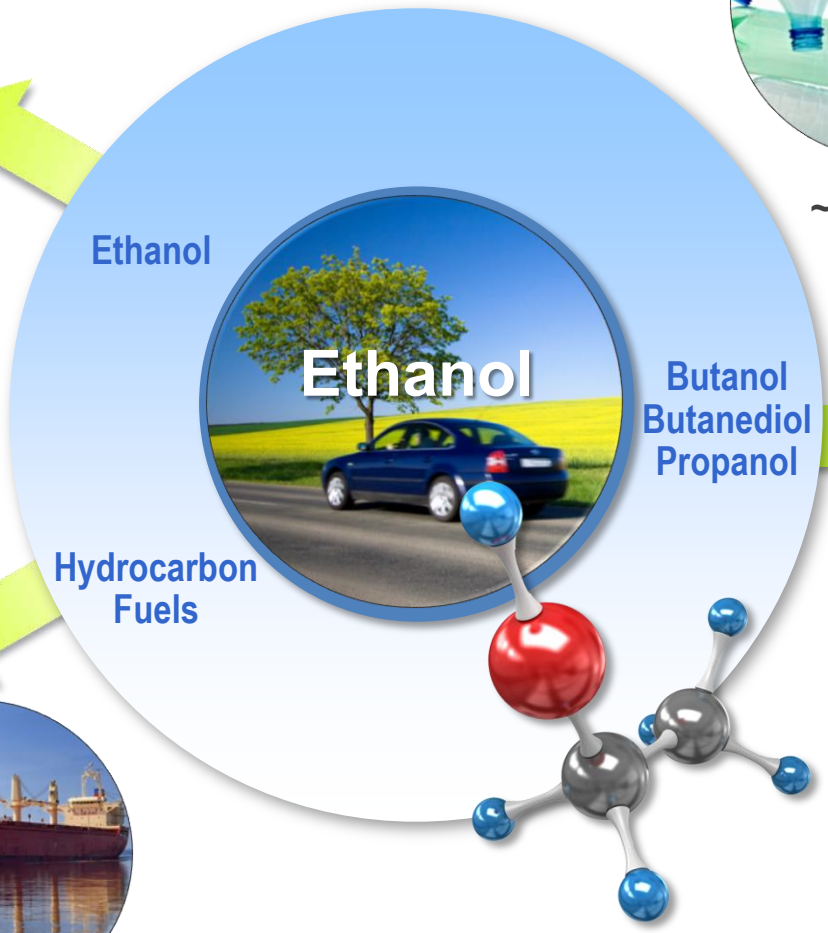
~4 M MTA

~5.5M bpd

~50 M MTA

~51M bpd

~8.5M bpd



Other Products

- Acetic Acid
- Succinic Acid
- Isoprene
- …

*2010 global consumption data -Harts, IEA

Hybrid Route to Aviation Fuel

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BETO is supporting LanzaTech and PNNL on a new route to jet fuel from biomass and other CO point sources

