Genomatica

- Sustainable chemicals
- Better economics
- Smaller footprint

Pacific Rim
Summit on Industrial
Biotechnology & Bioenergy
October 10-12, 2012

Nelson Barton, VP R&D

A Process for the Production of Bio-based 1,4-Butanediol (BDO)

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Genomatica at a Glance

The Company

Private company

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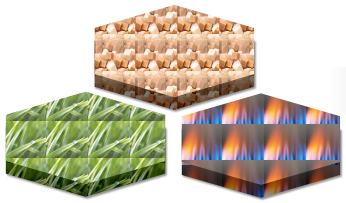
San Diego (USA)
105 people

Bio-Based Chemicals

Basic/intermediate chemicals
Technology provider



Top Financial Investors

Raised $125 MM to date

TPG

VANTAGE POINT CAPITAL PARTNERS

DRAPER FISHER JURVETSON

ALLOY VENTURES

MDV
MOHR DAVIDOW VENTURES

RUSNANO COM

Partnering with Industry

Global commercialization
feedstocks, scale-up, applications

MITSUBISHI CHEMICAL

TATE & LYLE

WM
WASTE MANAGEMENT

Novamont

M&G

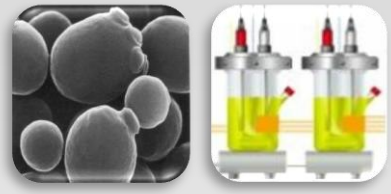
Genomatica: Focused on Bio-based Chemicals

Low-Cost Renewable Feedstock

TATE & LYLE

MG

WM WASTE MANAGEMENT



High Performance Organisms

High titer, Tolerance

High yield

High productivity

Basic & Intermediate Chemicals

Existing products sold globally

- **Exact same chemicals**
- **Better economics**
- **Equivalent performance**
- Reduced energy
- Lower carbon footprint
- Feedstock diversification

Direct production of chemicals likely to afford lowest cost process

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Bio-based 1,4-Butanediol

Crude Oil
& Nat. Gas

Acetylene

Propylene

Butane, Butadiene

Sugars

Direct Production

3 B lb/yr existing market

spandex

polyurethans

PBT

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Advantages of Identical Drop-in Bio-BDO

Fermentation

Existing Infrastructure

Direct Replacement

Bio-BDO Applications

PBT Pellets from Bio-BDO

- Downstream infrastructure in place
- Can blend with existing BDO
- Faster adoption
- Meet customer needs for renewable products

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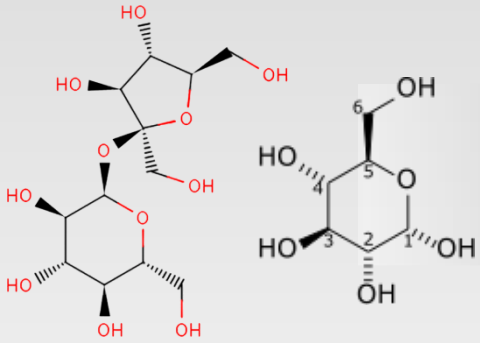
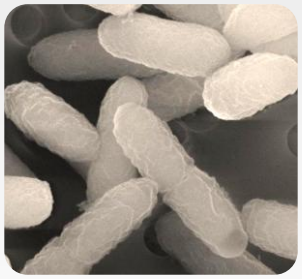
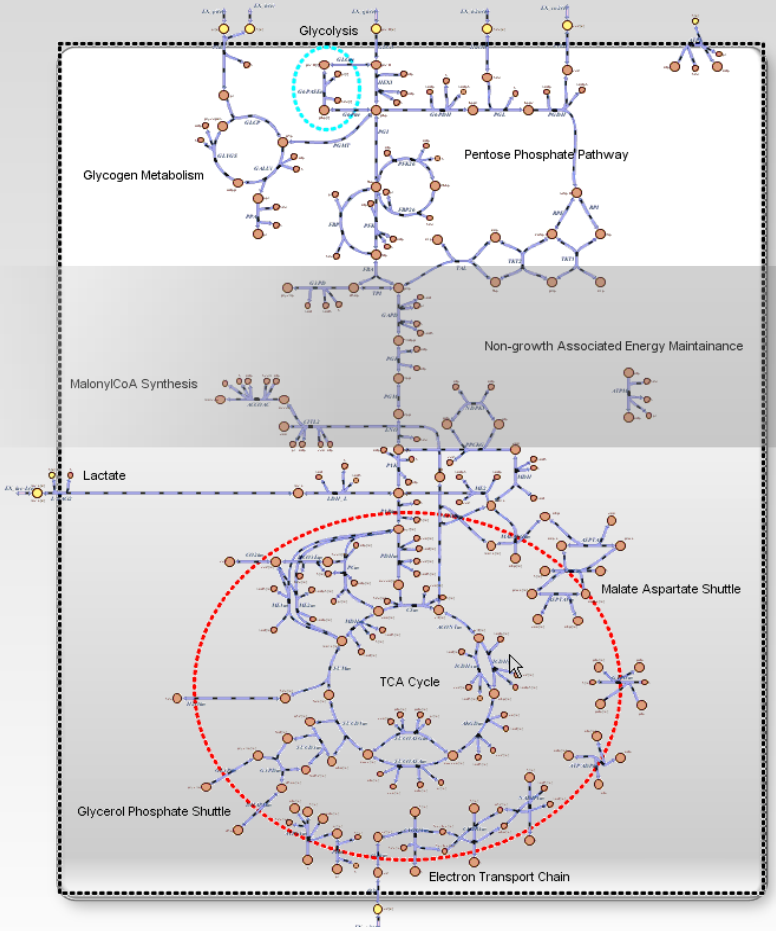
Genomatica's BDO Process in Engineered *E.coli*

Sugars

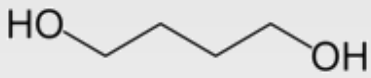




BDO-producing *E. coli*



1,4-Butanediol (Bio-BDO)



