

## SESSION 17: RENEWABLE FUELS, CHEMICALS, AND BIO-BASED PRODUCTS IV: COMMERCIALIZATION AND ECONOMICS



### Michael Japs - Rapid commercialization using an integrated approach to bioprocess development



Michael is a fifteen year veteran of the industrial biotechnology sector leading development, scale-up, and commercialization of novel processes for the production of chemicals via fermentation. In his current role, he is responsible for leading conceptual process design, economic analysis, and technical business development for new product opportunities. He previously formed and led Genomatica's process engineering department where he was integral in establishing the company's core bioprocess engineering capabilities. He is an inventor of Genomatica's renewable 1,4-butanediol (BDO) process which in 2013 received the prestigious Kirkpatrick Chemical Engineering Achievement Award recognizing *'the most noteworthy chemical engineering technology commercialized in the world during the past two years...'*. Prior to Genomatica Michael held several R&D and operations positions at NatureWorks LLC commercializing polylactic acid (PLA). Michael holds a B.S. degree in chemical engineering from the University of Minnesota.





# *Symposium on Biotechnology for Fuels and Chemicals*

Michael Japs

April 30<sup>th</sup>, 2015

**Rapid Commercialization using an Integrated  
Approach to Bioprocess Development**

## **Abstract: Rapid Commercialization using an Integrated Approach to Bioprocess Development**

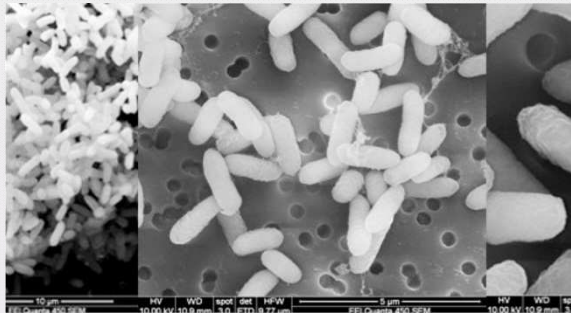
Genomatica has developed a complete, commercial-scale bioprocess for production of 1,4-butanediol (BDO) directly from carbohydrates, which has been producing thousands of tons since 2012. This presentation will discuss the integrated approach inherent to Genomatica's biotechnology platform that made this faster and less expensive than traditional bioprocess development and scale up. A key differentiator of this platform includes an emphasis on modeling and techno-economic analysis from the very start; using this information to guide decisions on organism, fermentation, and downstream process design. Combining this integrated approach with real-world commercial expertise enabled highly-reliable and predictable scale-up and scale-down results across multiple orders of magnitude.



# BDO commercialization journey and success

5 years from concept to commercial production

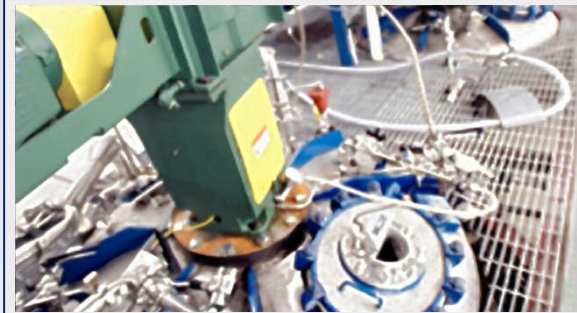
**BDO Producing Organisms – 2008**



**Purified BDO – 2009**



**3,000 Liter Piloting – 2010**



**Integrated Demo Plant – 2011**



**Shipping Tons at a Time – 2011**



**Commercialization – 2012**



# Commercial-scale production

2,500 tons in five weeks, Loudon-TN, produced Q4'12





# First Bio-BDO plant

under construction in Italy by Novamont



Bottrighe, Italy site under construction



# BASF licenses the GENO BDO™ process

“exceptionally advanced and reliable” process technology



The Chemical Company

#1 chemical company

#1 BDO producer

535KT BDO capacity

- Market leader and fully integrated derivative products producer
- Chose Genomatica process because *‘exceptionally advanced and reliable’*  
(Sanjeev Gandhi, Member of BASF Board of Executive Directors)



The Chemical Company

PRESS RELEASE – November 27, 2013

**BASF produces first commercial volumes of butanediol from renewable raw material**



We create chemistry

PRESS RELEASE – March 5, 2015

**BASF now offers bio-based PolyTHF**

- Properties identical to conventional PolyTHF
- Extends range of products based on renewable raw materials
- Opportunity for customers to test new market segments



