Novozymes perspectives on B2E

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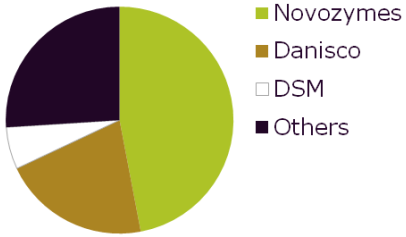
Novozymes Inc.

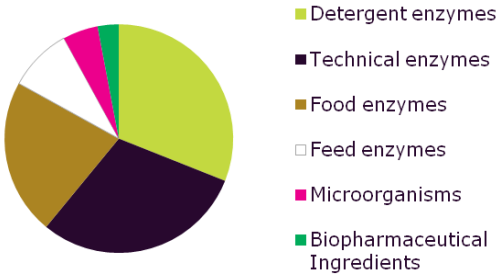
Novozymes in brief

- World leader in industrial enzymes & microorganisms and market leader in all industries where present
- Products sold in 130 countries in 40 different industries
- Total sales of USD 1.5bn in 2008
- 13–14% of revenue invested in R&D
- New products represented around 25% of total sales in 2008
- 43 new products launched during the last 5 years

Enzymes for industrial use
Market size ~ USD 2.9 billion



Distribution of Novozymes' business
Revenue 2008 ~ USD 1.5 billion



Source: Novozymes' 2008 estimates

Our commitment to the Ethanol Industry begins with our global efforts and focus

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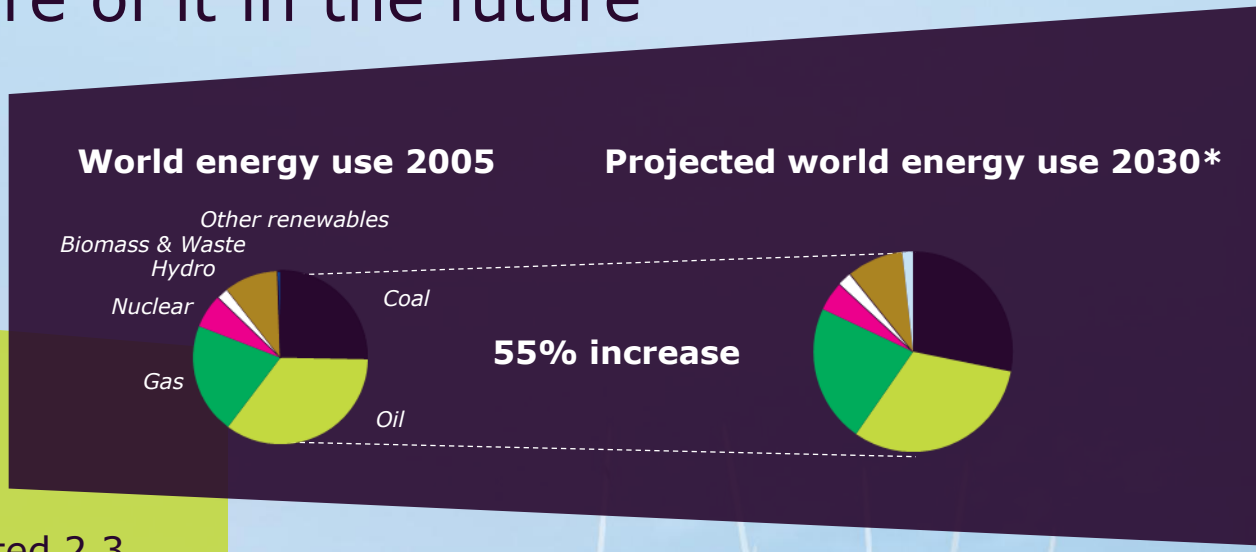
Rethink Tomorrow

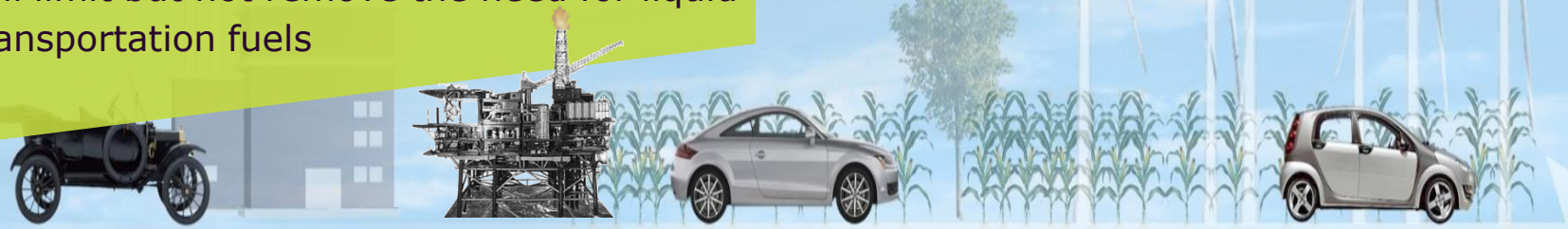
- Leading enzyme provider for starch-based ethanol enzymes in all regions where we operate
- Broad insight into cellulosic ethanol work – we are working on various feedstocks and technologies with different partners
    - Corn stover/cobs, wood, energy crops in US, wheat straw in Europe, bagasse in Brazil, corn stover in China
- 271 patents granted and 188 patent families submitted for biofuels to date – and growing
- Approx 30 first filings in cellulosic conversion – half of which are process related