100% bio-based content

Tate & Lyle facility

Strain, fermentation, process engineering → deliver BEP

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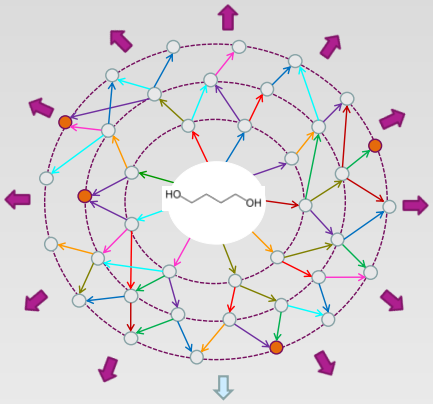
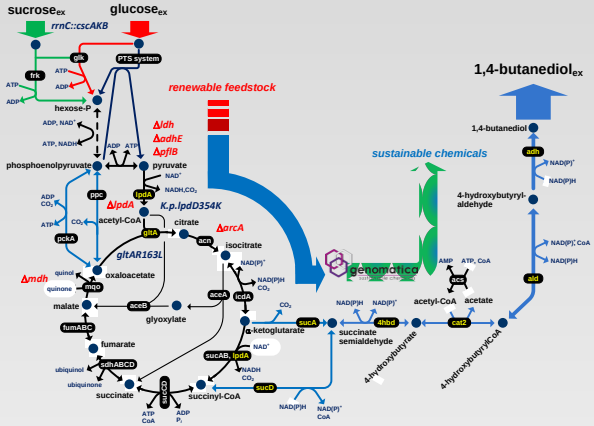
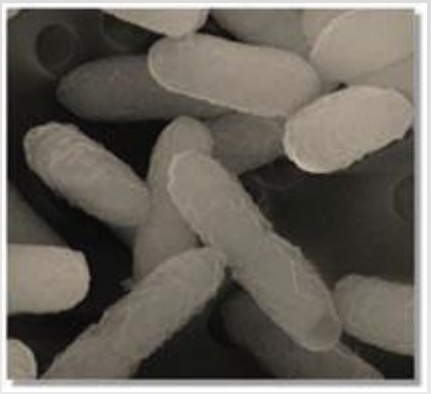
Journey to a BDO Production Strain



Pathway Identification and Engineering



Strain Design and Metabolic Engineering



Commercial Strain for BDO Production

Fermentation Metrics → Higher TRY = Lower COGS

- **Titer (g/L) -** Impacts equipment sizing and energy needs
- **Rate (g/L/h) -** Impacts # of fermentors, plant capacity
- **Yield (g/g) -** feedstock cost, by-product cost in DSP

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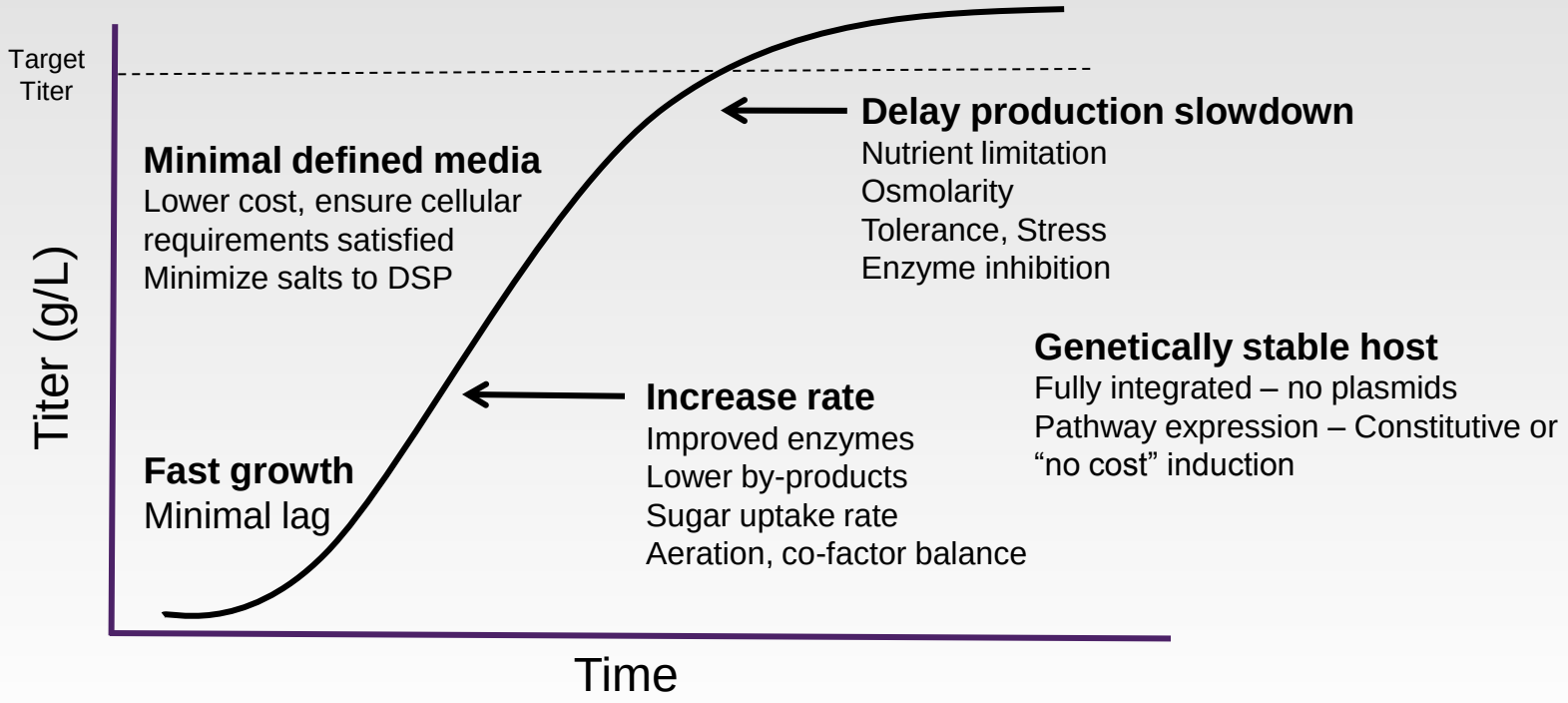
Commercial Strain Engineering Challenges