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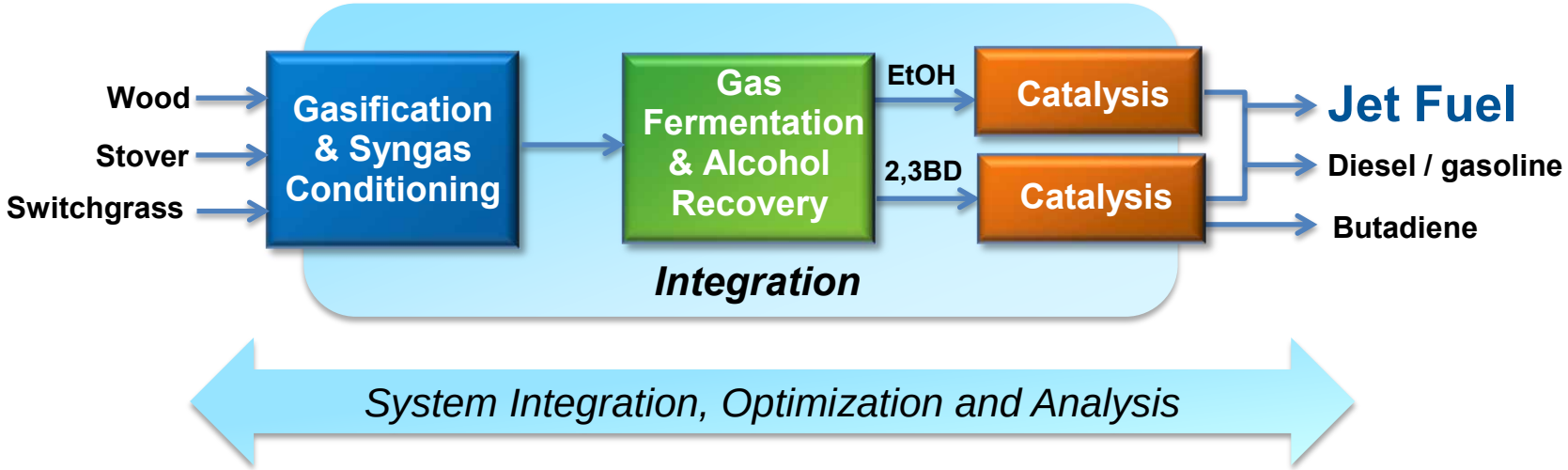
Pacific Northwest NATIONAL LABORATORY

Imperium Aviation Fuels



UNIVERSITY of DELAWARE

Michigan Tech Create the Future

OROCHEM Molecular Purification by Design

BOEING

Alcohol to Jet (ATJ) is in process of ASTM Certification

Commercialization of Aviation Fuel

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- **Production of jet fuel from LanzaTech ethanol demonstrated in 2012**
- **Off-take agreement executed with Virgin Atlantic**
- **ASTM certification: Approval targeted for 2014**