More than 150 employees dedicated to biofuels

The world needs energy not least for transport – and will need more of it in the future



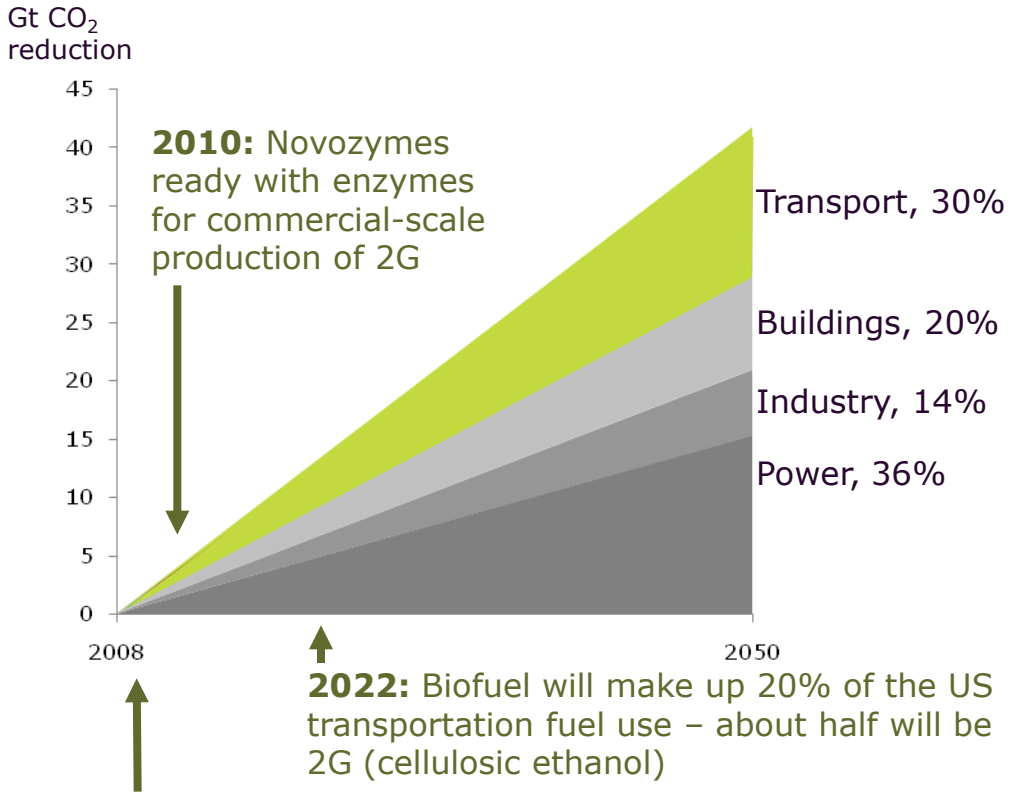
- Transport is the second largest energy user and by far the largest oil user
- By 2050 there will be an estimated 2.3 billion additional cars worldwide – 1.9 billion of these in developing countries
- Improved mileage and alternative vehicles will limit but not remove the need for liquid transportation fuels



* *Reference scenario, World Energy Outlook 2007*

Sources: International Energy Agency, Energy Information Agency, International Monetary Fund

To stabilize climate change a 42 Gt reduction in CO2 emissions is needed compared to 2005



Total reduction = 42 Gt
Emission peak in 2012 at 30 Gt

Novozymes solutions can aid GHG reductions in many different sectors of the energy industry as well as other industries

Source: International Energy Agency, OECD, Argonne National Laboratory, US Energy Security and Independence Act,