- Major Challenge – High Titer, Rate, Yield – “It is all about the Bug”
- Define commercial TRY targets needed to achieve desired economics



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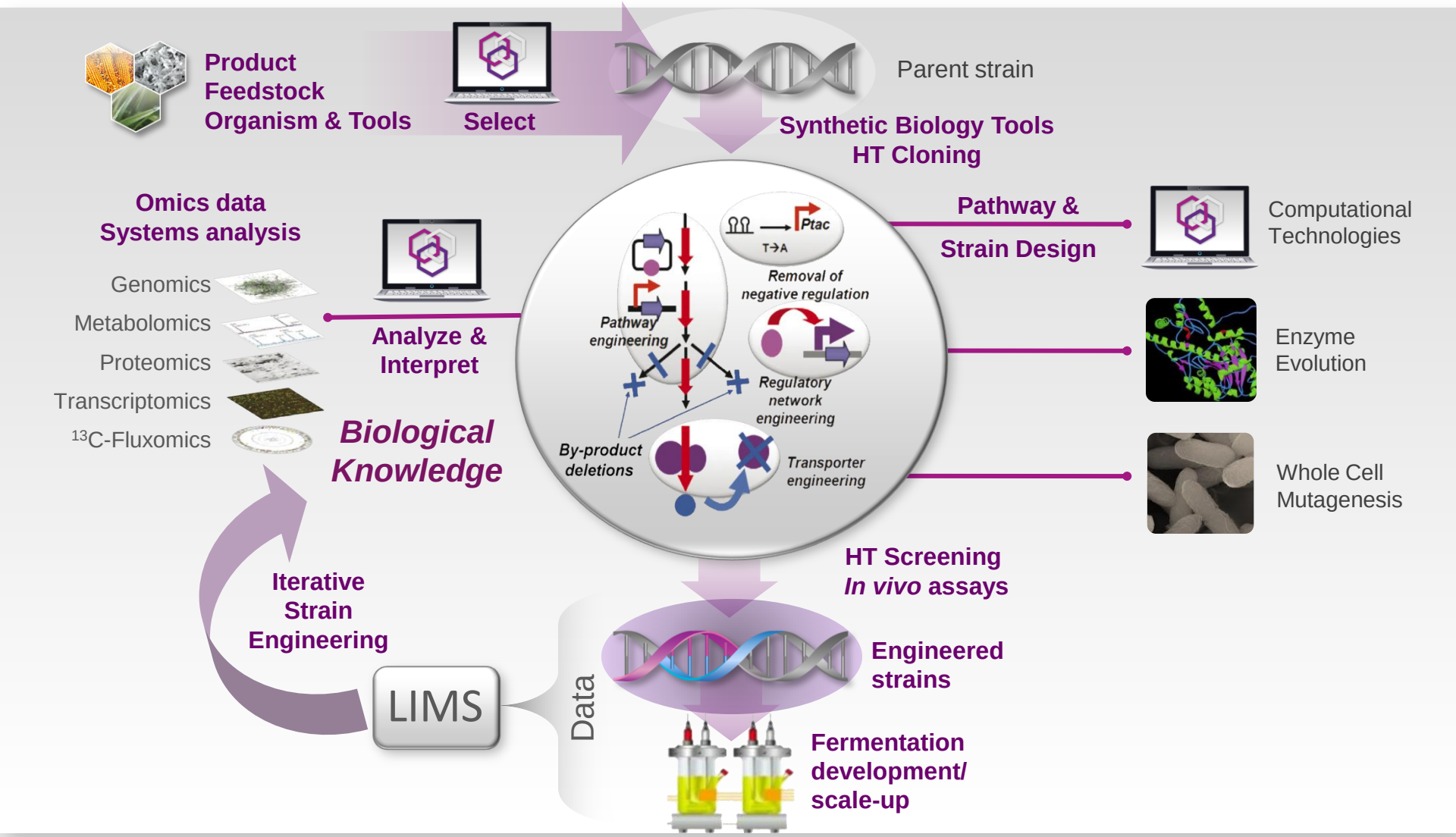
Genomatica's Systems-Based Strain Engineering