# Kirkpatrick Award

first biotechnology winner of this landmark chemical engineering award



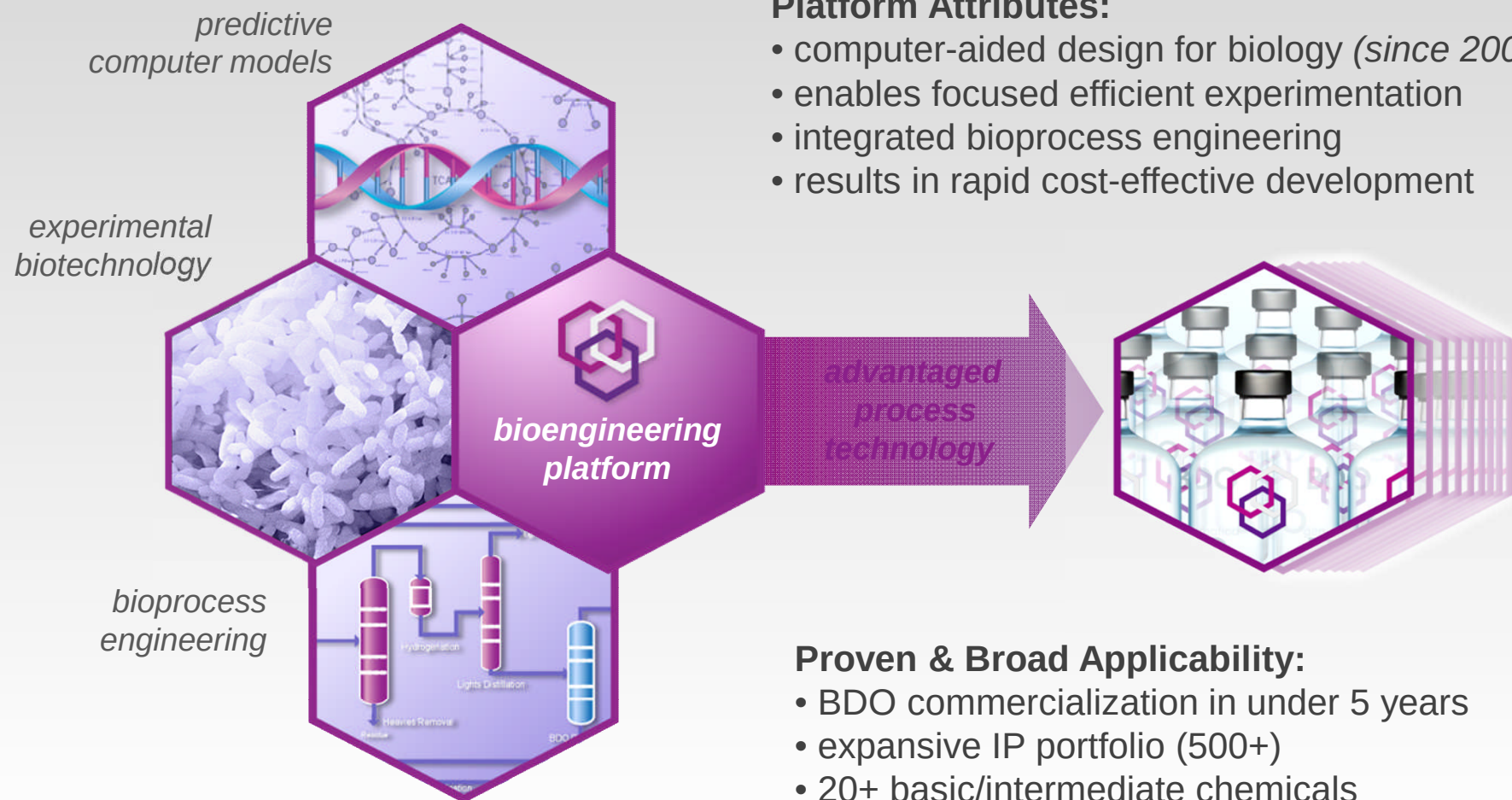
**“the most noteworthy chemical engineering technology commercialized in the world in the past two years”**

- Award to one company every 2 years
- 80 years of winners have shaped major parts of the chemical industry



# Integrated bioengineering platform

drives high impact innovation, products, solutions



## Platform Attributes:

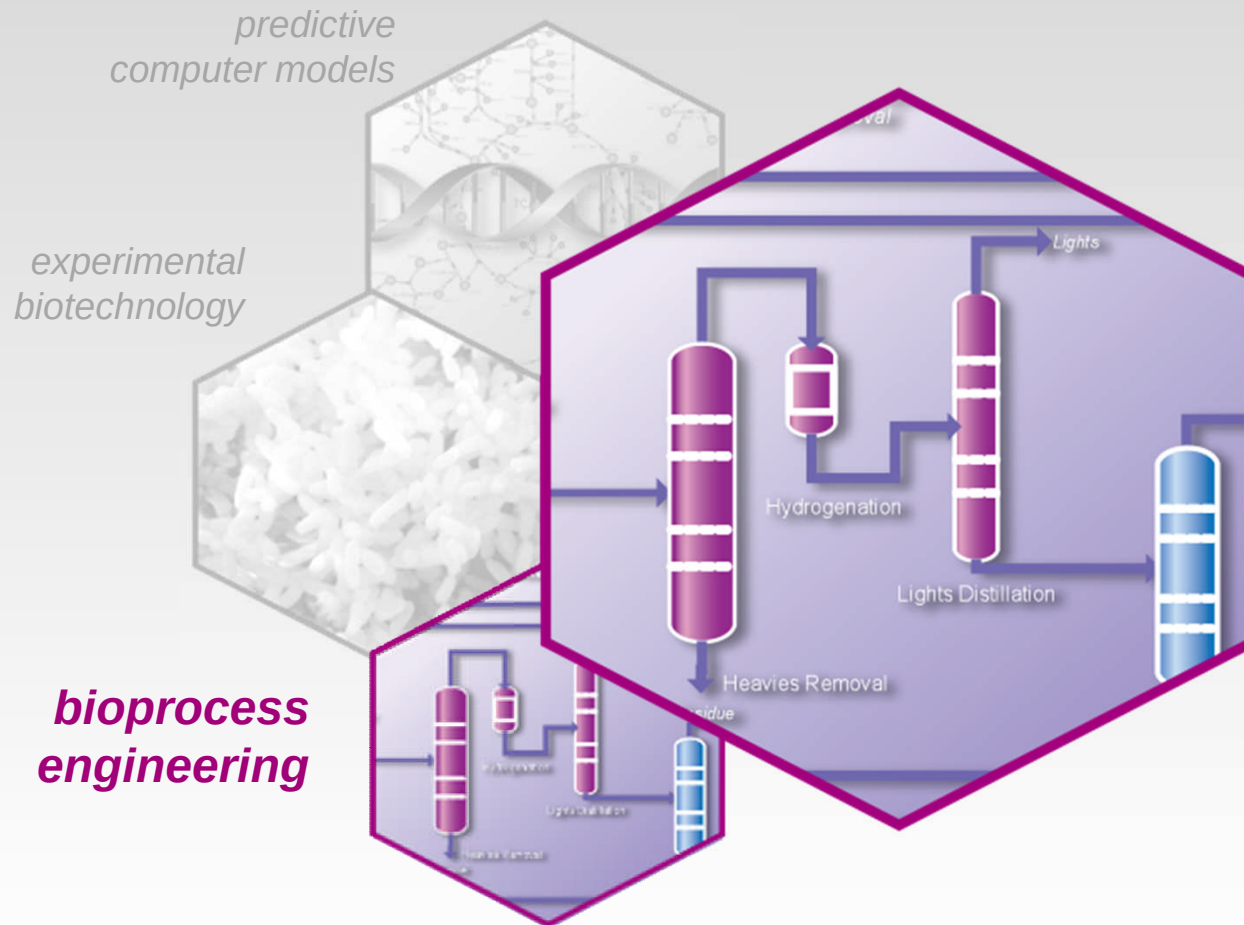
- computer-aided design for biology (*since 2000*)
- enables focused efficient experimentation
- integrated bioprocess engineering
- results in rapid cost-effective development

