Producing Protein and Plastics from Methane, a Sustainable Platform for Biotechnology

Bio World Congress
July, 2017

FeedKind™

FeedKind™ aqua

Thermodynamics and Economics of Carbon

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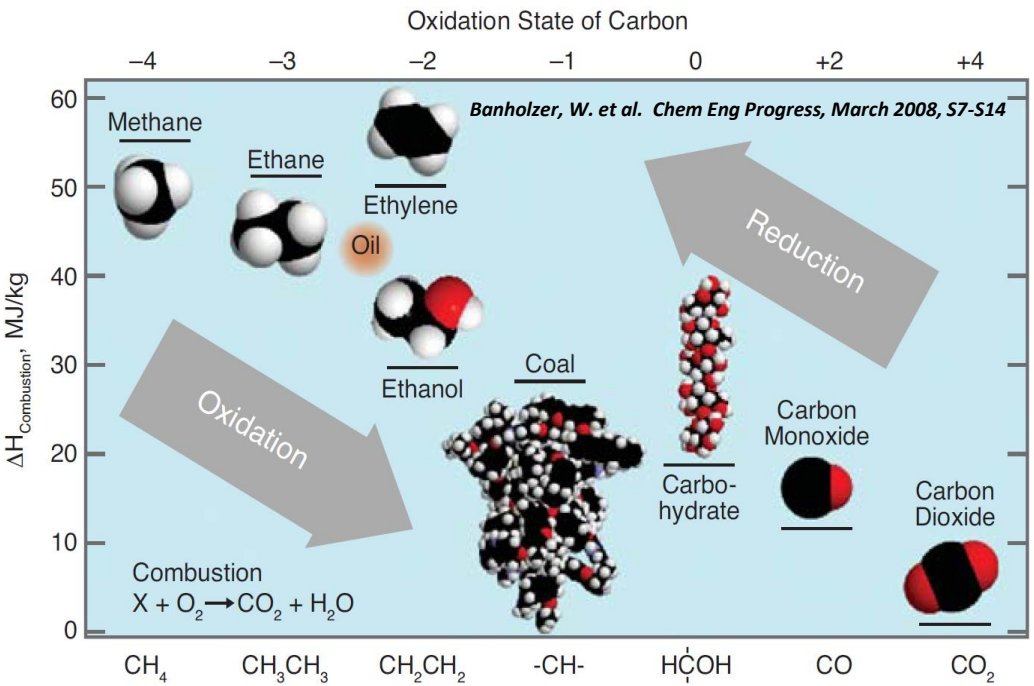

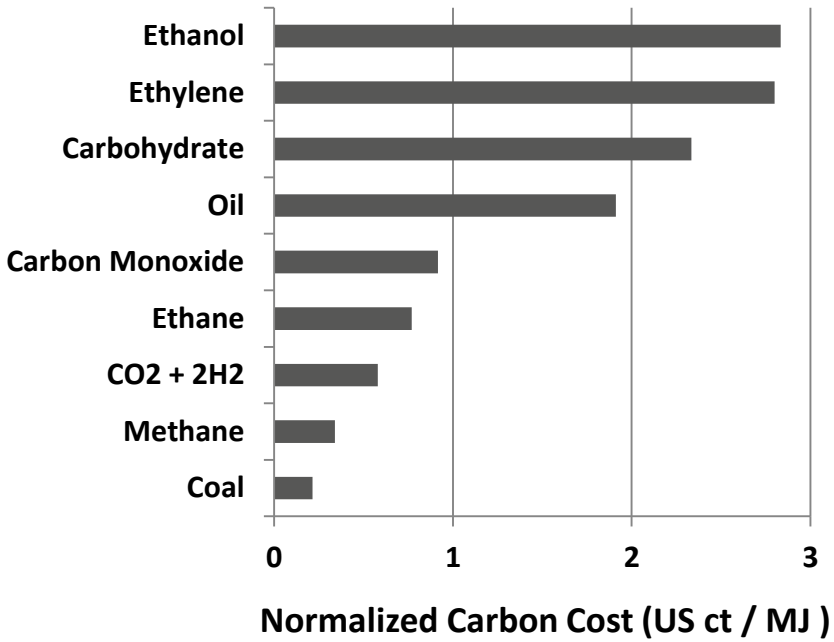

- All products are downhill from methane
  - *Key challenge is controlling the reaction, as full combustion is favored*
- Methane is an advantaged feedstock relative to carbohydrates or CO_2 for making diesel or other reduced products
- Methane is one of the cheapest sources of high-energy carbon