BOEING

Team Work is Key to Success

RSB
ROUNDTABLE ON SUSTAINABLE BIOFUELS

virgin atlantic

Imperial College of London

Waste Carbon as a Resource for Product Synthesis

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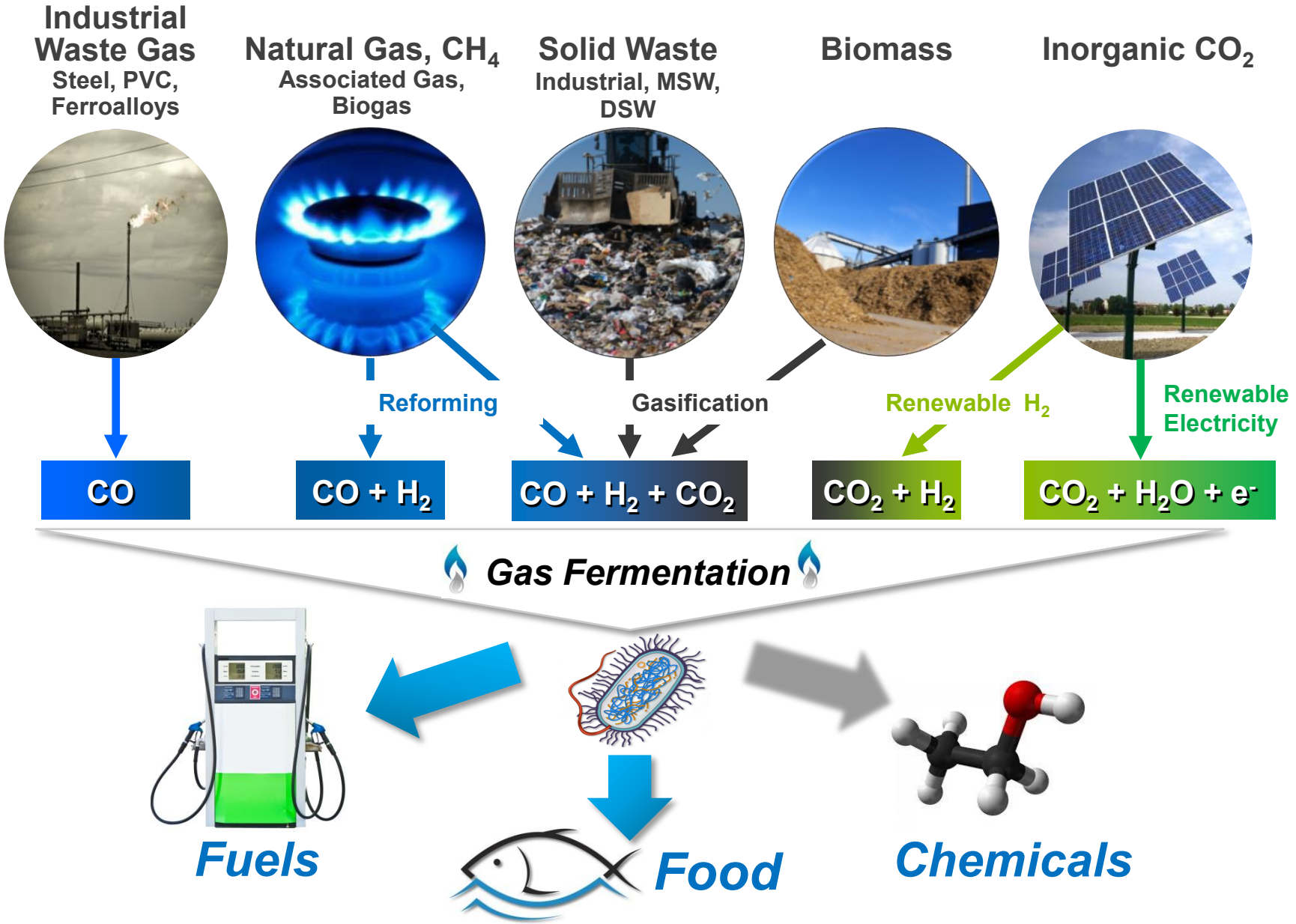

Conversion of Acetate to Lipids

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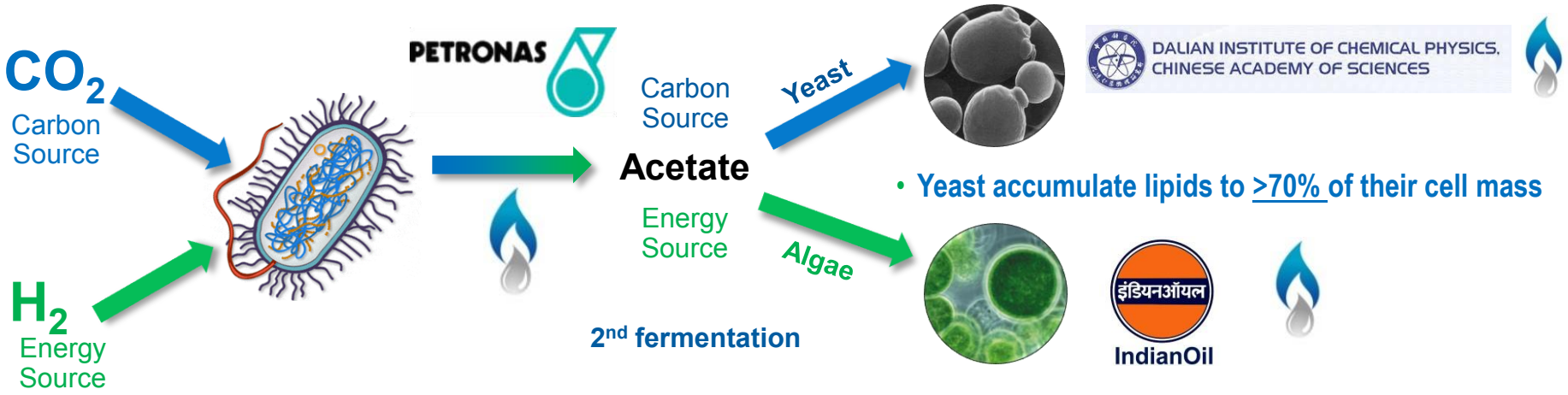