## Proven & Broad Applicability:

- BDO commercialization in under 5 years
- expansive IP portfolio (500+)
- 20+ basic/intermediate chemicals
- sugars (C6/C5) & C1 feedstocks

# Bioprocess engineering

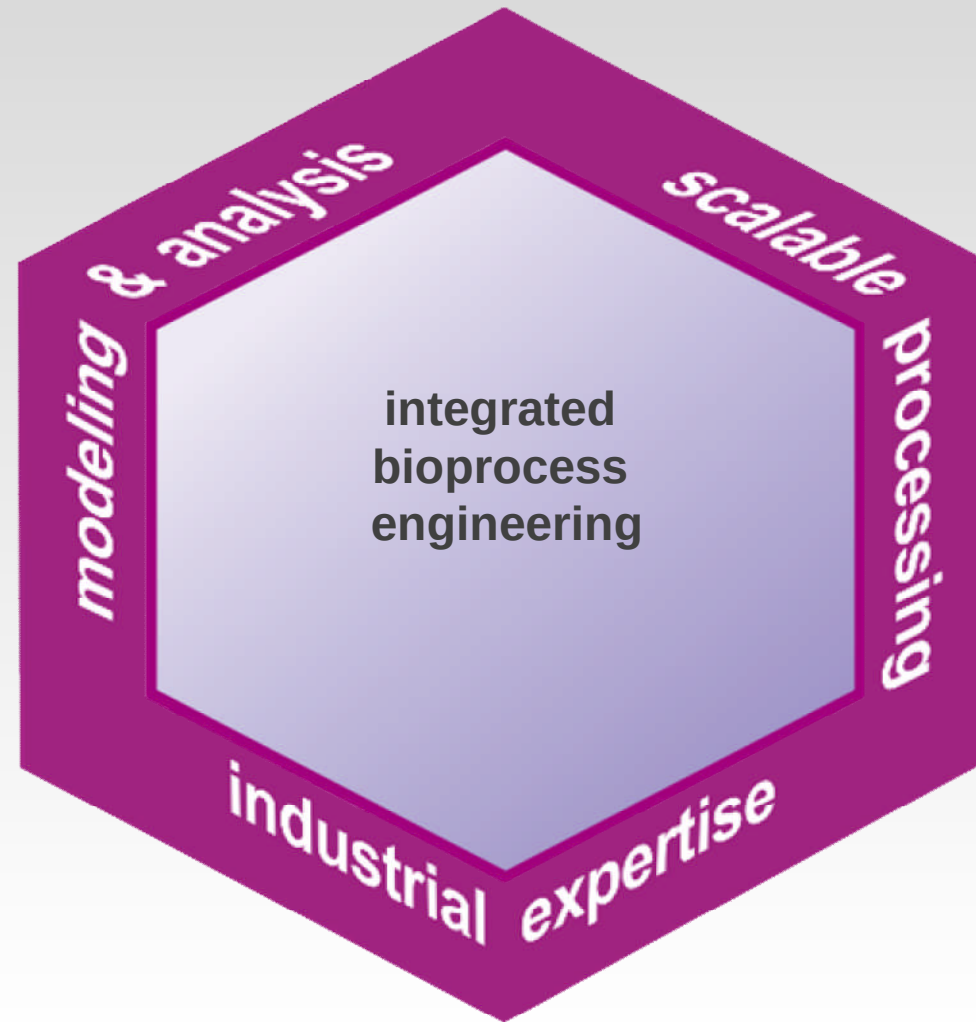
integrated bioprocess design, scale-up and economics





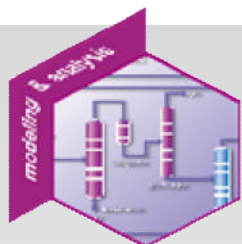
# Bioprocess engineering: capabilities

integrated bioprocess design, scale-up and economics

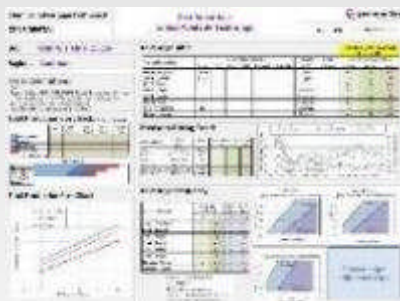
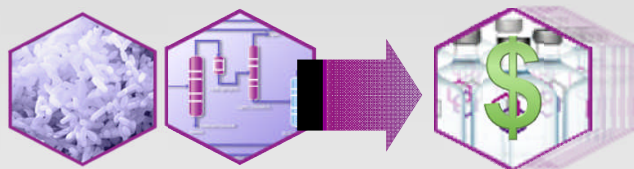