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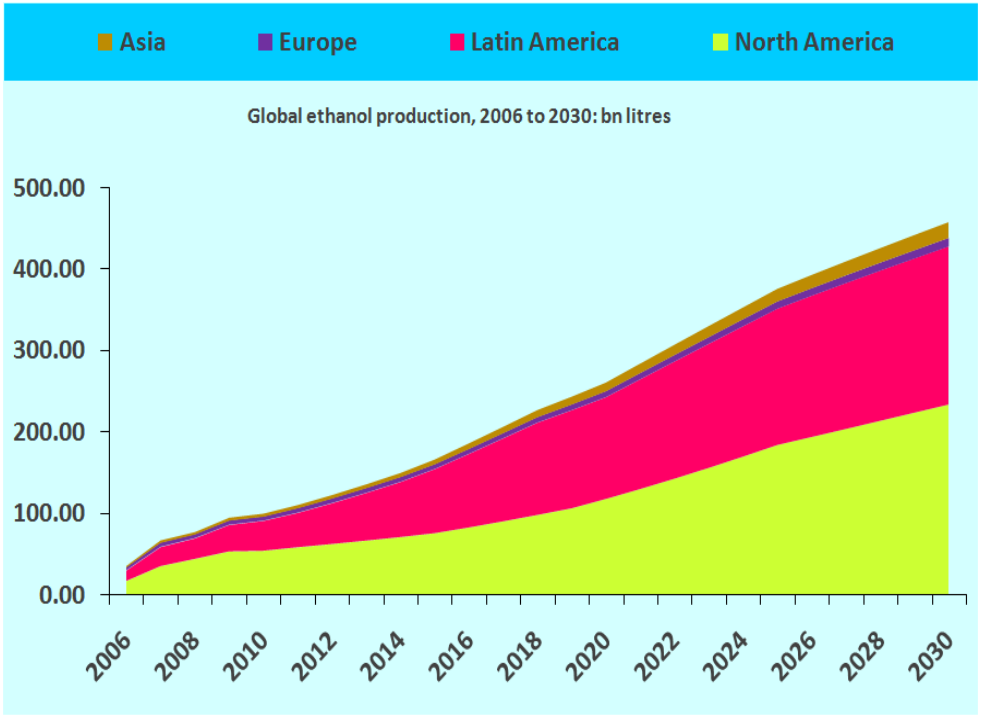
Global ethanol production is set to grow 12-fold between 2006 and 2030

The US and Brazil are the biggest contributors to production and growth

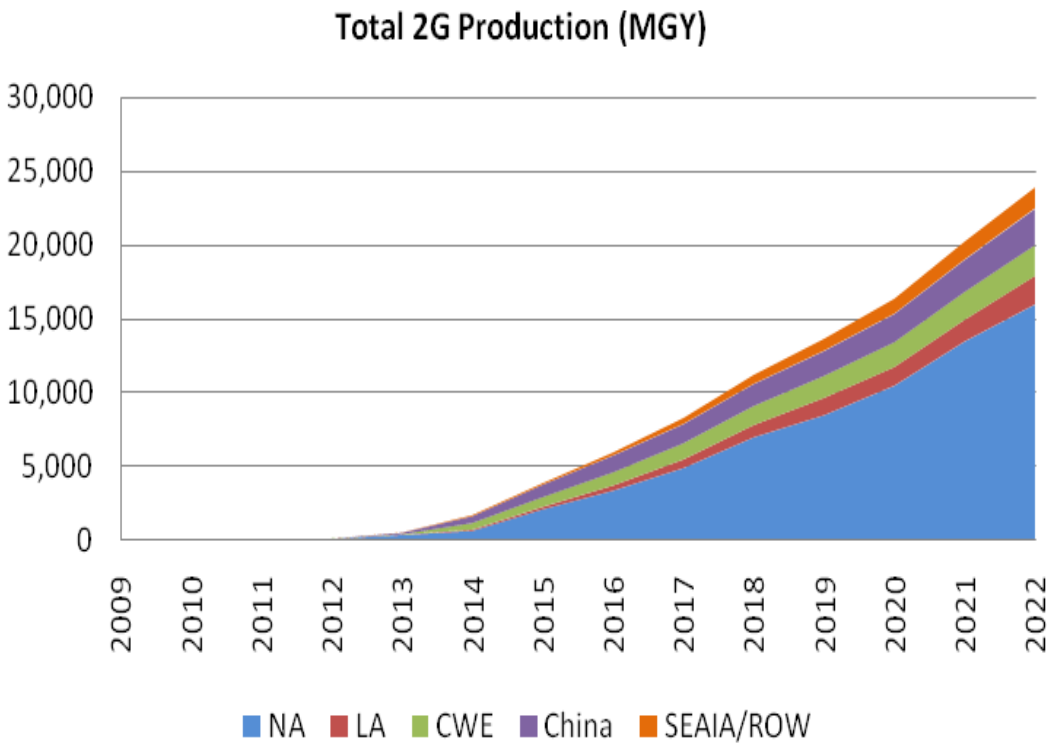


Notes:
1) Total production = production installed capacity;
2) North America: North America excl. Mexico;
3) Europe: EU excludes Eastern Europe.