- Yeast accumulate lipids to >70% of their cell mass
- Algae accumulate lipids to >50% of their cell mass
- 40% of algal lipids content are Omega-3 fatty acids (Specifically DHA)

Lipids Product Markets

Hydrocarbon Transport Fuels
>US $ 3 trillion/year

Oleochemicals
US $15 billion/yr

Animal Feeds
US $370 billion/yr

Food, Nutritional Supplements
US $25 billion/yr

Defining Commercial

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It's not just about size… the plant needs to make money

- **Is it enough money to satisfy all project investors?**
- **Is this a model that can be replicated?**
- **Will this activity guide a company toward financial sustainability?**

But first commercials are difficult, as the technology has never performed at this scale, economically

- **They take time**
- **They take money**
- **And more time, and more money**
- **Need supportive investors/partners and project stakeholders that will stick with you – willing to take a risk**

Bridging the Valley of Death

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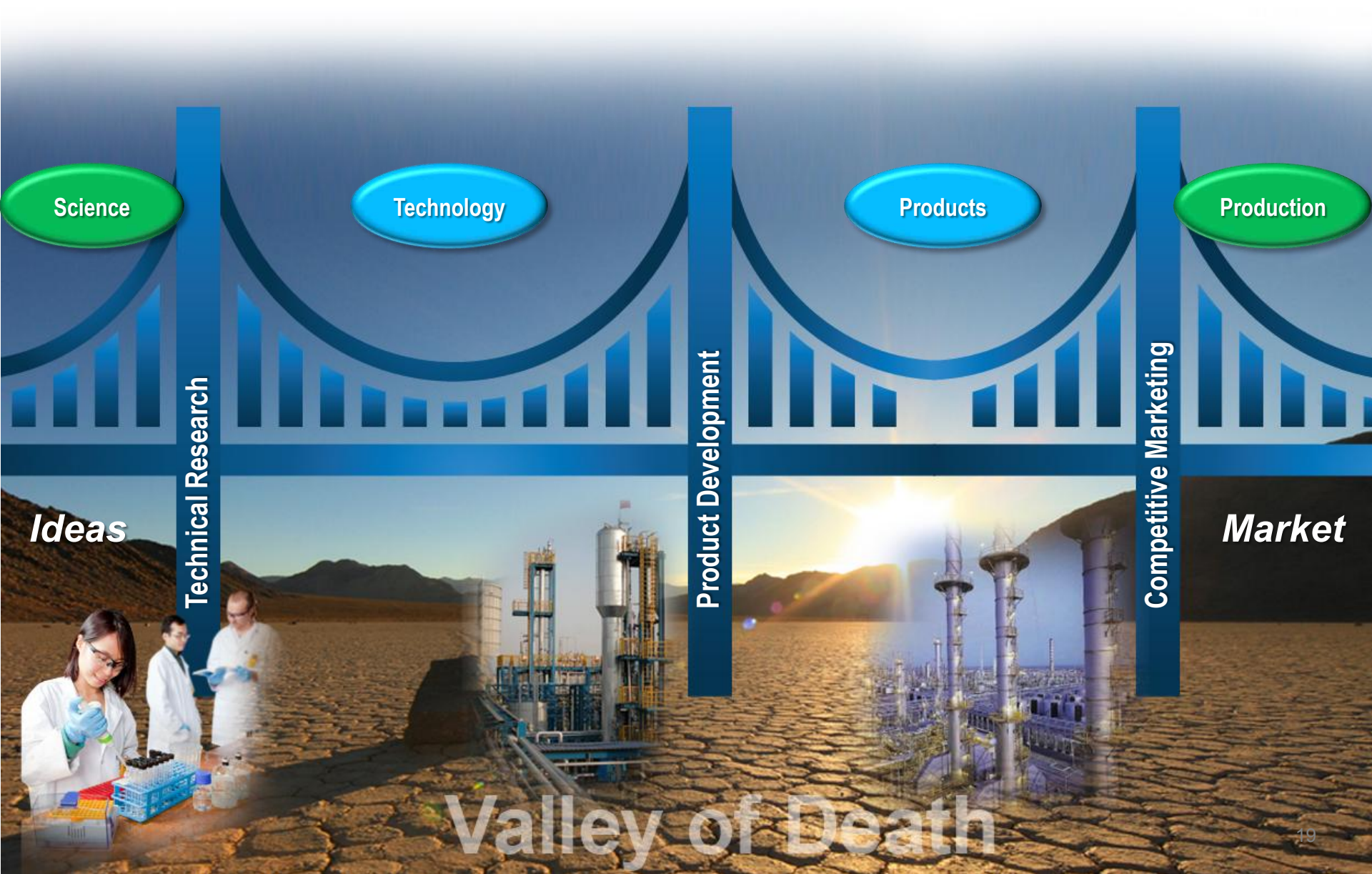