Low-Cost, Non Food-Based Carbon Offers an Advantaged Feedstock…

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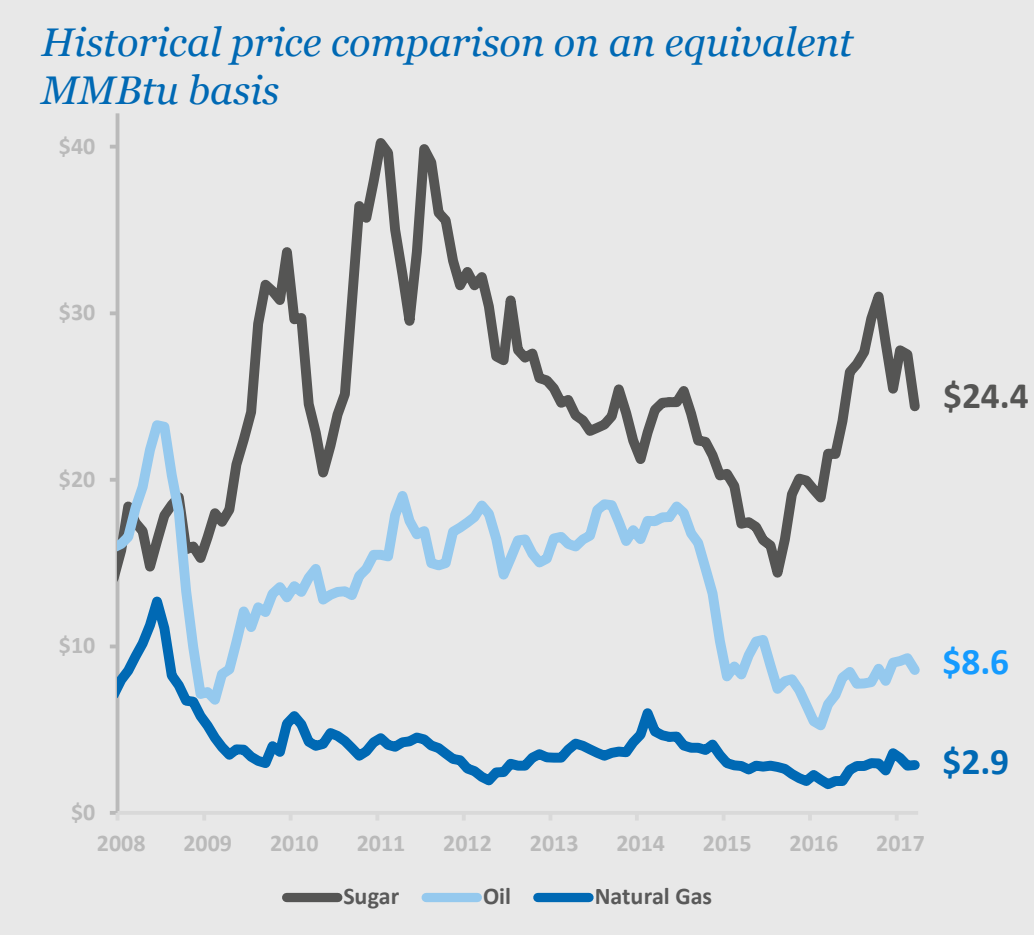
- Available from **multiple sources**: natural gas, biogas from MSW, ag waste, wastewater treatment
- **Homogeneous** – doesn't vary due to weather or growing conditions
- **Transportable** – pipeline transport is cheap, reliable, and efficient
- **Infrastructure** – pipeline transport infrastructure is available globally
- **Affordable** – natural gas in the North America is the world's cheapest source of carbon
  - Current U.S. natural gas forward curve shows gas <$3.75 per MMbtu through 2029
- As a green house gas, methane is **84x more potent** than CO_2 in the short term



Source: IndexMundi and EIA data for historical pricing as of 31-Mar-2017.
Bloomberg market data as of 19-Apr-2017 for NYMEX Henry Hub natural gas futures. 2017 – 2028 implied average price from the forward curve is $3.10 per MMBtu.

Methanotrophs in Nature

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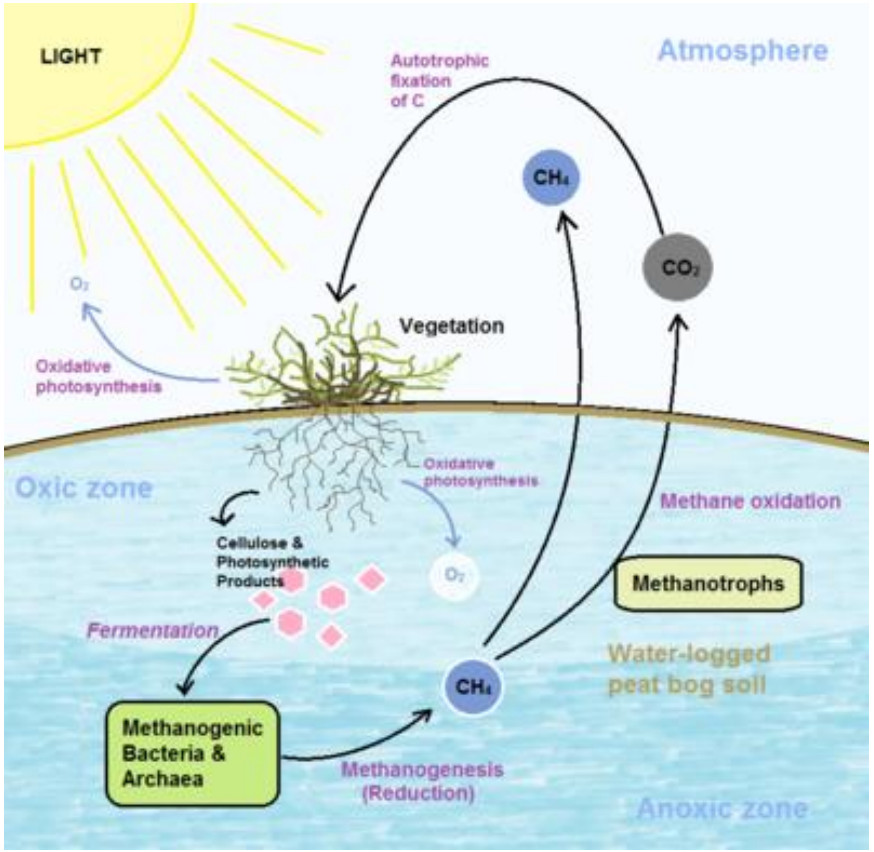
Aerobic methane-oxidizing bacteria (methanotrophs) are widely distributed in the environment and play a key role in the cycling of the potent greenhouse gas methane. They oxidize much of the methane produced by the anaerobic metabolism of methanogenic archaea before it escapes to the atmosphere, thereby mitigating the effects of global warming. Methanotrophs have been isolated from many different environments, including freshwater and marine environments, soils, sediments, acidic peatlands, rice paddies, landfill, alkaline soda lakes, hot springs, cold environments, and even from highly acidic, thermophilic environments.