Sources: Unica, US DOE, New Energy Finance

Where a sizeable part of this growth is expected to come from cellulosic ethanol

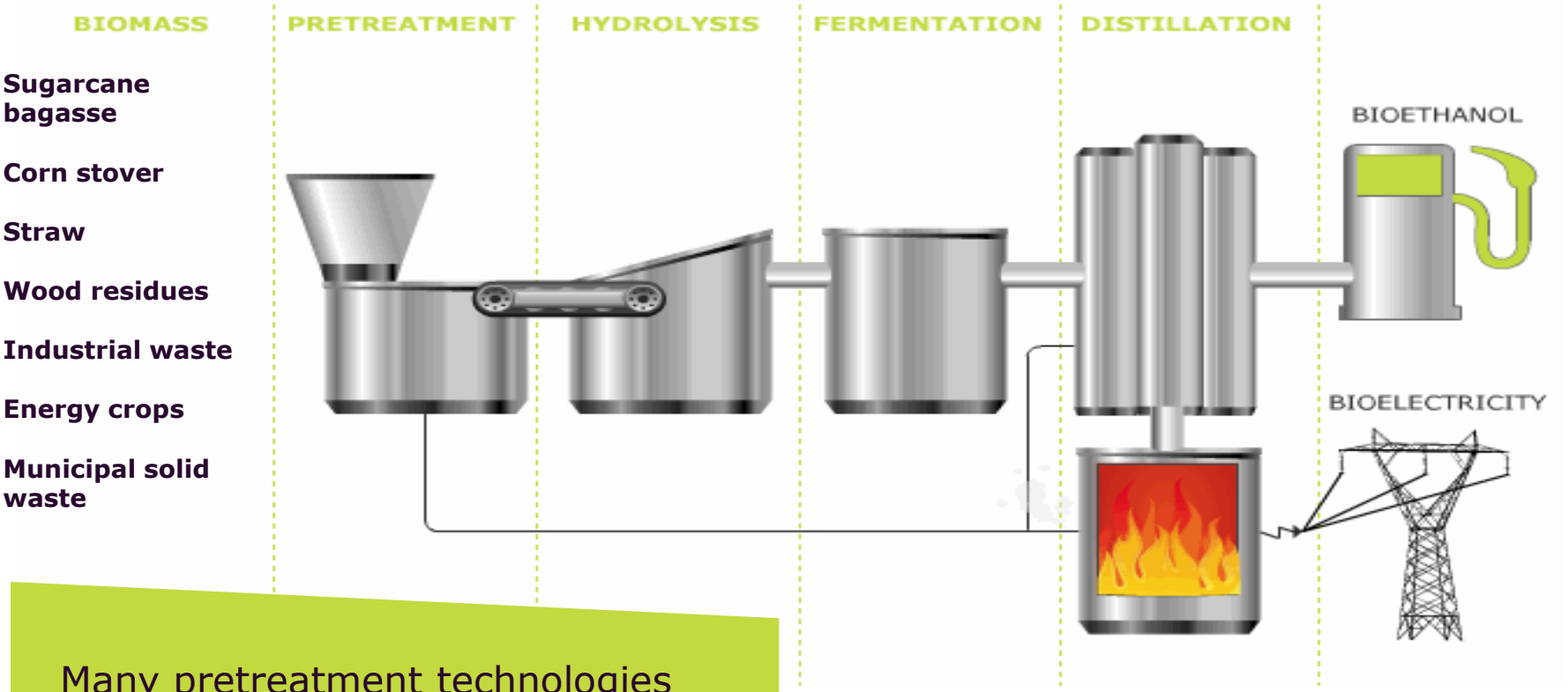
The US represents on average >50% of total 2G production



Notes:
1) Figures based on May 2009 MTP revisions

Sources: Internal NZ estimates

Enzymatic route from biomass to ethanol



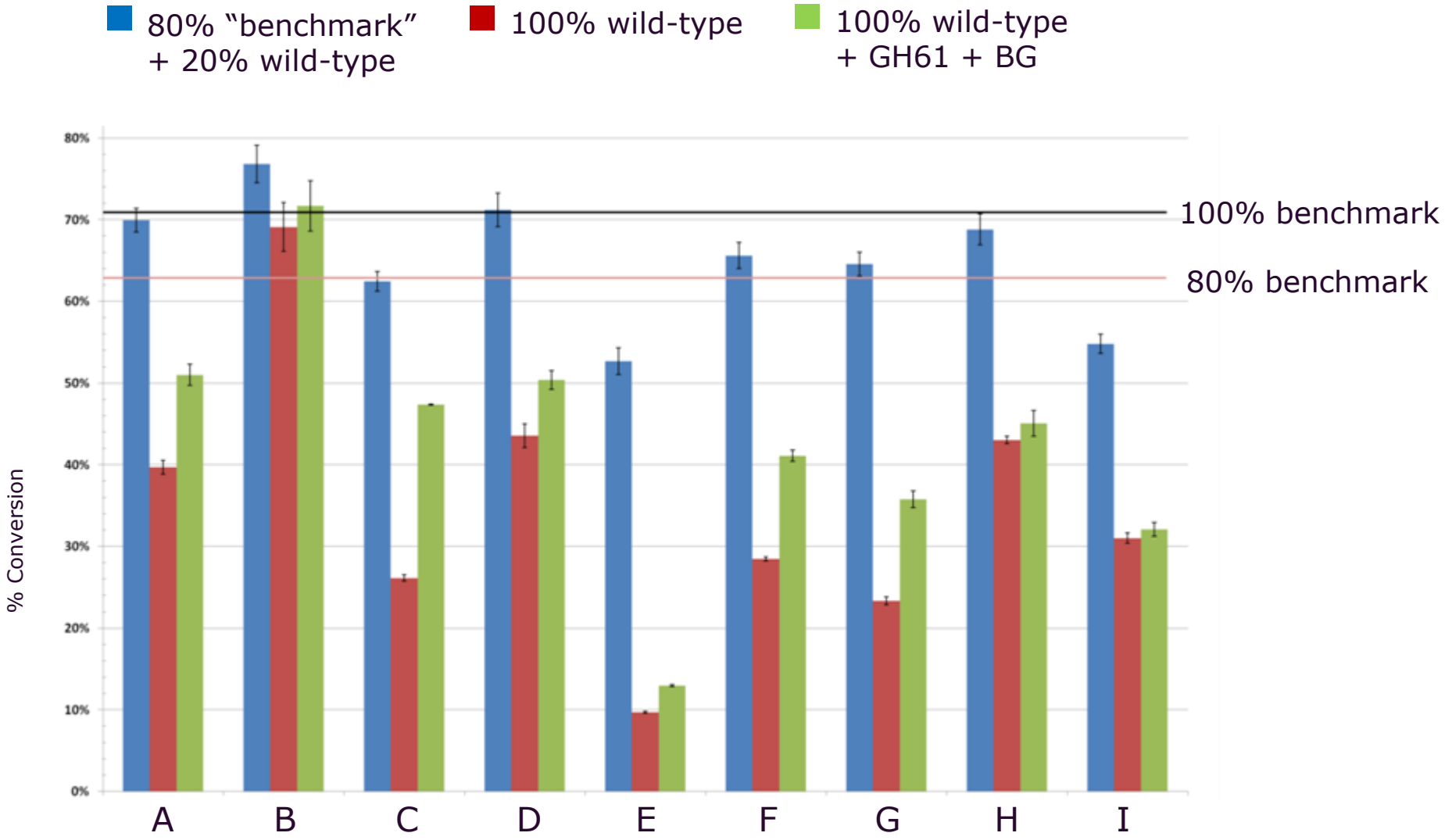
Many pretreatment technologies exist – all impacting subsequent hydrolysis and fermentation of sugars.