# Core capability: modeling & analysis

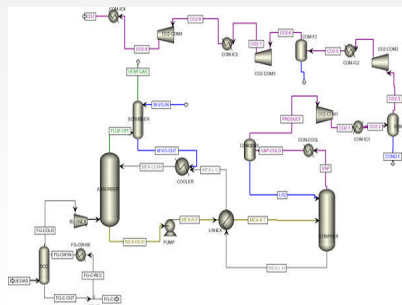
quantitative approach guides R&D to reduce capex/opex



## Techno-economic analysis



## Dashboard



## Process simulation

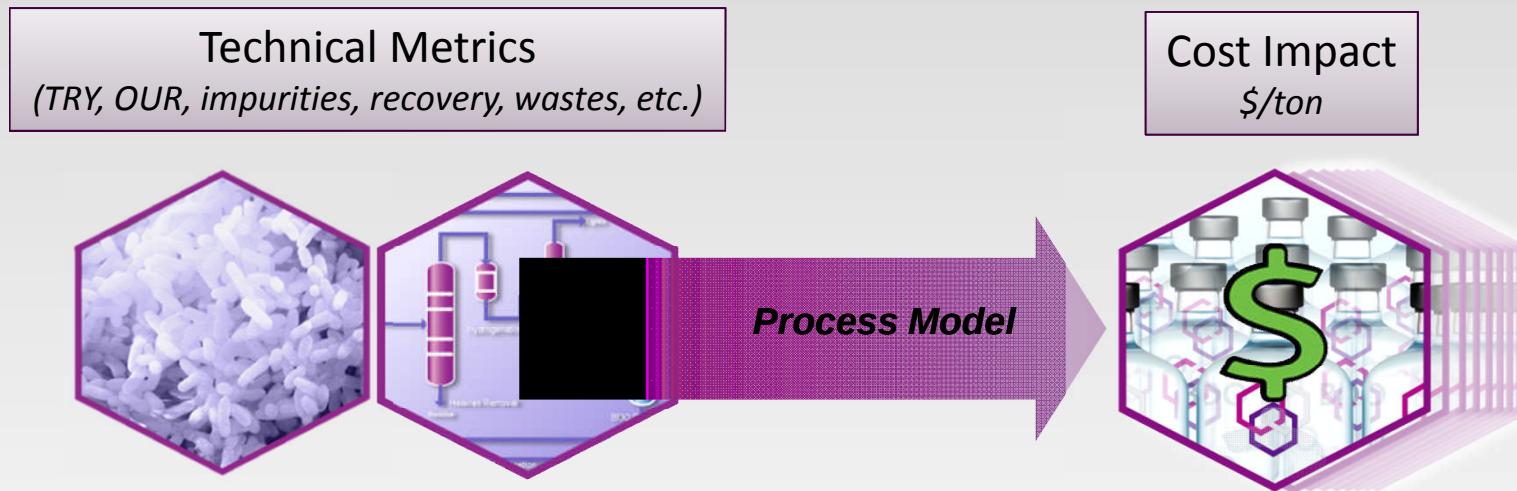
- Proprietary economic modeling tools identify leverage points
- Process simulation using AspenPlus, Excel, more
- Reliable modeling of fermentations
- Singular focus on metrics
- Design the entire process before the first gene is cloned



# Techno-economic analysis

core competence that focuses R&D on reducing production costs

Definition: **Combined (simultaneous) process modeling and economic evaluation**



- ◆ Assess potential of new opportunities
- ◆ Identify high-impact areas for optimization
- ◆ Compare economics of design alternatives
- ◆ Provide metrics for tracking performance

***Framework for guiding all R&D decisions!***

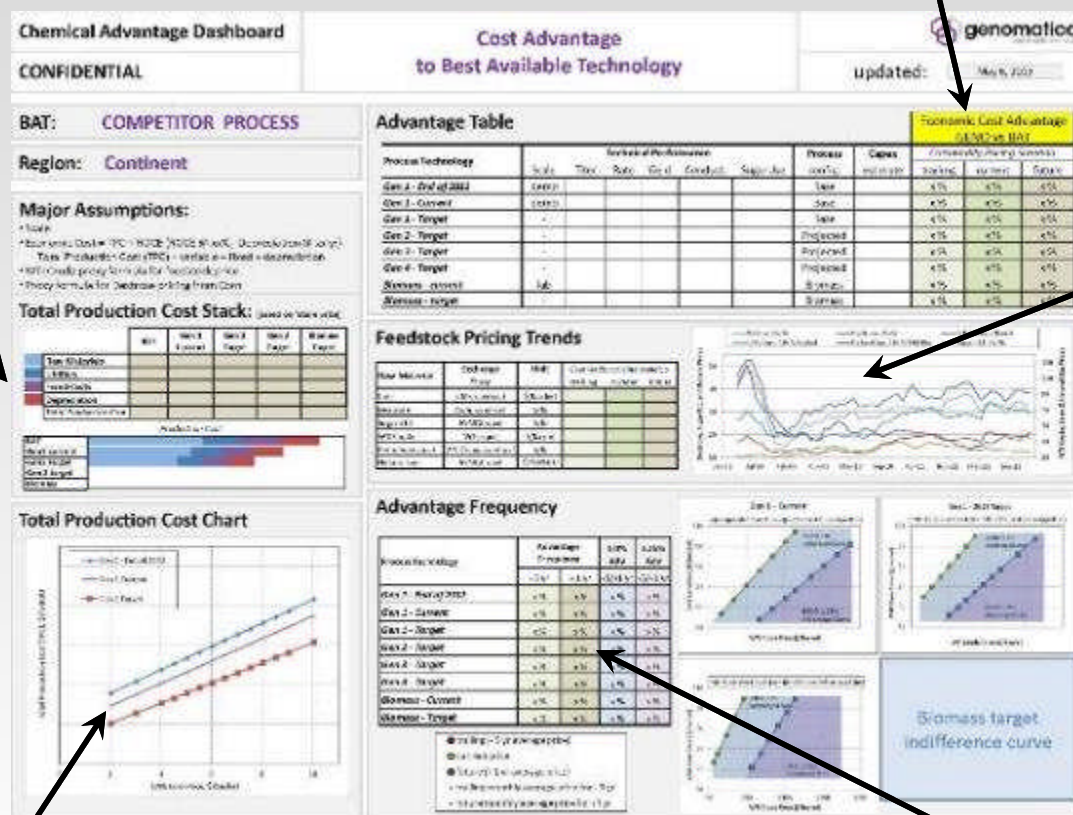
# Example: modeling and analysis

competitive dashboards – using TEA to drive cost advantage

What are the key elements of the cost stack?