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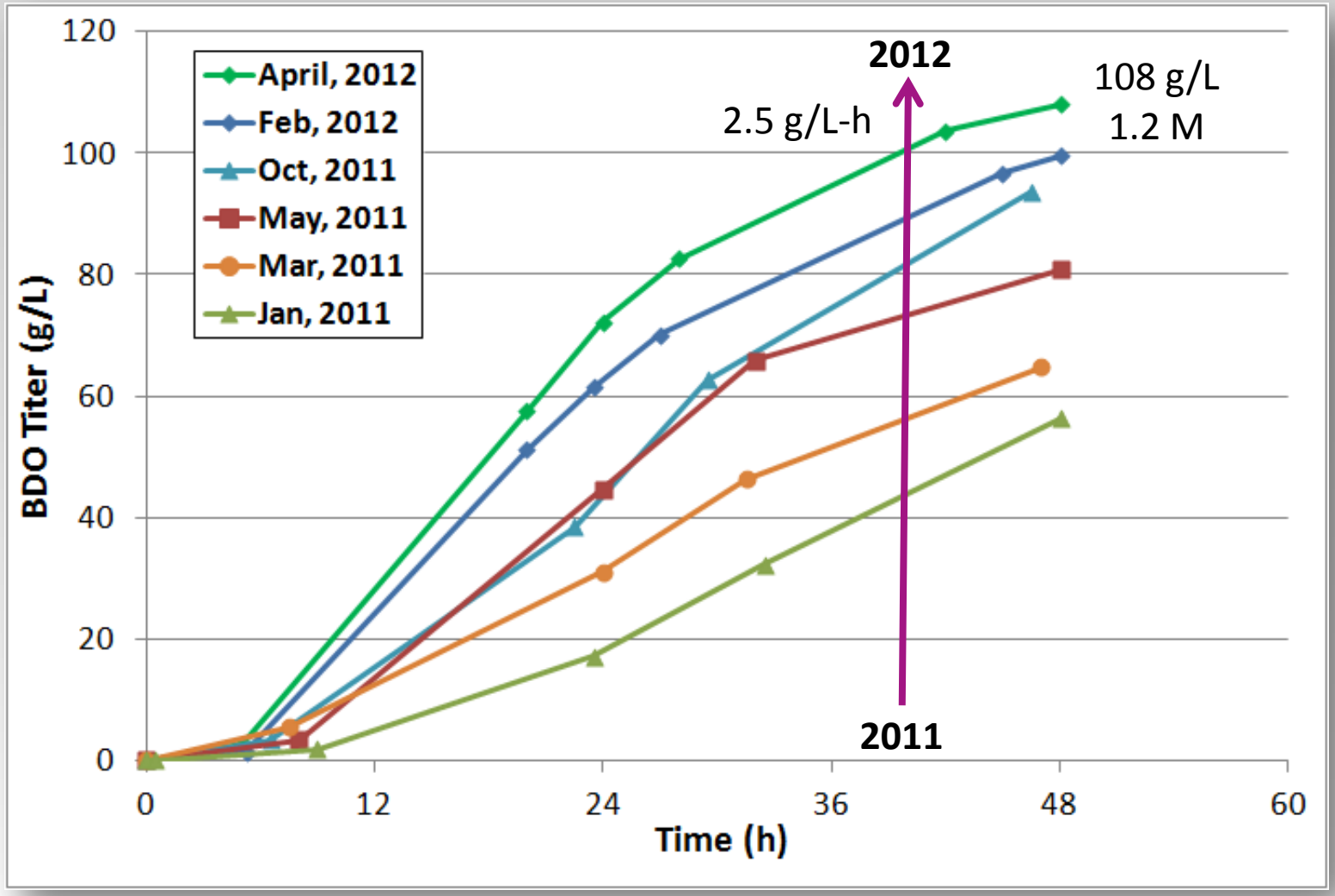
BDO Strain Engineering Progress



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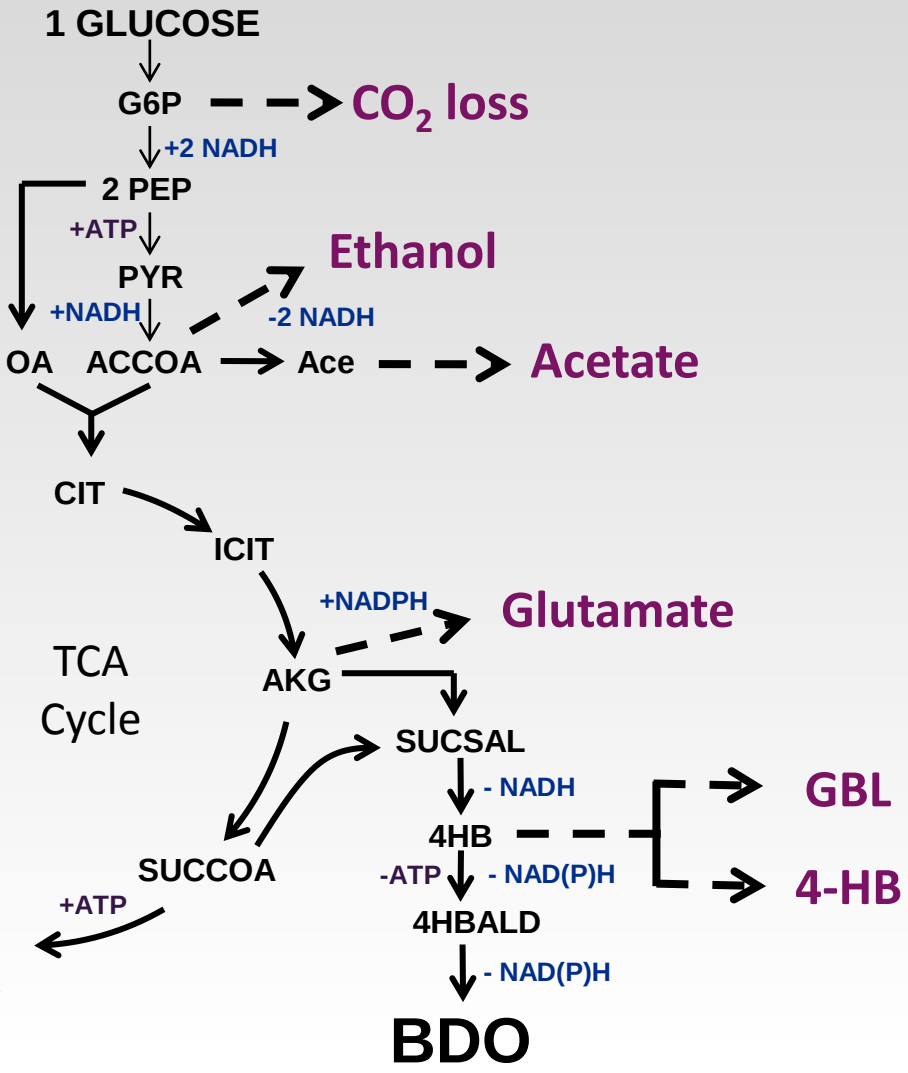
Increasing Rate and Lowering By-products

Key Advances
- Eliminate backflux
- Improved enzymes
- Redox supply
- ATP supply
- Regulation
- Balanced expression
- Fermentation PD