Distillation and generation of energy

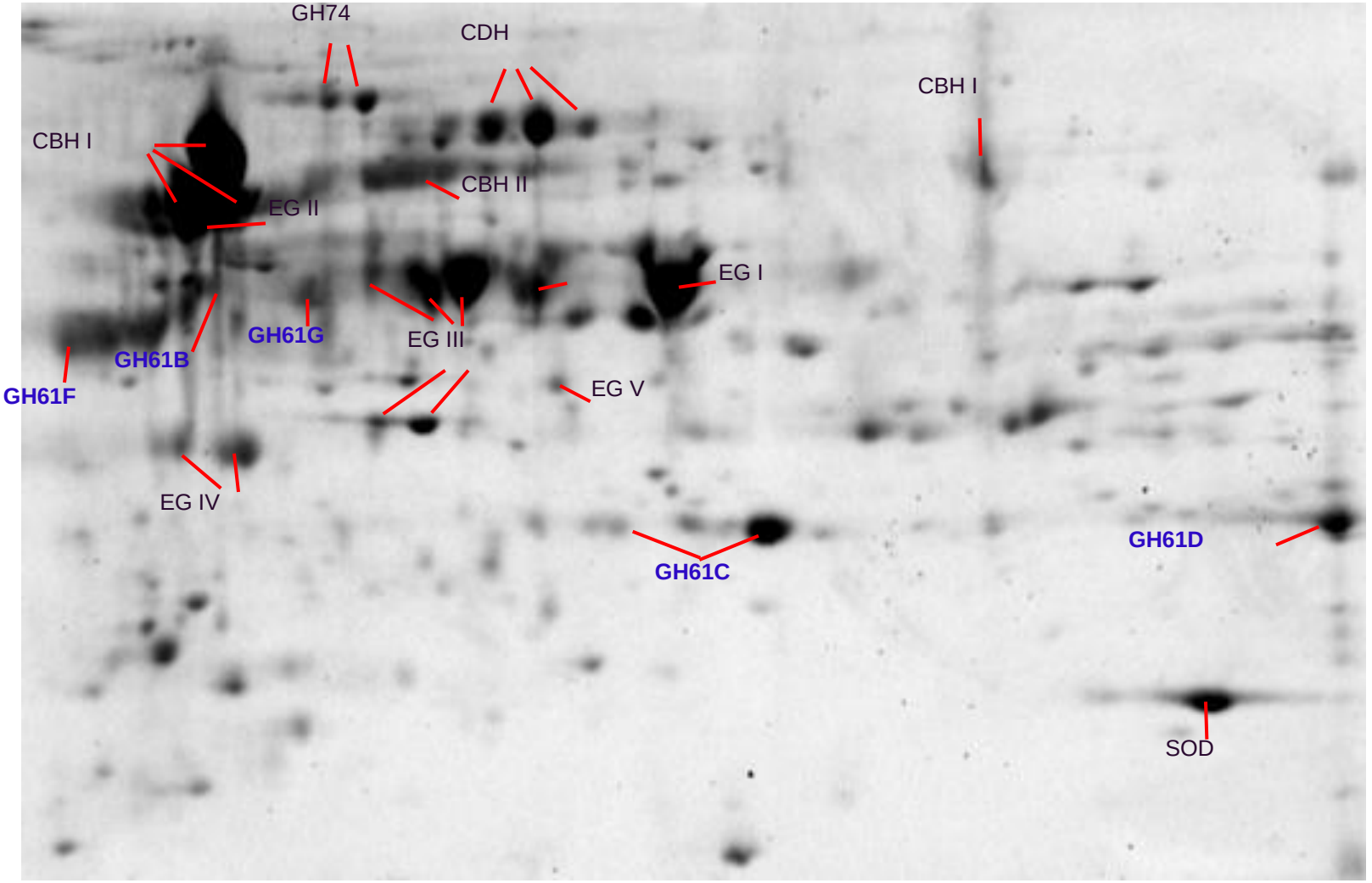
Approaches to making enzymatic hydrolysis viable for B2E – explored by NZ