What is our current advantage or disadvantage?

Where are feedstock prices headed?



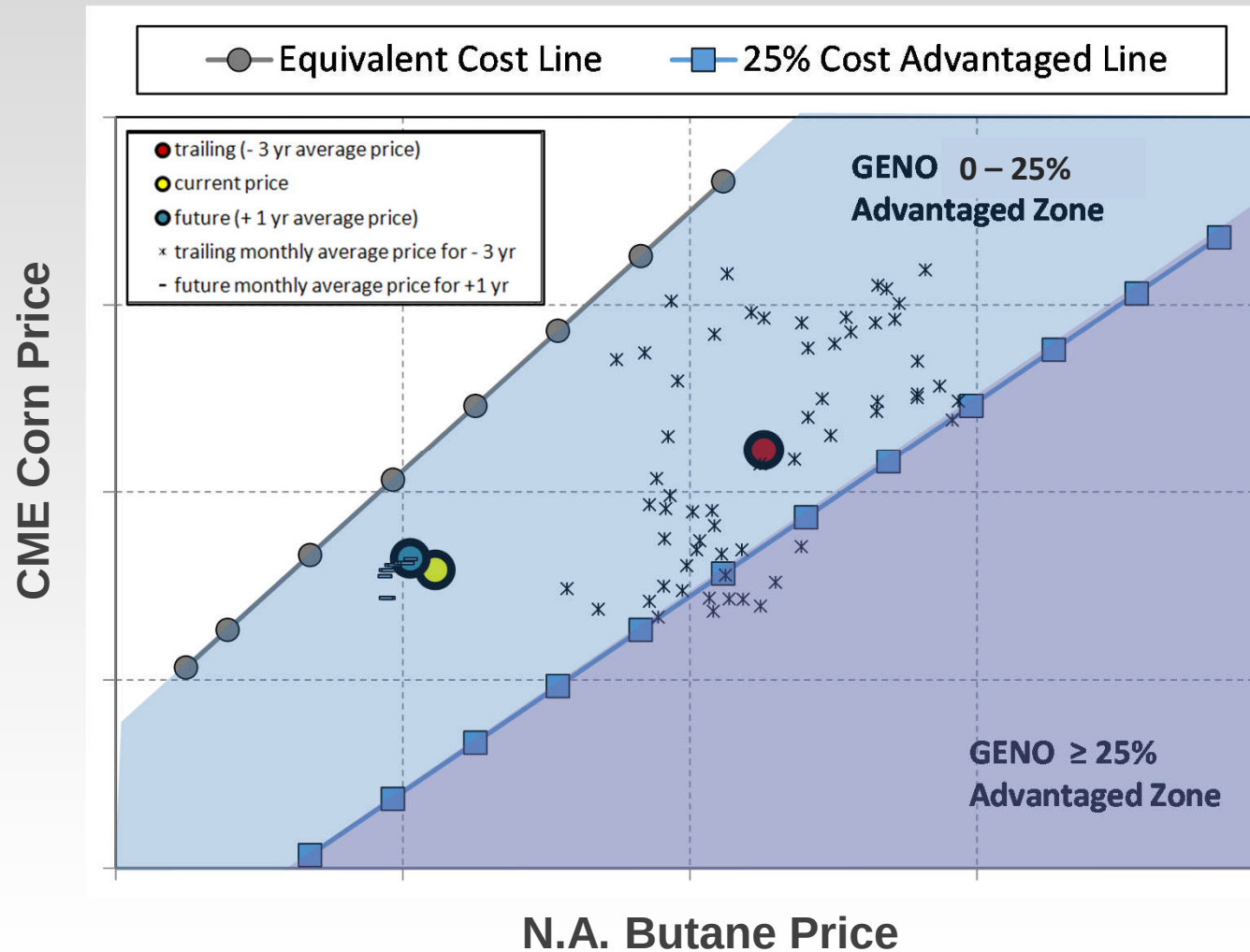
Sensitivity analysis

How often are we advantaged or disadvantaged? (past 3 years and next year pricing scenarios)

When is the process advantaged? When by 25%?

# Biotechnology can be advantaged even at \$50 oil

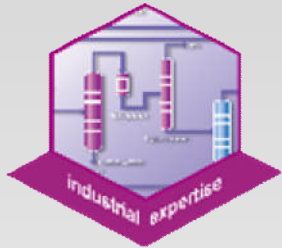
shown here: GENO BDO vs. best available petroleum-based, 50KT scale





# Core capability: industrial expertise

unique blend of bioprocess engineering and biotech skills



**Make customers successful**



- 25+ experienced engineers
- Built/operated many plants
- Multiple technology transfers
- Ties everything together: process engineering, modeling, economics, safety, fermentation, filtration, distillation, scale-up / down, operations,...