More metabolic steps in a pathway increases avenues for by-products

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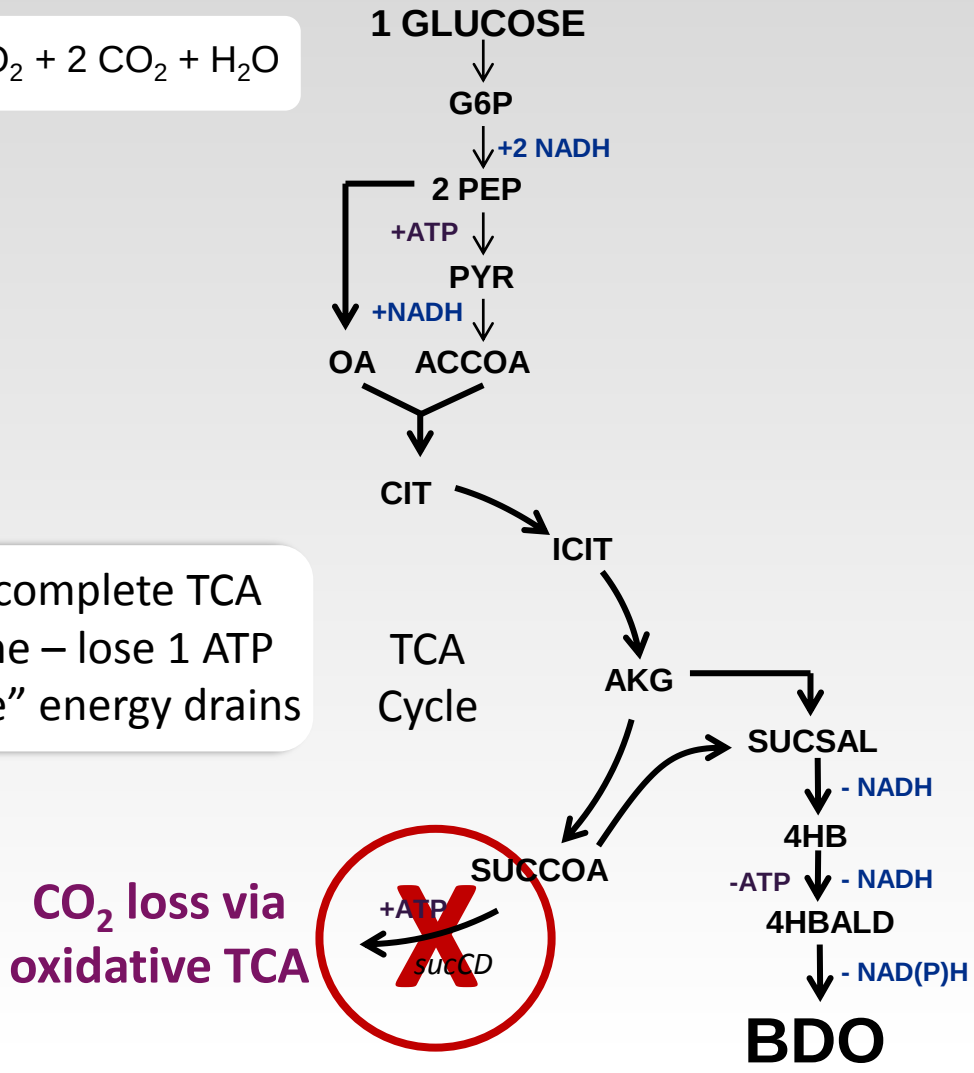
Lowering By-Products: Excess CO_2

$C_6H_{12}O_6 + 0.5\ O_2 \rightarrow C_4H_{10}O_2 + 2\ CO_2 + H_2O$

- Excess CO_2 from complete TCA
- Delete *sucCD* gene – lose 1 ATP
- Eliminated "futile" energy drains



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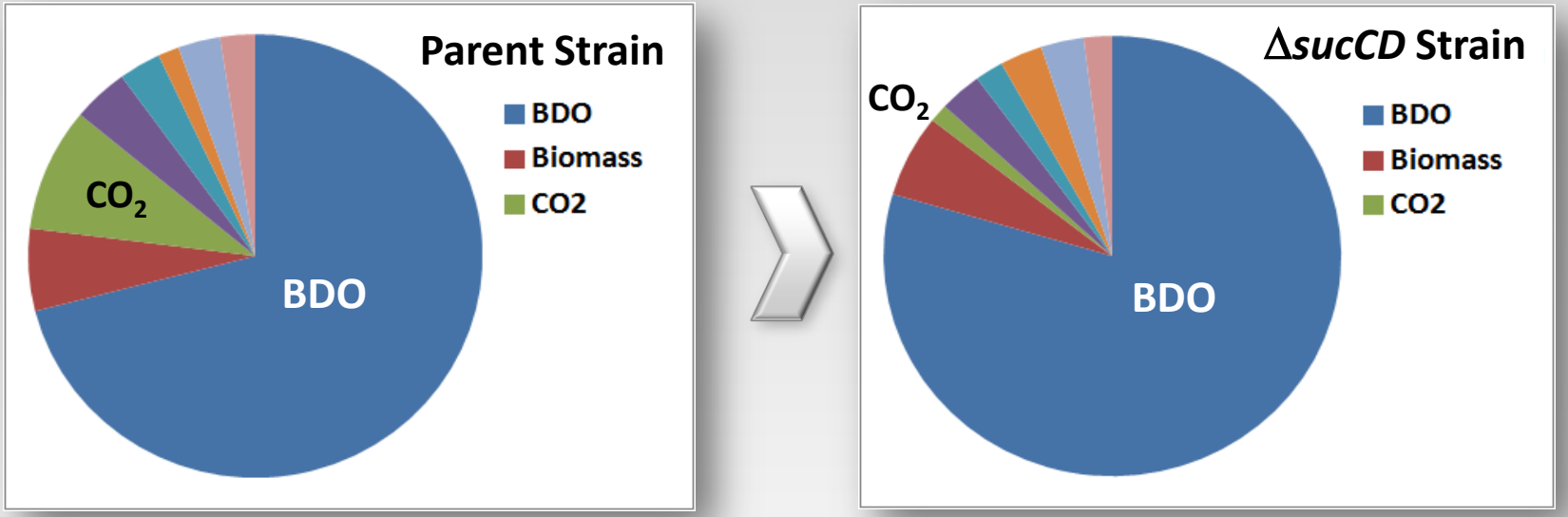
Lowering Excess CO_2 via *sucCD* Deletion