Handbook of Hydrocarbon and Lipid Microbiology (2010) Chen, Y & Murrell, J.C. pgs 3067-3076



Calysta's Platform: Methanotrophs

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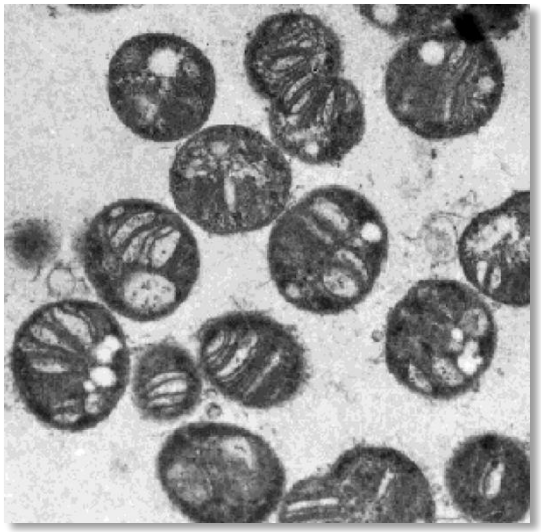
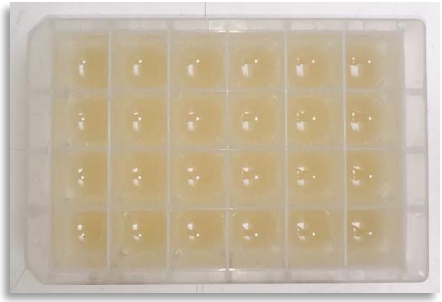
Methylococcus capsulatus Bath current "work horse"



- Gammaproteobacteria, type I methanotroph
- Relatively fast growth rate (methane:oxygen mix)
- Genome sequence available
- Amenable to genetic manipulation
- Only methanotroph proven at commercial scale
- Variety of formats for strain testing: 24-well plates, pressure bottles, 2L fermenters
- Amended media and optimized feeding strategies produce high cell densities in small scale.



Calysta's Platform: Strain Engineering

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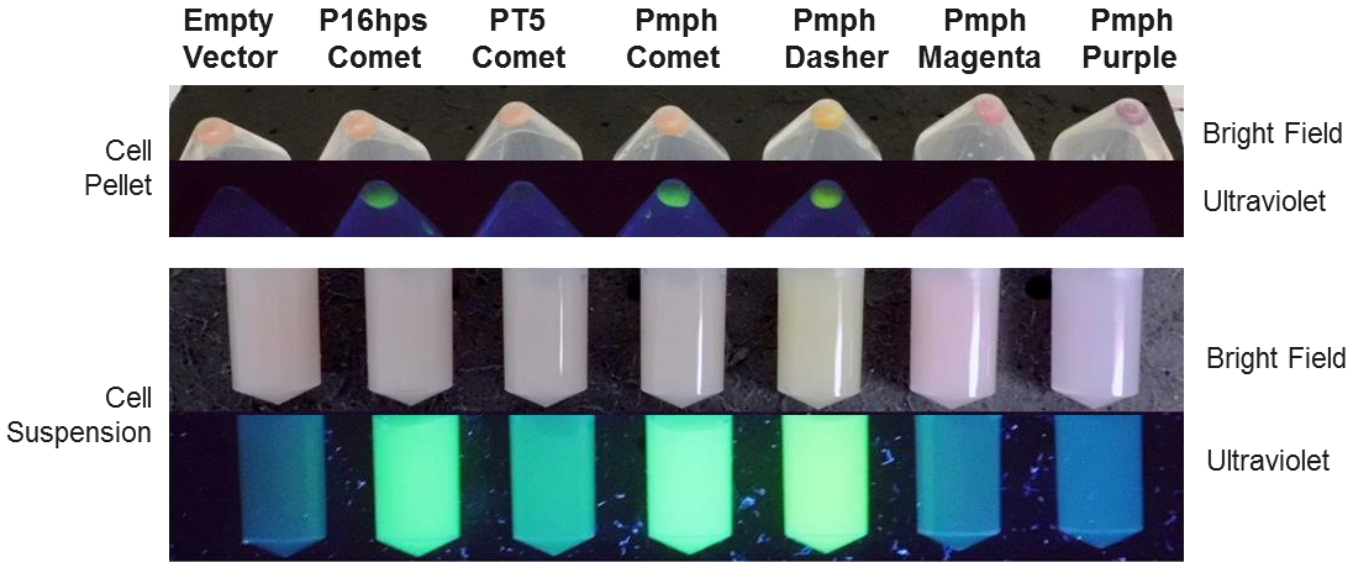
Calysta has developed a set of novel engineering tools for methanotrophs:

- Reporter genes



Different promoter gene-fusions with synthetic fluorescent and chromogenic proteins (non-*Aequorea*) expressed in *M. capsulatus*

- Plasmids that replicate both in methanotrophs and in *E. coli*
- Constitutive and inducible (low/med/high) promoters
- Techniques for chromosomal knockin and knockouts

Calysta's Integrated Bioplatform

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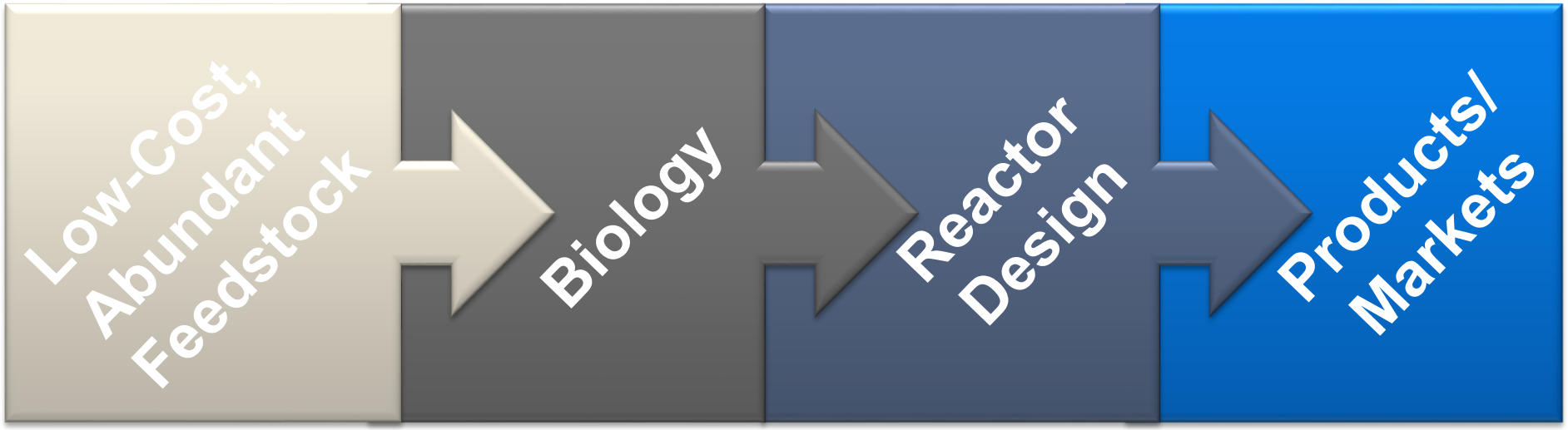
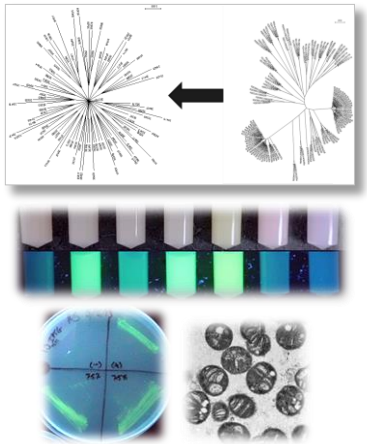
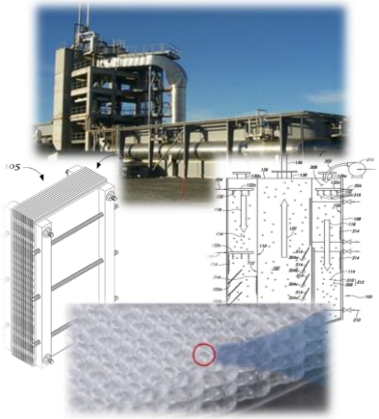


Methane
(Nat Gas or Renewable)