# Core capability: scalable bioprocessing

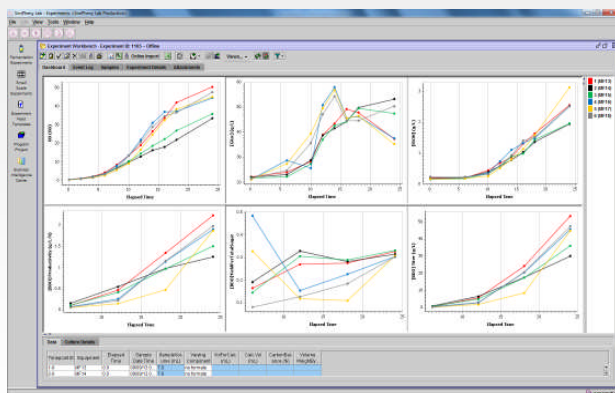
accelerated commercial process delivery: smaller, cheaper, better, faster



## Flexible fermentation capabilities



## Iterative experiment design

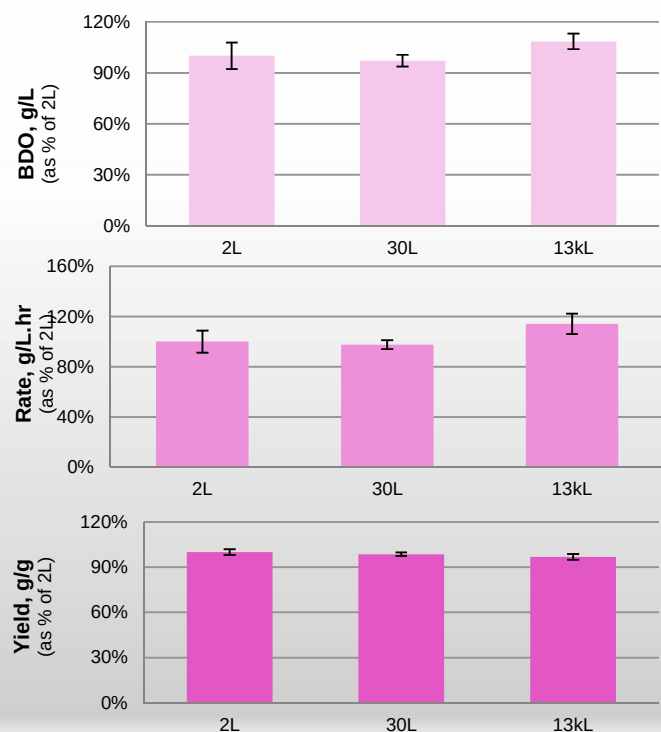


- Full capability process lab
  - 50 bioreactors
  - Wide range of unit ops for separations and purification
  - 30L piloting suite to generate kg samples
  - Integrated LIMS
- Reliable 100,000-fold scaling
- Quantitative small-scale fermentation design

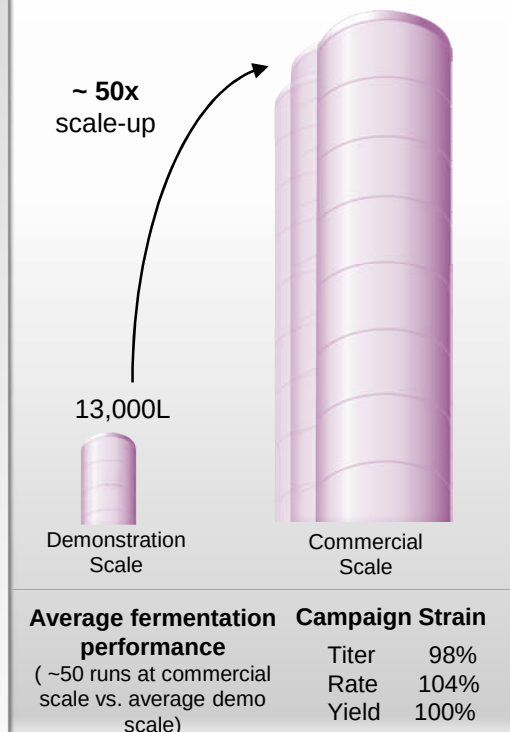
# Example: scalable bioprocessing

highly predictable scale-up/down

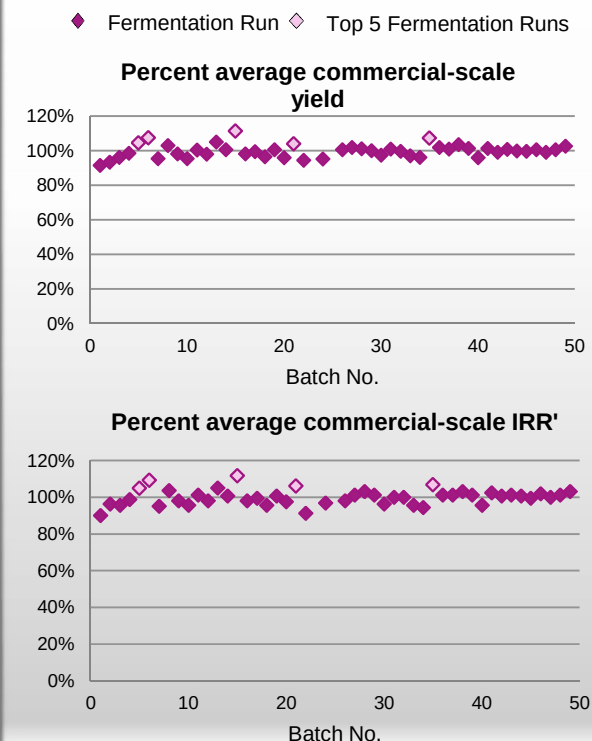
## Consistent performance across development scales