Δ*sucCD* Strain: higher BDO, much lower CO_2

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BDO Scale-up and Commercialization

Joint Development Partnership with Tate & Lyle

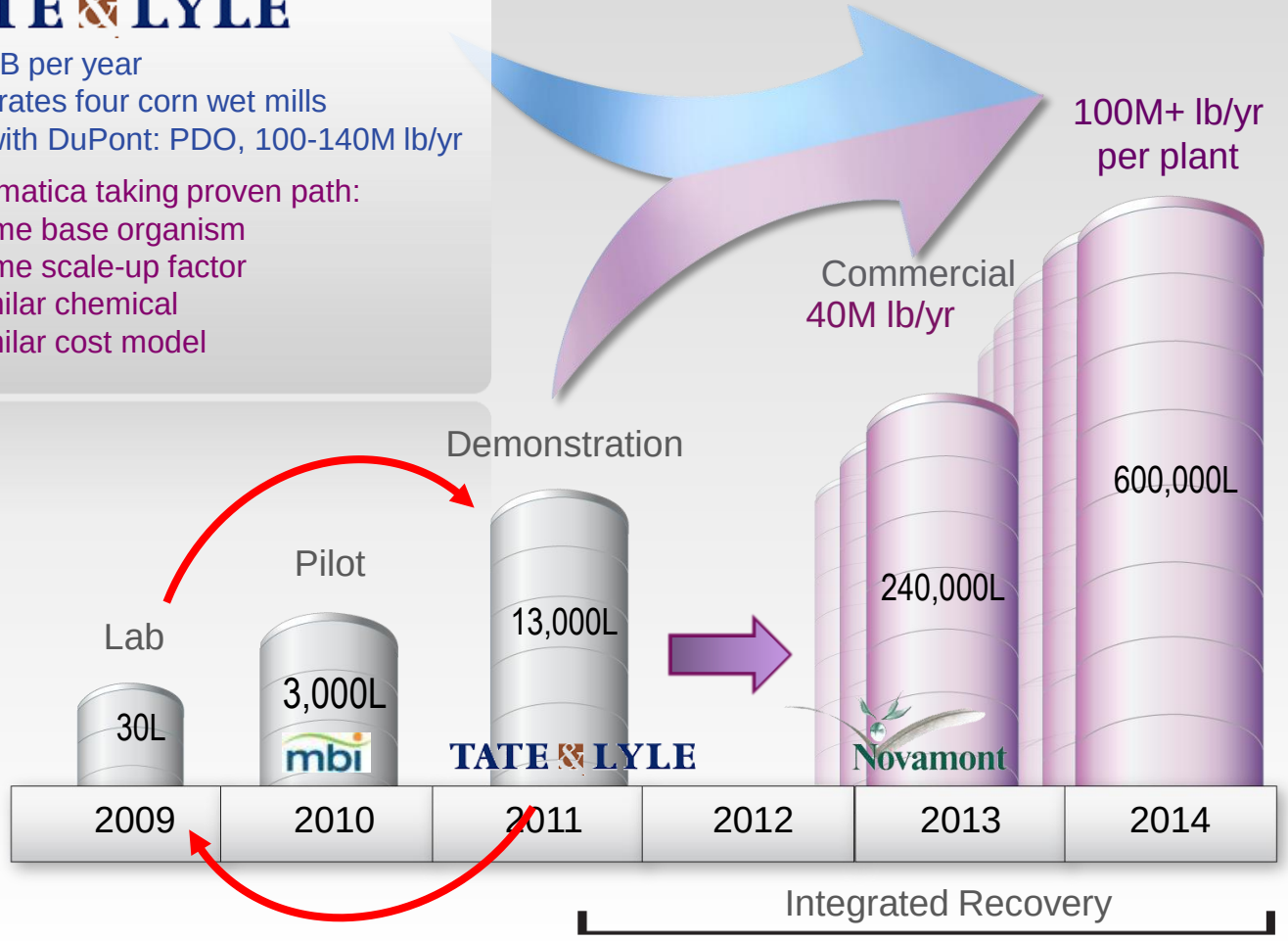
TATE & LYLE

- $4.3B per year
- Operates four corn wet mills
- JV with DuPont: PDO, 100-140M lb/yr

Genomatica taking proven path:

- ✓ Same base organism
- ✓ Same scale-up factor
- ✓ Similar chemical
- ✓ Similar cost model

13,000 L fermentor
in Decatur demo plant



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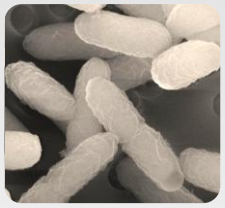
Complete Process Technology for Bio-BDO



Fermentation

recycle streams (water)

Cell Separation

Salt Separation

Water Evaporation

BDO Purification

High Purity Bio-BDO

Completely Compatible

- ✓ >99.9% pure
- ✓ No color (< 10 APHA)
- ✓ Water < 100 ppm
- ✓ GBL = <1 ppm
- ✓ Sulfur < 1 ppm