- Improving enzyme performance
  - Additional activities to existing efficient cellulolytic complex
- Improving process compatibility with enzyme hydrolysis
  - Separate hydrolysis and co-fermentation of C5&C6 sugars
- Improving enzyme production cost
  - Optimizing expression yields
  - Near site of use production (hub-model) – Nebraska production plant

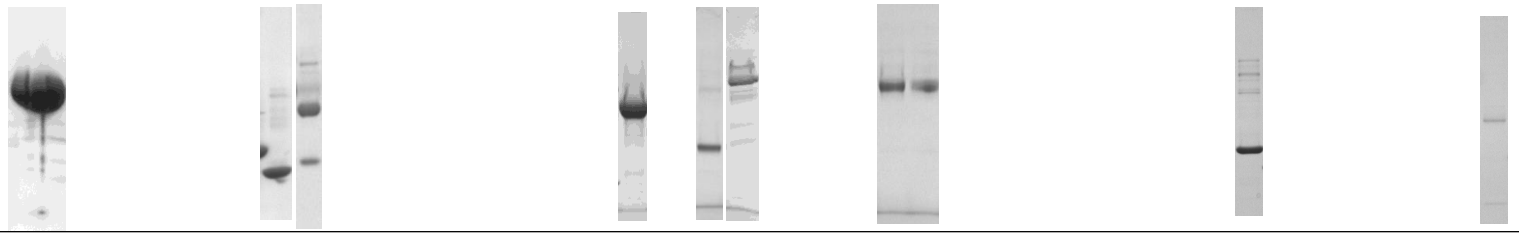
Screening natural cellulolytic systems

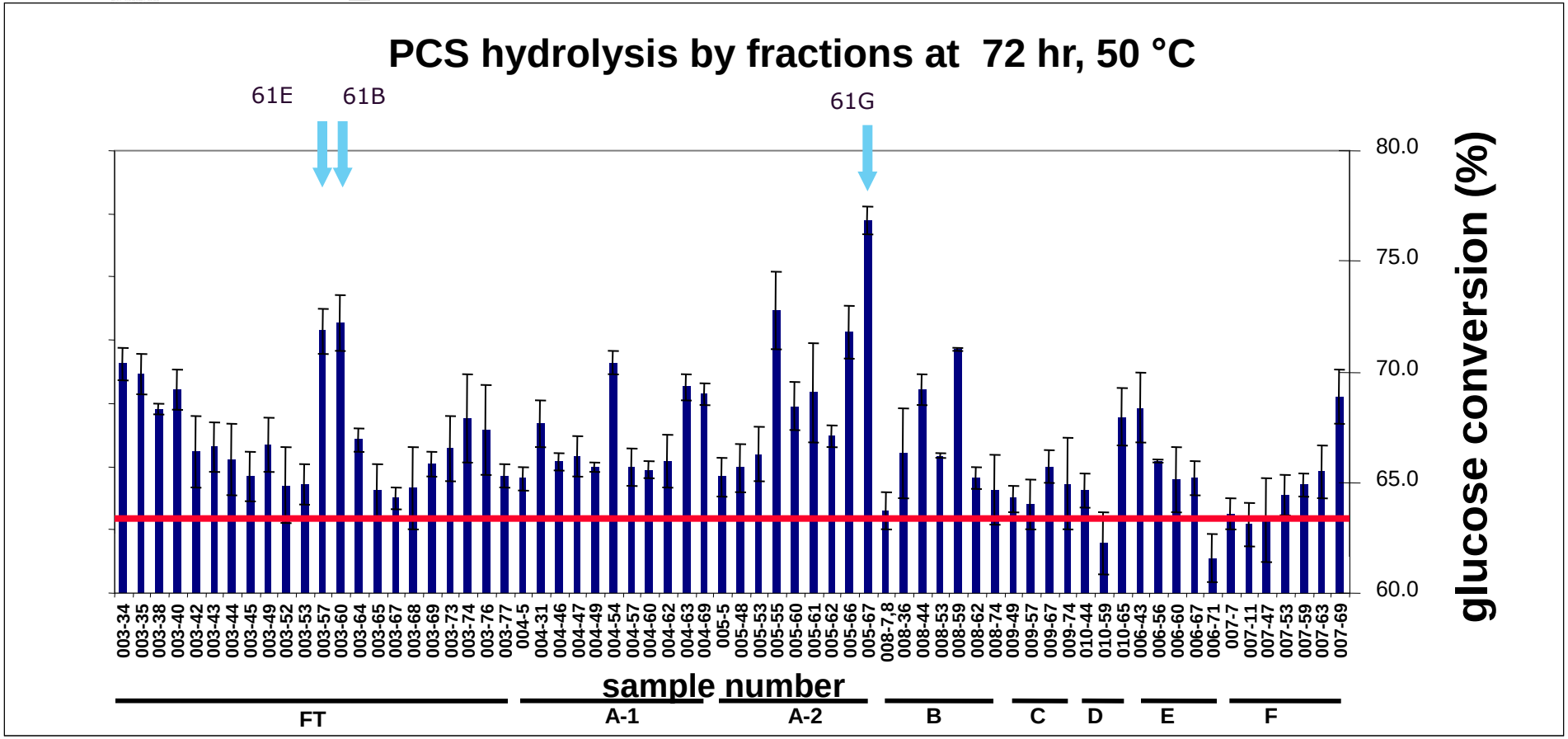