Getting a New Process to Scale

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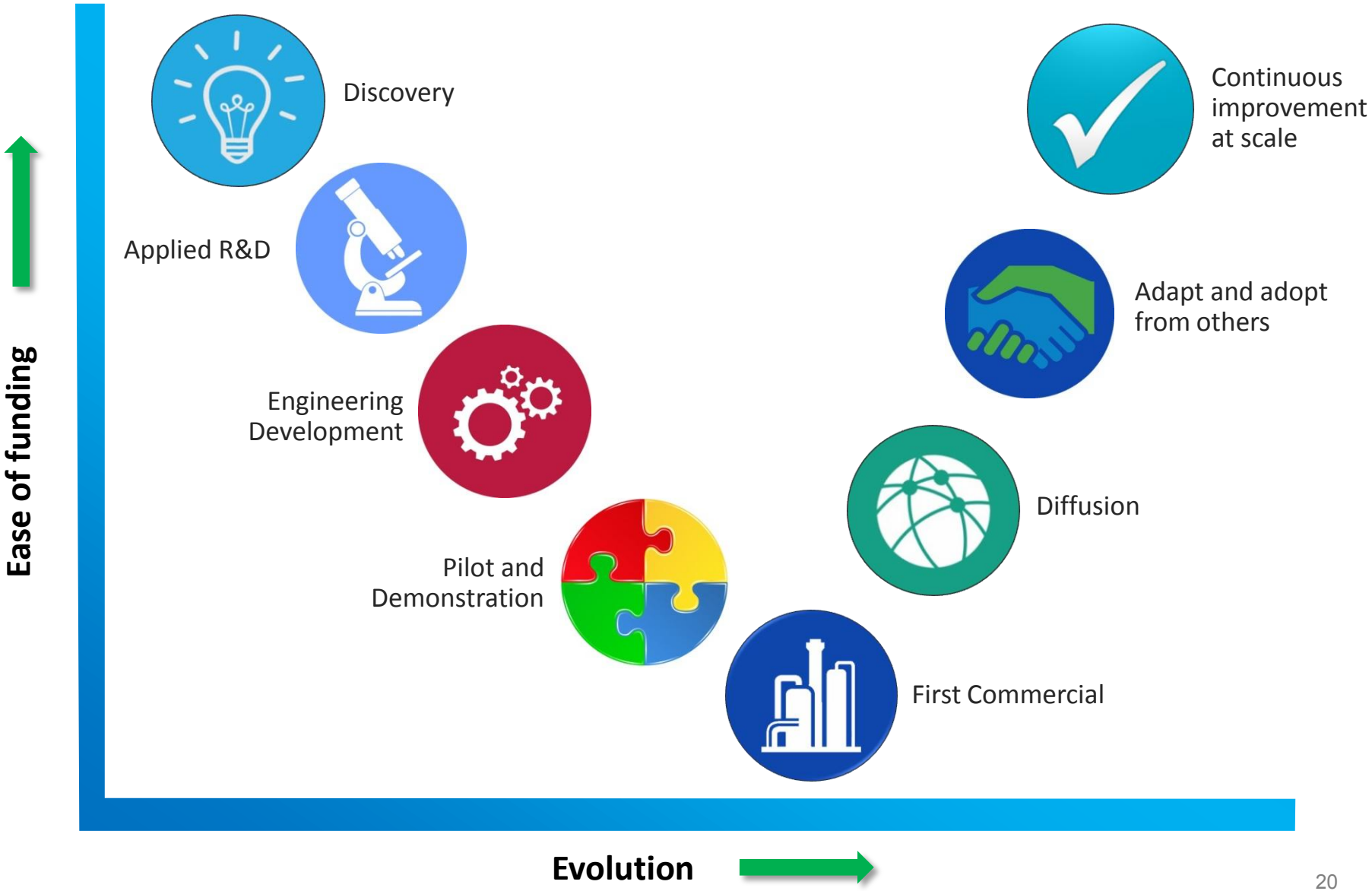