Successful customer conversions

- No reformulation
- Can blend with existing BDO

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Shipping tons at a time…

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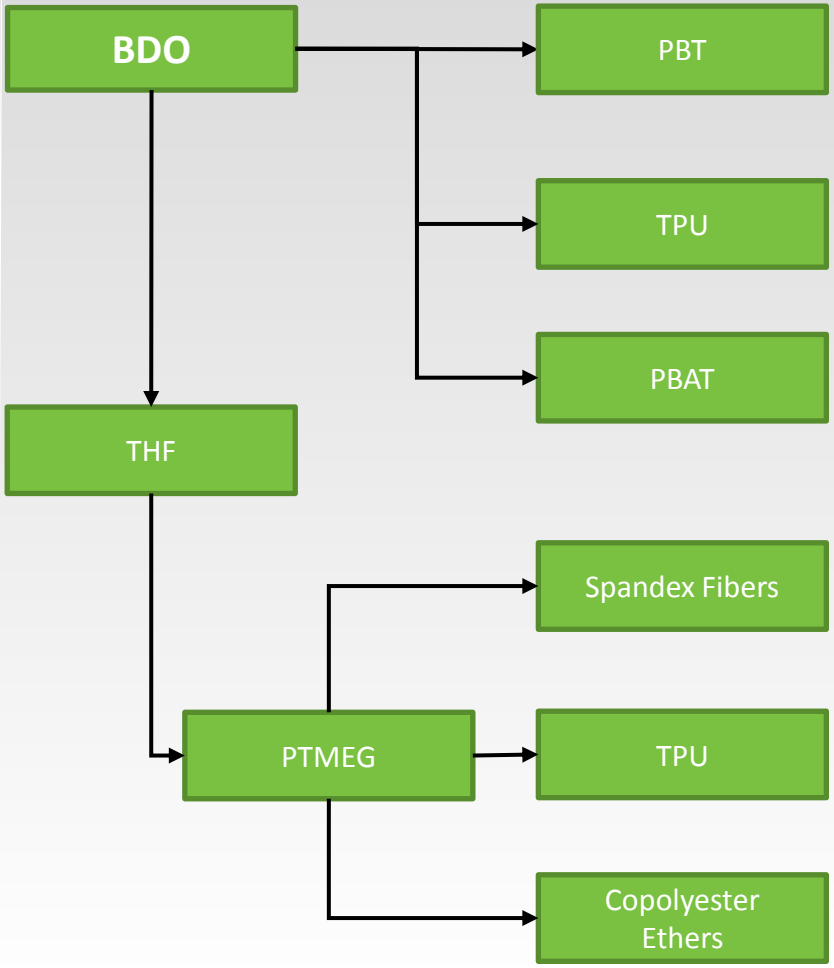
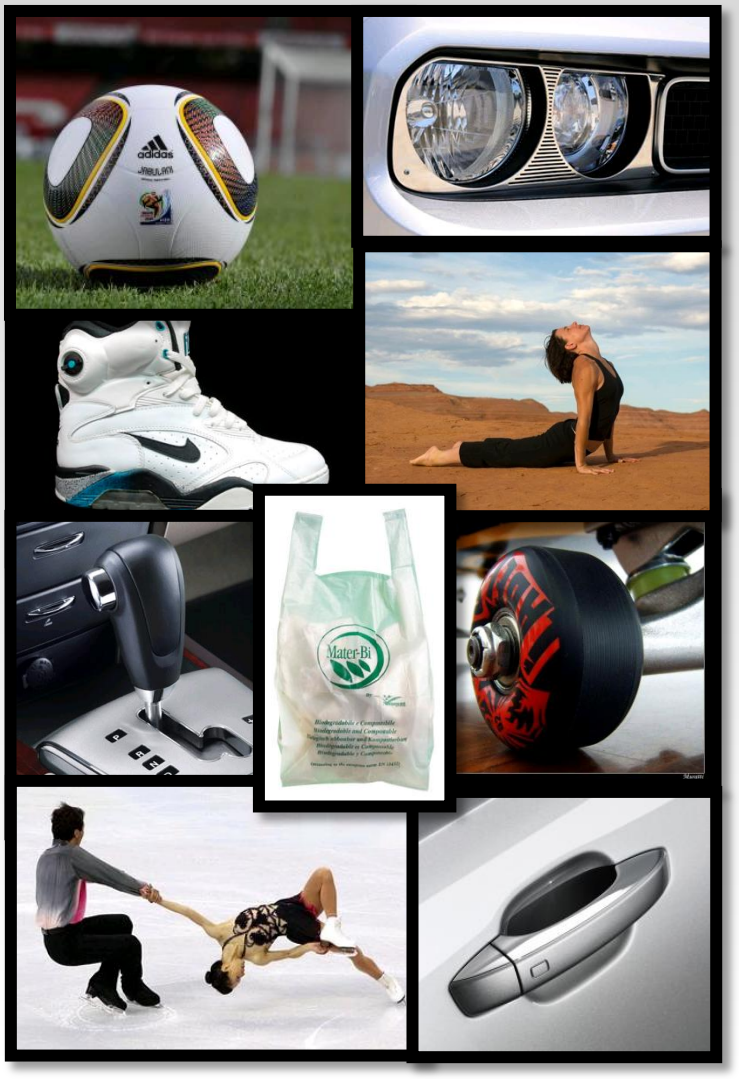
BDO Applications





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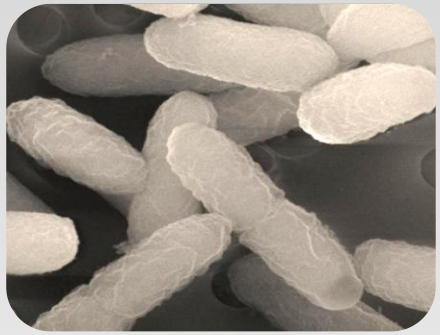
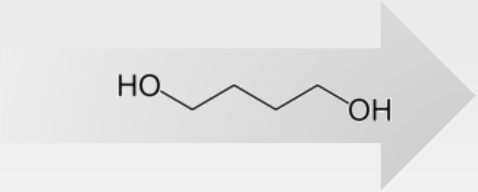
Bio-BDO® Becoming a Commercial Reality