## Consistent scale-up to commercial



## Robust performance at commercial-scale



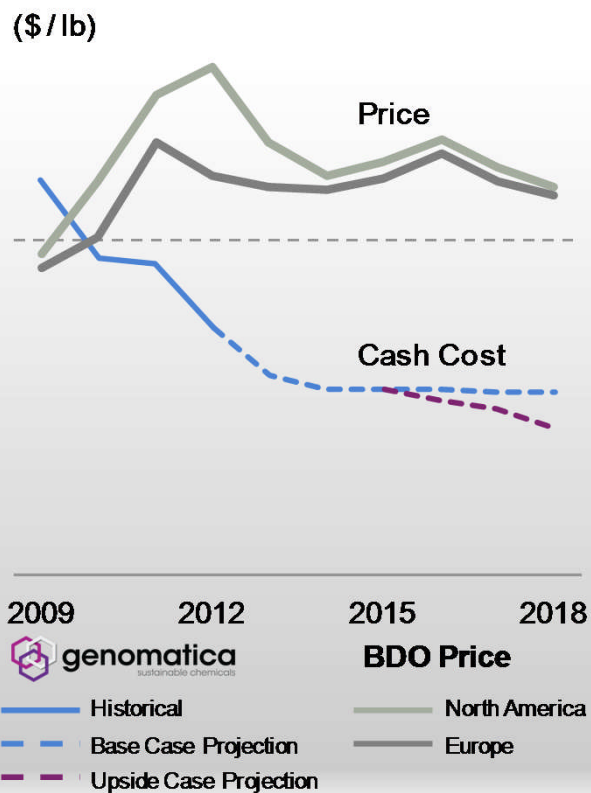
- Fermentation performance across lab, pilot, and demo scales is highly consistent, enabling rapid lab-to-commercial scale development path
- Average commercial-scale performance over ~50 campaign fermentations equivalent to demonstration-scale performance for same strain (+/-2%)
- Low variability in performance across ~50 campaign fermentations, indicates process robustness and predictability



# The end result: GENO BDO™ process

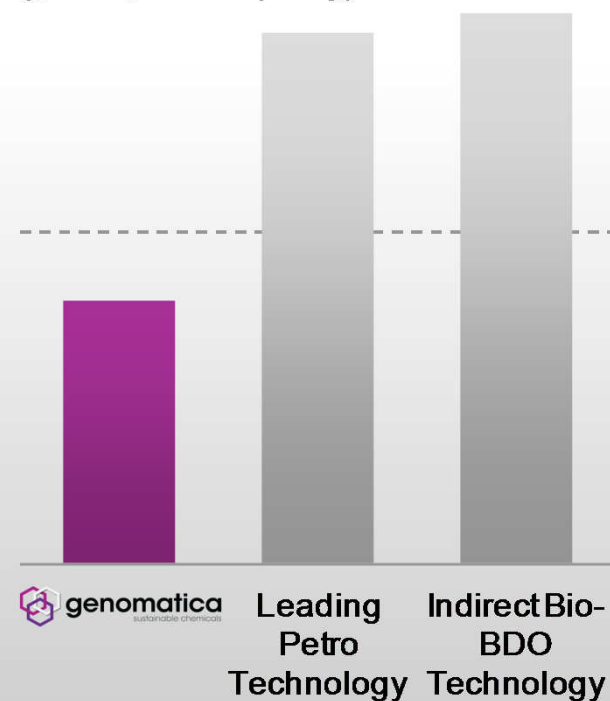
cost competitive; capital efficient; enhanced sustainability attributes

## Cost Competitive Today Robust Improvement Path



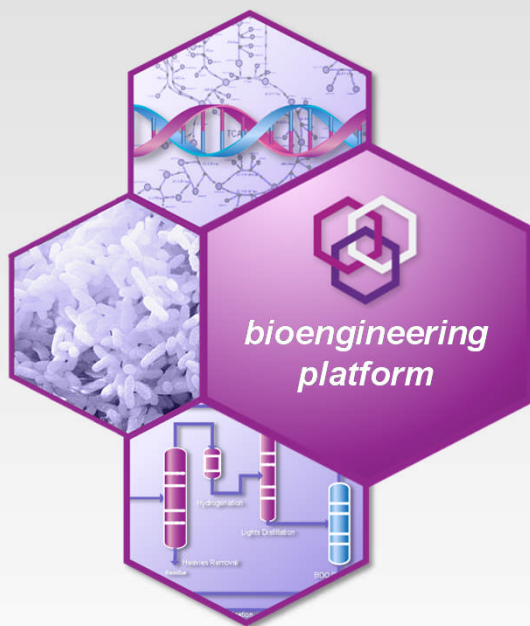
## Lower Capital per Ton

(\$/Ton, 50KT Capacity)

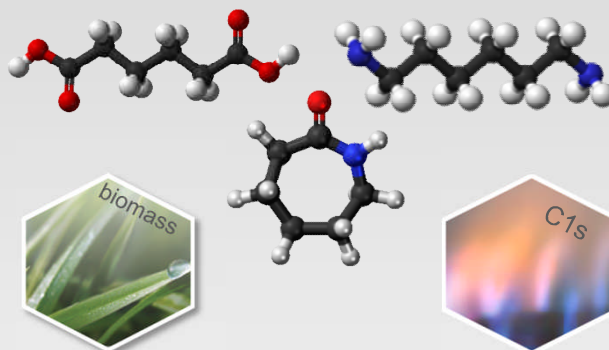


# Continuous stream of innovations

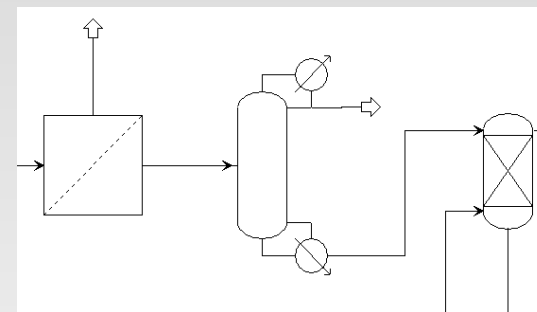
solving new problems, reducing costs, faster time to market