Proprietary Tools/ Algorithms



High Mass Transfer Gas Reactors

Industrial Partnerships

Making Everything from Plastics to Protein

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Non-Food Based Carbon

Research	Development	Commercial
Future Food	***Nutritional Supplements***	FeedKind® aqua
N-butanol	***Palatants***	FeedKind® terra
Biodiesel	***Probiotics***	FeedKind® pet
Butadiene	***L-amino acids***	
Crotonate	Lactate	
ω-3 fatty acids	Succinate	
Fatty alcohols	Pentamethylene diamine	
1,3 BDO	Isoprene	
3-hydroxypropionate	Malate	***Autolysate***
	2,3 BDO	
	Acetate	
	Citrate	
	Acetoin	
	3-hydroxybutyrate	
	polyhydroxybutyrate	
	polyhydroxyalkanoates	

Legend:

Chemical products

Nutritional products

The Calysta Opportunity

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- Calysta's FeedKind protein can help address one of the greatest threats to global growth: food security
- Proprietary fermentation platform for producing protein and other nutritional products
- High quality FeedKind protein has been extensively validated in aquaculture, the most demanding and fastest growing food production system in the world

FeedKind®

- Experienced team with proven track record of successful execution across multiple disciplines
- World-class partners and investors including Cargill, Mitsui and Temasek
- Construction of the world's largest gas fermentation facility underway in Memphis, Tennessee, U.S

Food Security Is the Issue of the Future

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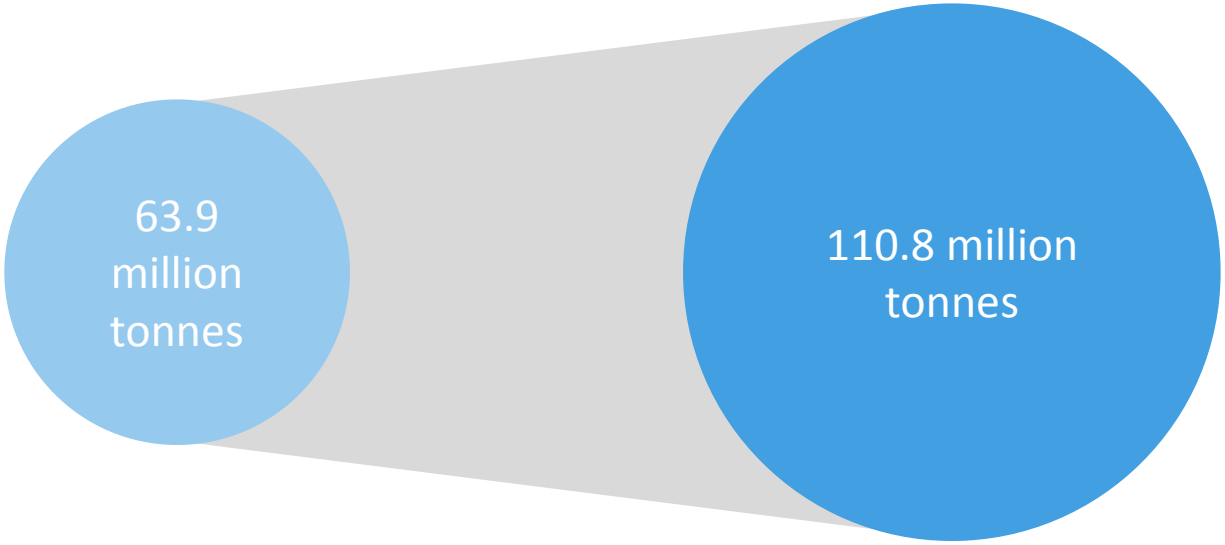
By 2050, 9.6B people will demand 75% more protein than currently available

2006 Protein Demand *2050 Protein Demand*



> **"Our research shows people will spend one-third of any increase in incomes on a more varied high-protein diet"**
>
> *Greg Page – Former Chairman of Cargill*

Source: UN World Population Prospects: The 2012 Revision. World agriculture: towards 2030/2050. Food and Agriculture Organization of the United Nations, 2012. Creating a Sustainable Food Future, World Resources Institute Report 2013-2014: Interim Findings