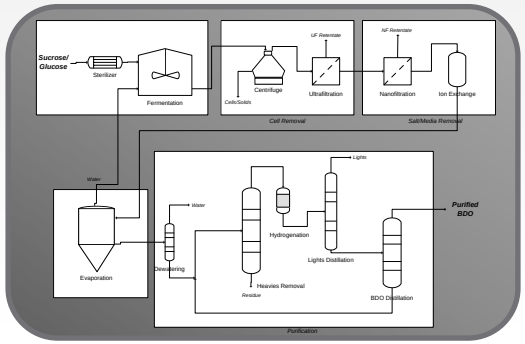
PBT from Bio-BDO

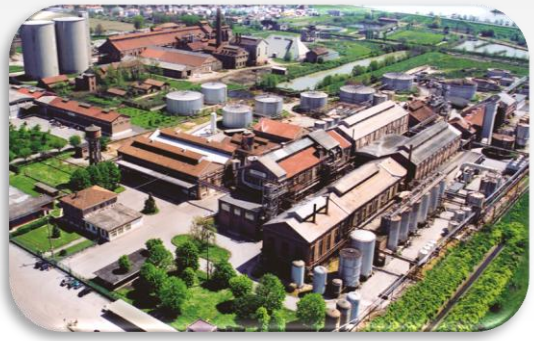
High quality Bio-BDO converted into all downstream derivatives by partners

2008
first production of 1,4-BDO from carbohydrates



2013
commercial scale production (40M lbs/yr)





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Novamont: BDO in Europe

- Joint venture for commercial-scale production of BDO
- Novamont financing 100% of construction costs (~$50M)
- Begin production 2013
- 40 million pounds per year
- Committed to purchase 100% of production for captive use
- Option for second plant

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Biomass-to-Chemicals

Dedicated feedstock

Bio-based Chemicals

Biomass sugars offer:
Lower price volatility
Lower cost potential
No food vs chemicals

Biomass-to-BDO
$5 M DOE Grant

M&G BETA RENEWABLES

Currently producing BDO in *E. coli* from PROESA biomass sugars at ~85% of performance vs dextrose

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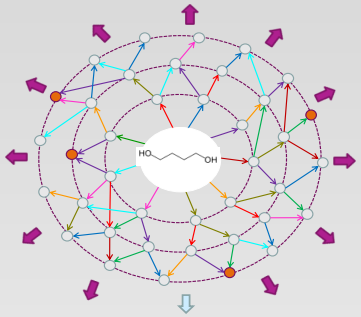
Development of a Robust BDO Production Strain



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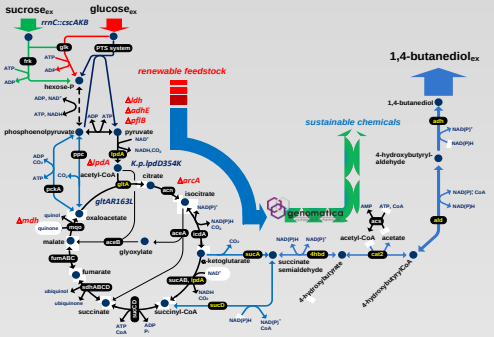

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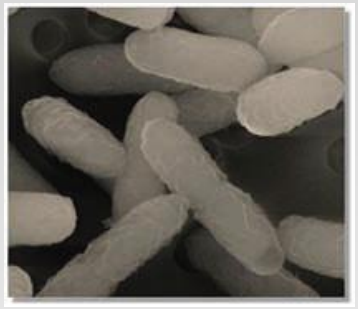
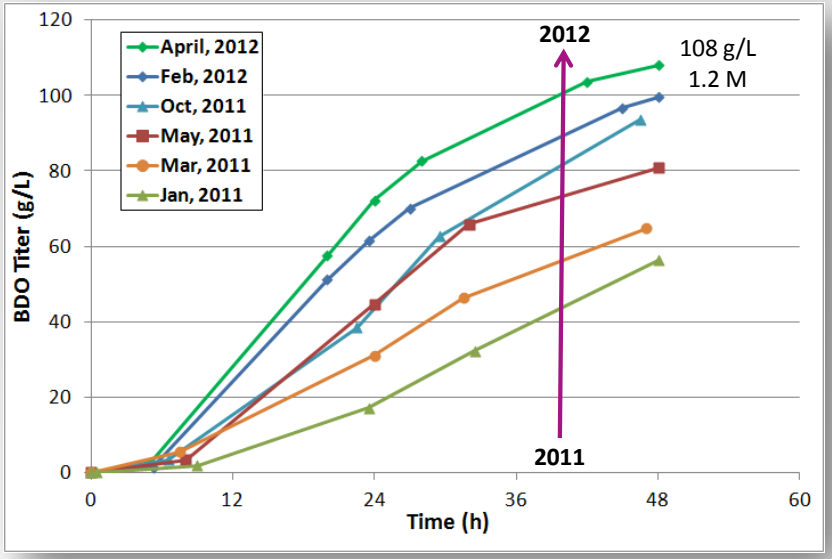


Commercial Strain for BDO Production



- ✓ Systems-based approach
- ✓ Over 35 genetic manipulations
- ✓ BDO from dextrose, sucrose, biomass
- ✓ Achieved commercial TRY targets
- ✓ Process scale-up to 13,000 L (1 ton/wk)

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Genomatica BDO Team - Past and Present

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Eric Van Name
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Joseph Woodcock
Don Miller
Gian Oddone
Amruta Bedekar
Rebecca Bratcher
Jason Crater
Akhila Raya
Alex Navarro

SAB
Bernhard Palsson
Sang Yup Lee
Jens Nielsen
George Church
Lee Hood
Harvey Blanch
Bernhard Hauer

Christophe Schilling, CEO Bill Baum, CBO
Mark Burk, CTO Jeff Lievense, EVP, Process Development

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Questions?

Thank you

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