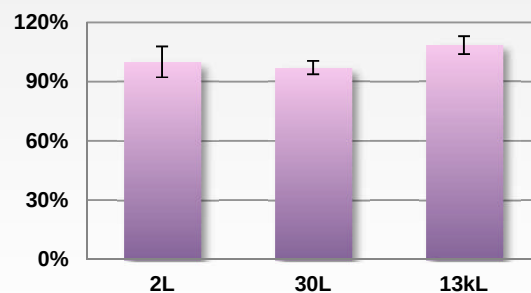
## Novel Pathways & Feedstocks



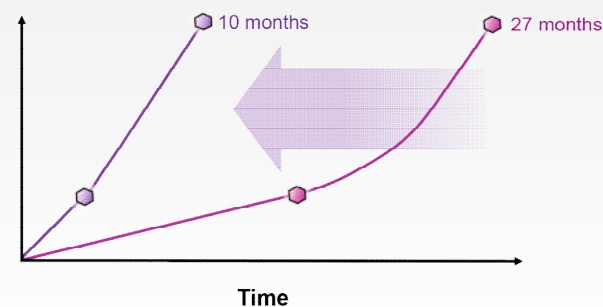
## Downstream Purification



## Reliable scale-up



## Faster Development

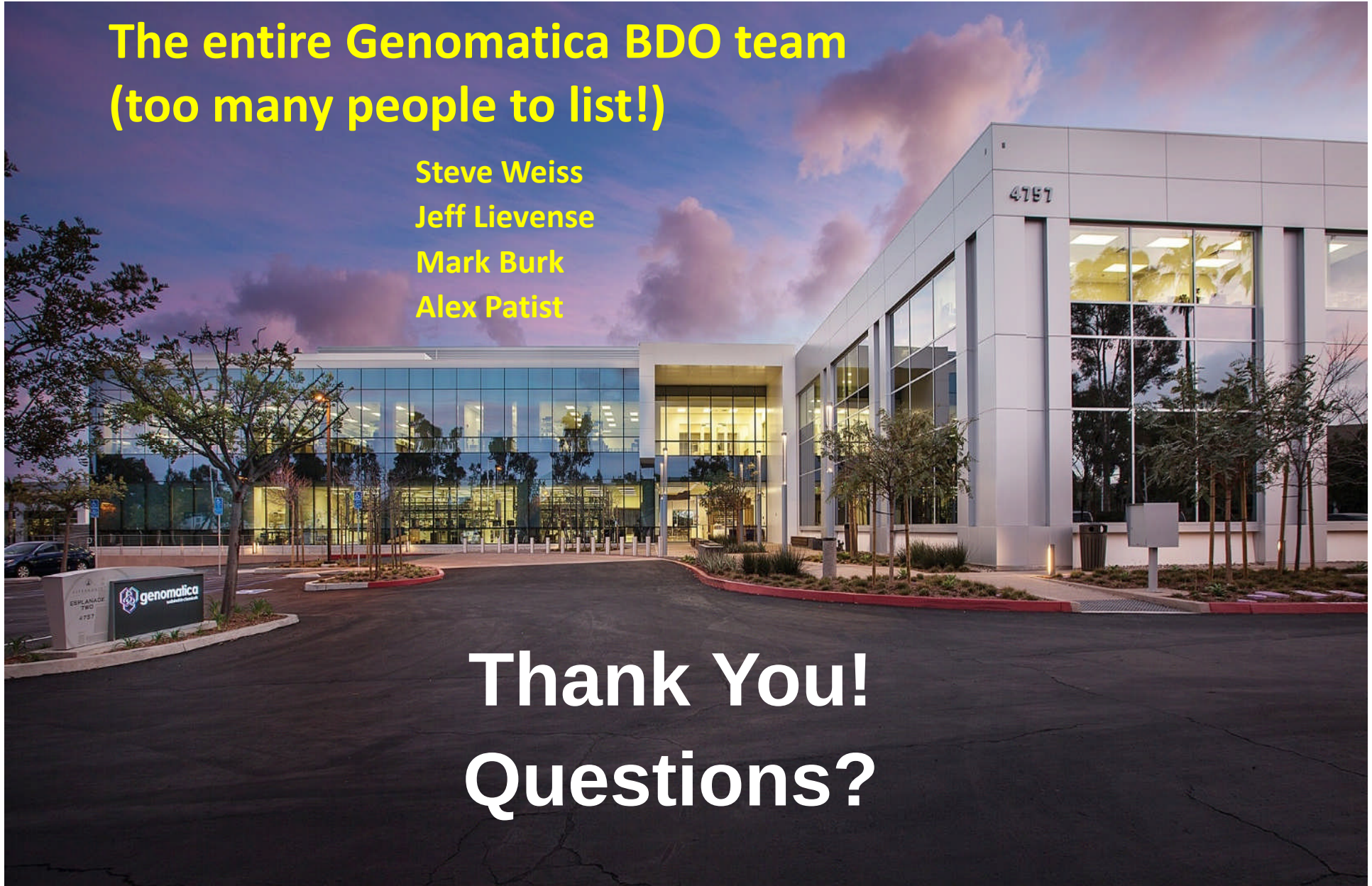


# Acknowledgments

**The entire Genomatica BDO team  
(too many people to list!)**

**Steve Weiss  
Jeff Lievens  
Mark Burk  
Alex Patist**

**Thank You!  
Questions?**







## our core purpose

Lead the irresistible transition to sustainable materials through our technology and, united with industry leaders, make our world a better place.

## our core values

### we are real

Results count. Commitments count. Integrity and honesty are absolutes.

### we are innovative

We invent, experiment and create—across our entire business. We seek out and embrace differences, to help us think differently.

### we are united

We work better together. Shared mission. Shared accountability. Shared learning. Shared success.

### we are relentless

We don't give up. We strive for excellence. Our passion flows from our shared vision.