Demand for Protein is on the Rise Globally

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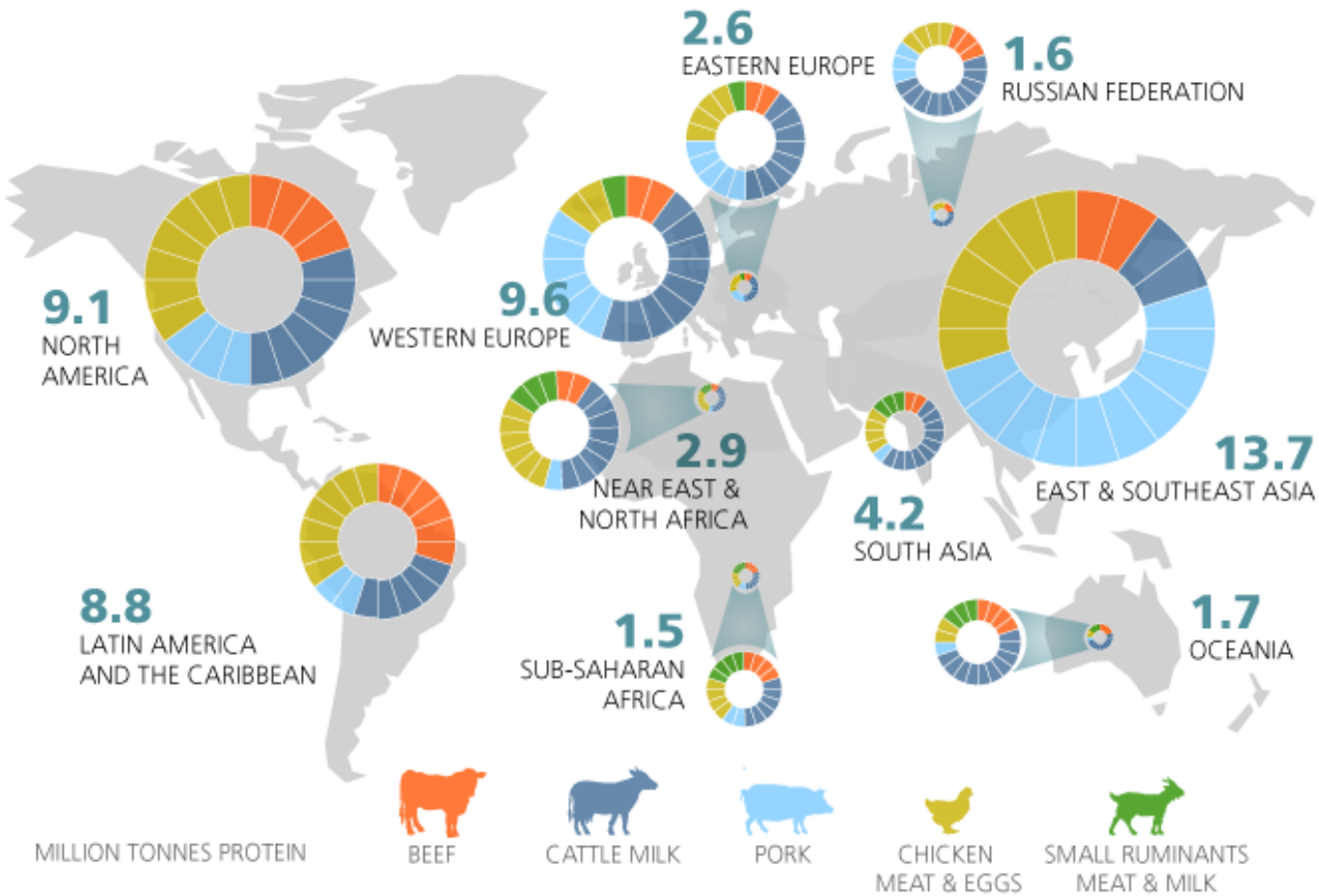
The global protein ingredients market for animal feed and human food and beverage is $40B growing at 5-6% per year



Source: Alltech Feed Survey, 2016. Markets and Markets, Protein Ingredients to 2020. FAO Global Livestock Environmental Assessment Model.

Two Problems…One Solution

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Food Security

Global Warming

"Future Fit Feed"

- No agricultural land use
- 77-98% less water than agricultural products
- 40% improved CO_2 emissions compared to combustion of methane
- FeedKind protein does not compete with the human food chain
- No animal derived ingredients
- Helps mitigate global warming losses at 5% of global GDP (IPCC 2014)

Independent Analysis Confirms Environmental Benefits

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Assessment of environmental impact of FeedKind™ protein

CARBON TRUST

Table B: Impacts of feed ingredients in relation to protein content

Ingredients	Protein content (%DM)	CO^2e emissions ($kgCO^2e/kg$)	Water consumption (m^3/kg)	Land occupation (m^2/kg)
FeedKind™ Powder	71	2.2	0.01	0.00
Fish meal (medium)	64	2.6	0.02	0.01
Soy protein concentrate	66	0.8	0.14	6.66

- Comparable impacts to fishmeal
- Dramatically improved water and land footprints compared to agricultural products

http://www.carbontrust.com/media/672719/calysta-feedkind.pdf

Source: Carbon Trust, 2016

FeedKind® is a Natural, Non-GMO Protein Source Offering Significant Differentiating Benefits

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Naturally occurring microorganisms metabolize methane as their sole source of carbon and energy, producing a nutritious, high-protein biomass

Multiple Monetization Opportunities:

Supply Chain	Consumer	Sustainability	Under development
• Traceable • Consistent product • Year round production • Long shelf life • Reduced enteritis from plant proteins	• Non-GMO • Natural fermentation process • Reduced fish-in / fish-out ratio • Saturated fatty acids • No animal based ingredients	• No agricultural land use • Little water use • Additive to the human food chain	• Amino acid modifications • Omega-3 • Prebiotic and probiotic effects

EU Approval Already Received for Use in Fish and Livestock:

EU Feed Registration:

12.1.2	**Protein from *Methylococcus capsulatus (Bath), Alcaligenes acidovorans, Bacillus brevis* and *Bacillus firmus***	Protein product of fermentation with *Methylococcus capsulatus (Bath)* (NCIMB strain 11132), *Alcaligenes acidovorans* (NCIMB strain 12387), *Bacillus brevis* (NCIMB strain 13288) and *Bacillus firmus* (NCIMB strain 13280) ([1]) on natural gas (approx. 91 % methane, 5 % ethane, 2 % propane, 0,5 % isobutane, 0,5 % n-butane), ammonia, and mineral salts, the crude protein is at least 65 %.	Crude protein Crude ash Crude fat

FeedKind Has a Superior Nutritional Profile When Compared to Other Fishmeal Alternatives

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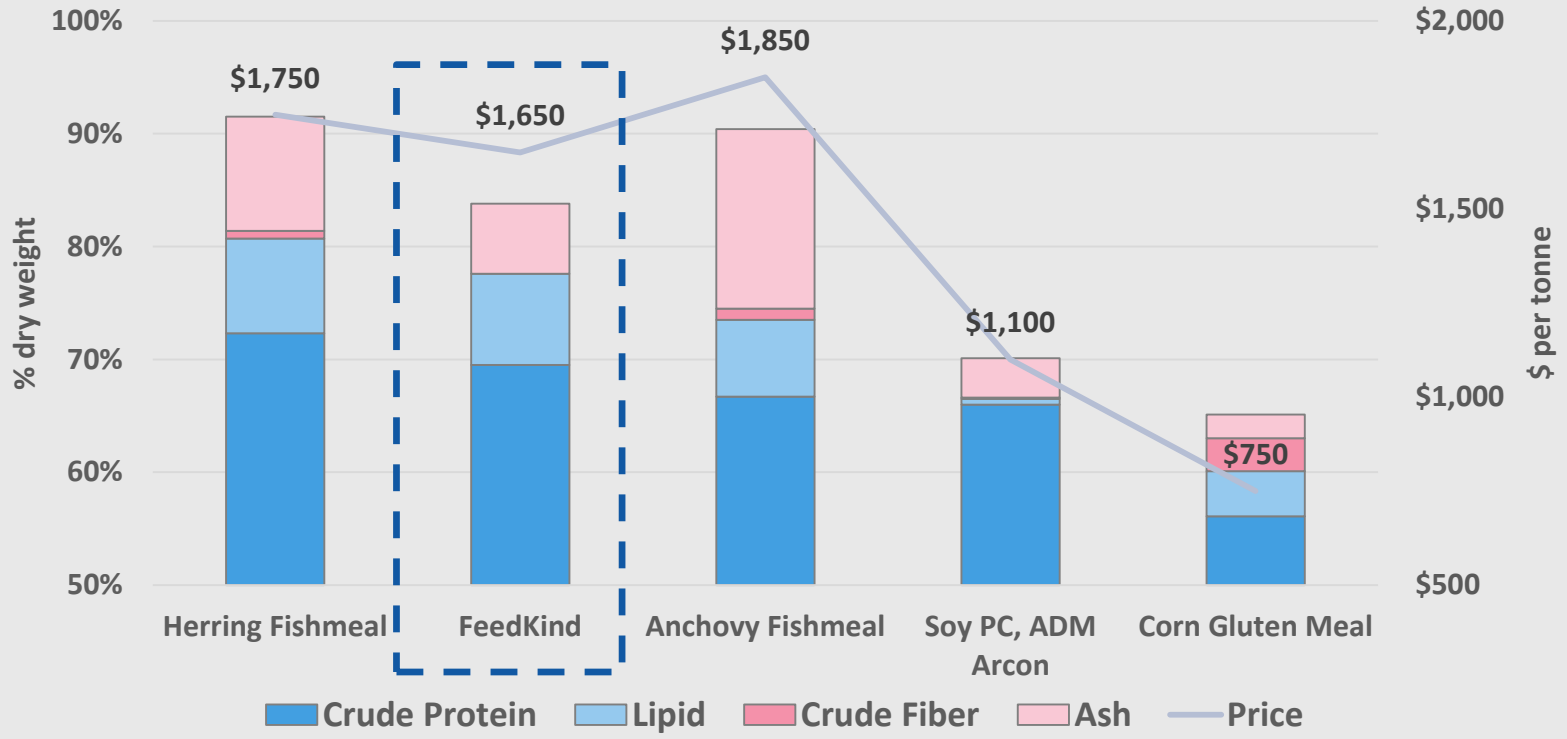
Major aquaculture feed ingredients and indicative pricing



Source: FAO Feed ingredients and fertilizers for farmed aquatic animals, 2009.