So What's Really Needed to be Commercial?

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- ✓ **Viable technology - mitigated risk through rigorous scale up**
- ✓ **Capital**
- ✓ **Market**
- ✓ **Regulatory environment**
- ✓ **Strong/invested partners**
- ✓ **Luck**

Long, Difficult Path

Funding Options Enable Scale-up

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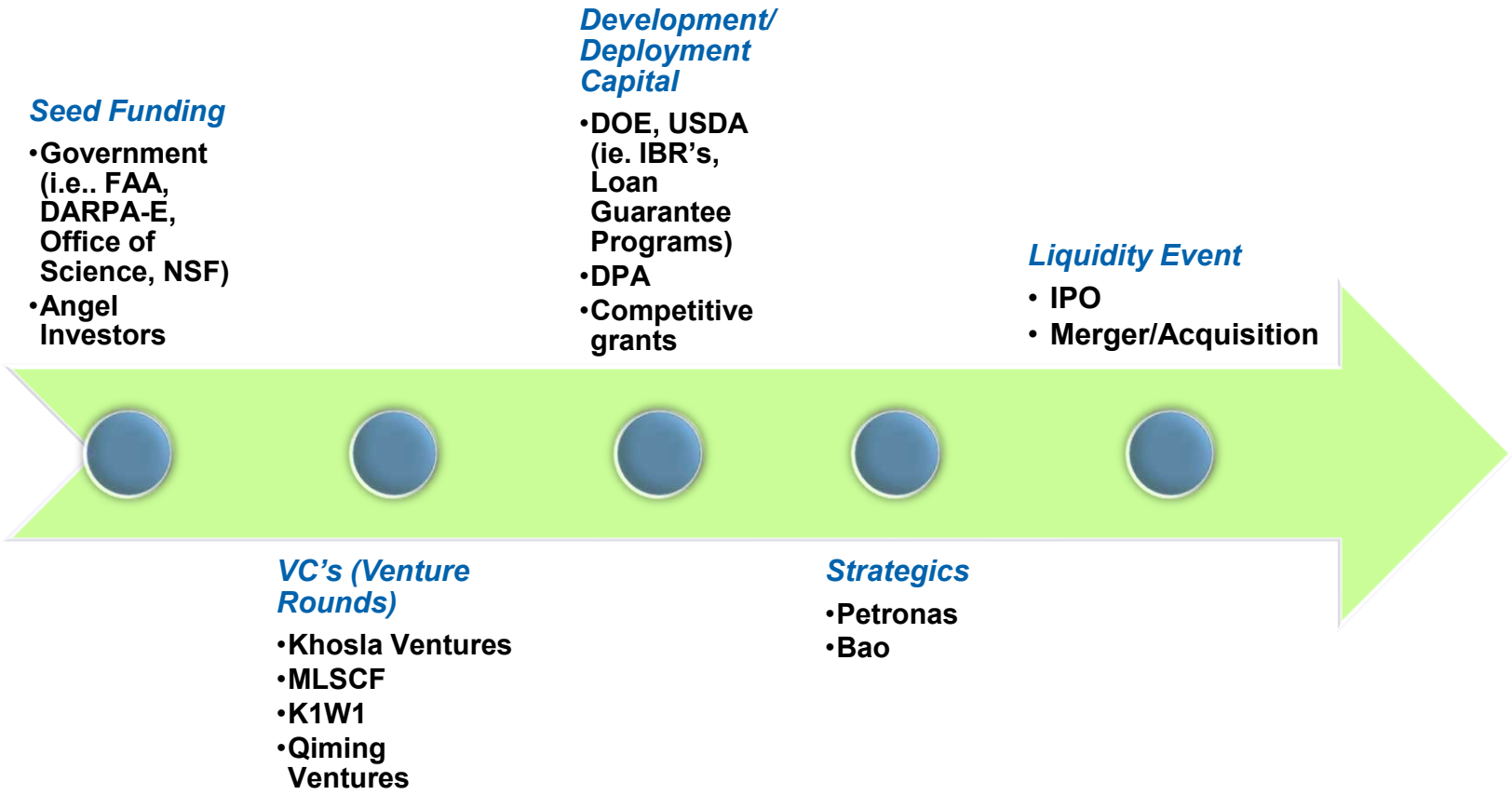

10+ Years to Cash Flow Positive

Remember, this isn't the IT Industry!

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IT/Software		
Company	**Development Years (prior to buyout)**	**Liquidity Event Value**
Whatsapp: Bought by Facebook 2014	5	$19B
NEST Labs: Bought by Google 2014	~4	$3.2B
Instagram: Bought by Facebook 2012	2	$1B
LinkedIn: IPO 2011	8	$4.5B

Biofuels/Bioproducts			
Company	**Development Years (Lab to Commercial)**	**Liquidity Event Value**	**Current Market Value**
Gevo: IPO 2011	~7: Commercial production initiated at Luverne facility in 2012 but faced delays/shutdowns. Planned butanol ramp up in future.	$373M	$66.1M
Kior: IPO 2011	~7: Columbus, MS facility started limited commercial production Nov 2012 and early shipments began in 2013. Currently facing production problems. Developing plans for flagship commercial facility in Natchez, MS.	$1.5B	$153.8M
Amyris: IPO 2010	~8 : Past contract manufacturing. Ramp up commercial facility in São Paulo, Brazil this year.	$688	$336.2M
Solazyme: IPO 2011	~8: Commercial production online in February 2014 at Clinton, IA facility.	$853M	$918.2M
LS9: Bought by REG 2013	~9 (no commercial production)	$61.5M	NA

Significantly More Time and Development Funds Needed to Commercialize Industrial Biotech

With The Help of Our Friends

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Jump to the Next Curve

Creating a Low Carbon Future

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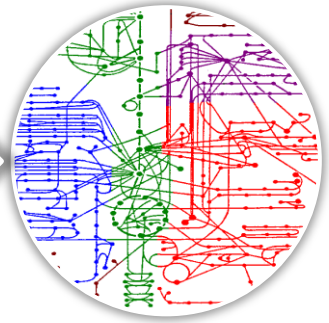
The Path Forward is Biology

Built for small scale
- Extremely high selectivity
- Direct, one-step conversion
- Single set of process conditions

Adapted for changing environments
- Feedstock flexible for same product
- Tolerant of contaminants
- Evolved for high efficiency

Complexity is free
- Regenerative catalysts
- Process upgrades with no down time
- Tailor products for each application



China Today

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Woman on Catwalk in a Fashion Show, Shanghai
As Shown in Taiwan Paper 12/7/13

View out of Sheraton Pudong 12/8/13 and 1/14/14

A Few Predictions

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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.'

"It is very difficult to predict the future, it is much easier to invent it."

Alan Key

A INNOV TION

the Game Changer...