Calysta's Proprietary Natural Fermentation Platform Drives Substantial Value Creation

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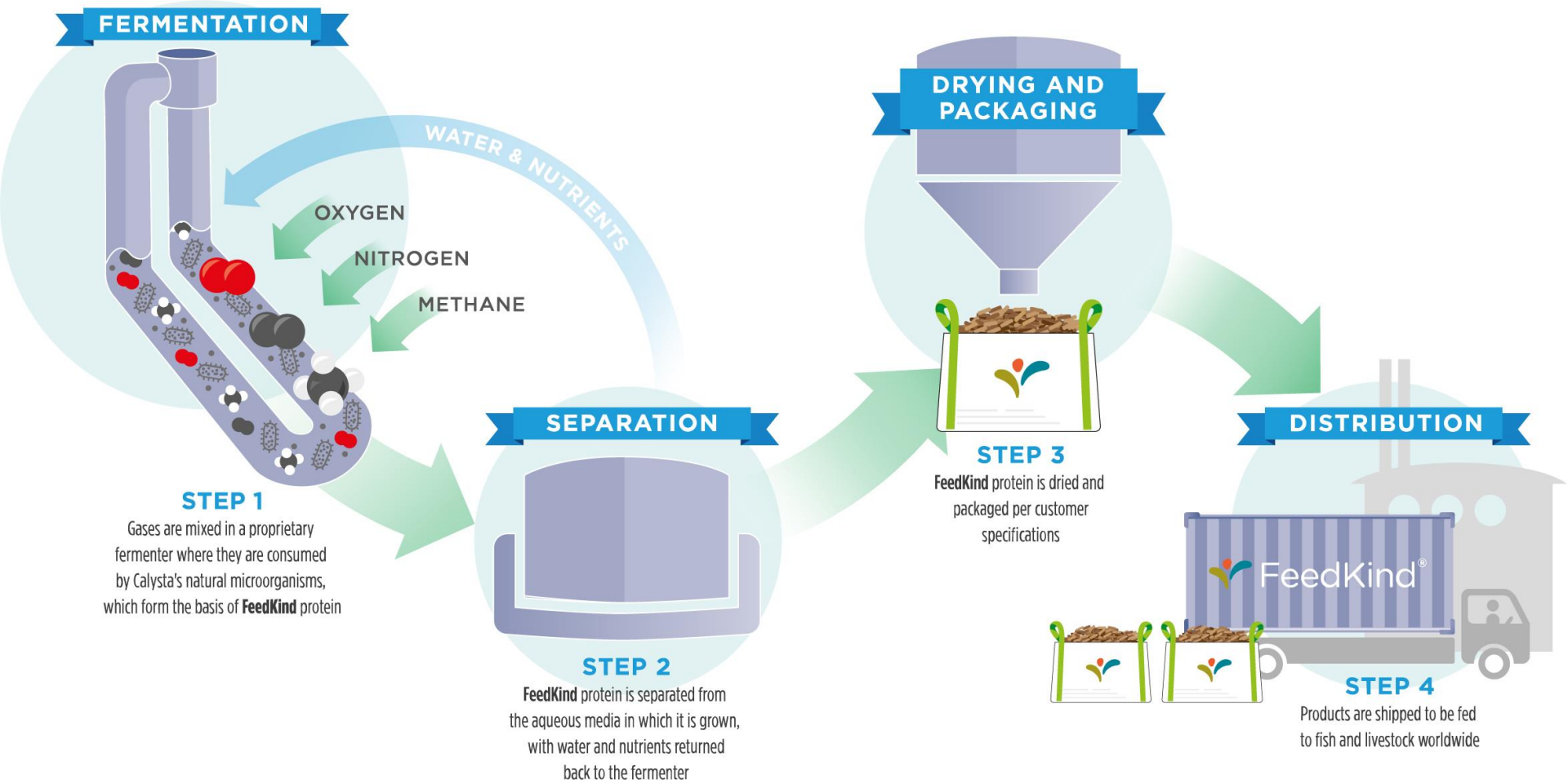

Ultra-efficient carbon conversion, with every ton of FeedKind sold providing a ~10x upgrade to the price of the carbon-equivalent input.

FeedKind Protein Commercial Samples Shipping Worldwide from Teesside UK Plant

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- Over 5 tonnes of FeedKind protein already produced in 2017
- Shipping commercial samples to customer and partners worldwide
- Facility is a “scale-down” of the original Tjeldbergodden, Norway reactor, demonstrated to produce at a rate of 10,000 mtpa
- Successful maintenance of 8+ weeks of continuous fermentation, meeting design parameters for key commercial metrics such as yield and productivity
- Partnered with Center for Process Innovation (“CPI”) to provide on site services and well trained staff

Fermenter in Teesside, England.

Ground Has Broken on 1st Commercial Plant in Memphis, Tennessee

CALYSTA

- Collaborating with Cargill on what will be the world's largest gas fermentation facility, occupying 37 acres of Cargill's 69-acre property on President's Island in Memphis

Cargill™

- Modular design lends itself to phased construction process: 20 fermenters, each similar in size to a football field end zone, plus several dryers, each approximately the height of a six-story building

- 20,000 mtpa Phase I coming online Q1 2019, with total production capacity of 200,000 mtpa by 2021

NouriTech™

Calysta Commands a Leading IP Position, Creating Significant Barriers-to-entry

CALYSTA

- **46 granted** patents with **over 100 pending** applications covering more than **22 patent families**
- Strong claims covering proprietary reactor design that have already invalidated one potential competitor's patent
- Broad claims granted in 2016 covering biological production of any chemical from natural gas
- Aggressively filing on new gas fermentation reactor designs and improvements
- Continuing to develop new applications for products across species and markets