Wild-type fungal broths

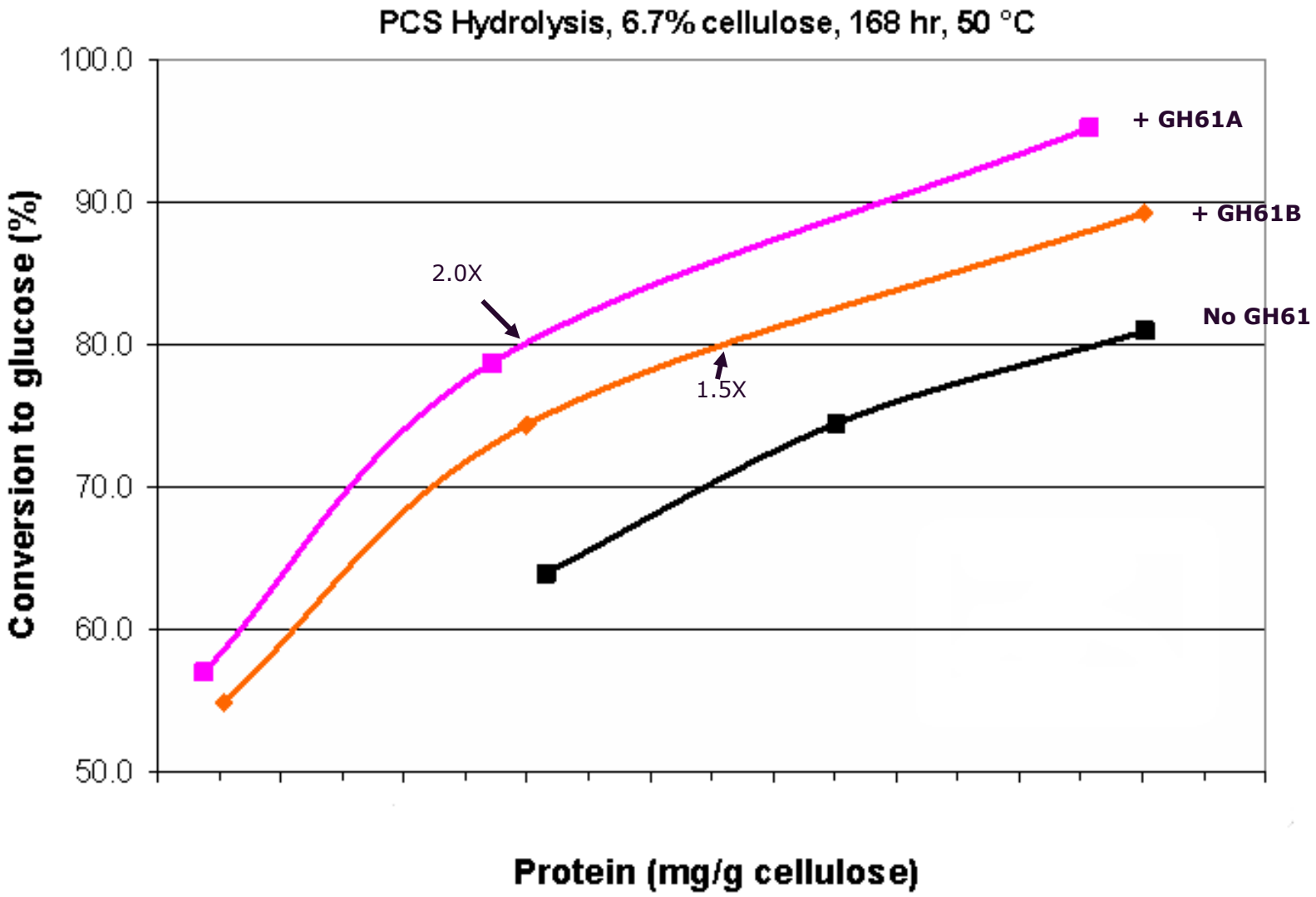


Synergy assay on fractions





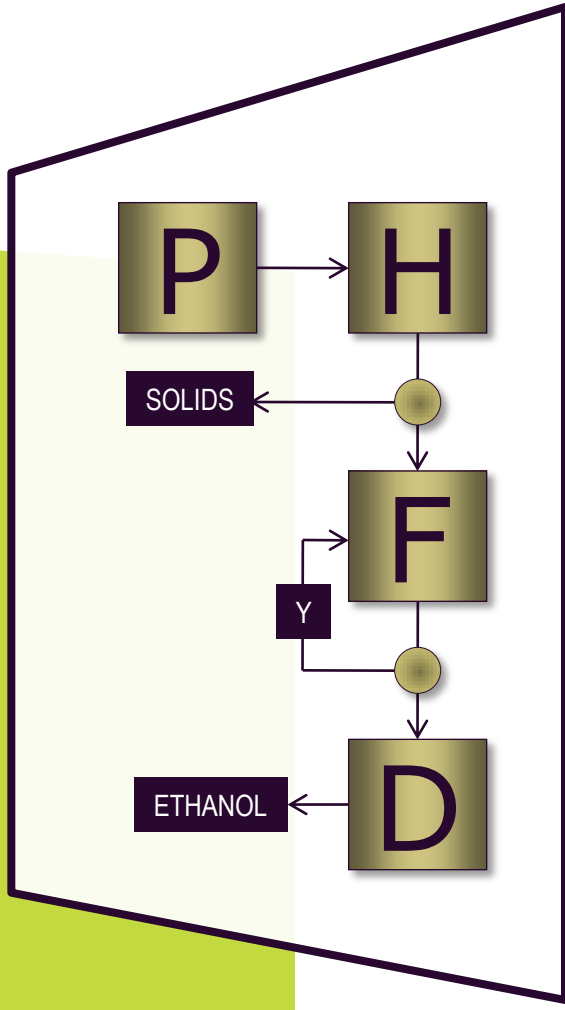
GH61 effects on *T. reesei* celluloytic complex



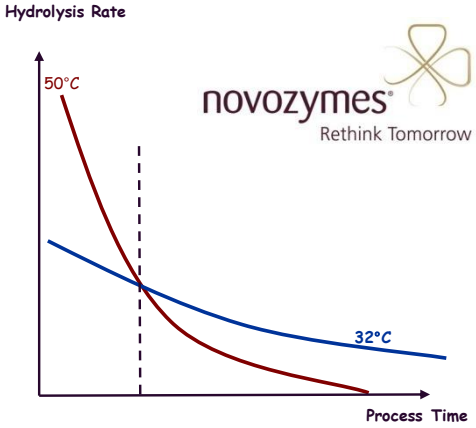
Fast Fermentation Concept

Enables simultaneous C5 & C6 sugar fermentation

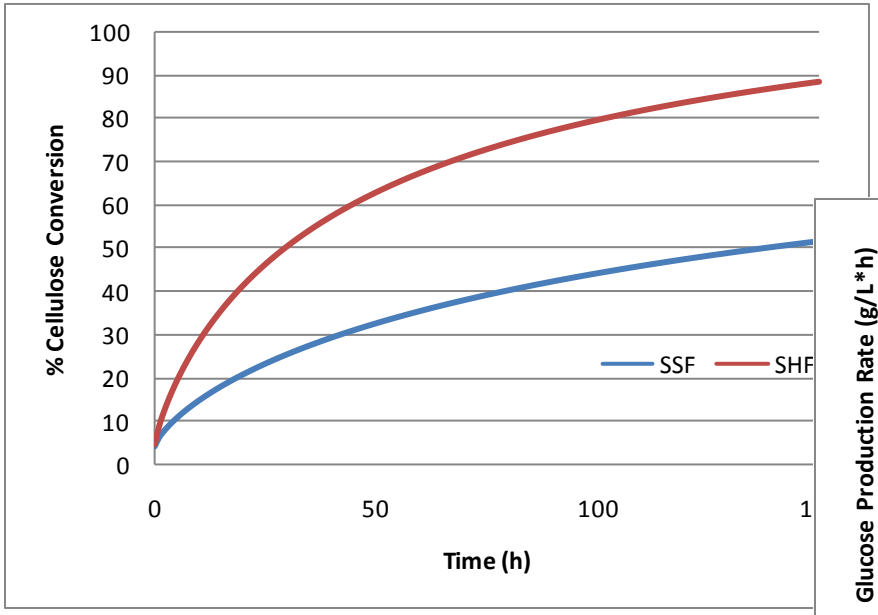
- The Fast Fermentation concept is a promising commercial solution for C5 & C6 sugar fermentation
- Xylose and glucose are simultaneously fermented utilizing a combination of a high cell and fed batch setup
- A dedicated hydrolysis separate from fermentation allows for better enzyme performance and optimization of the hydrolysis step
- Part of concept is based on mature Brazilian technology w similar ethanol titer and cell recycling
- Focus going forward will be on optimizing the dedicated hydrolysis step and piloting the Fast Fermentation concept

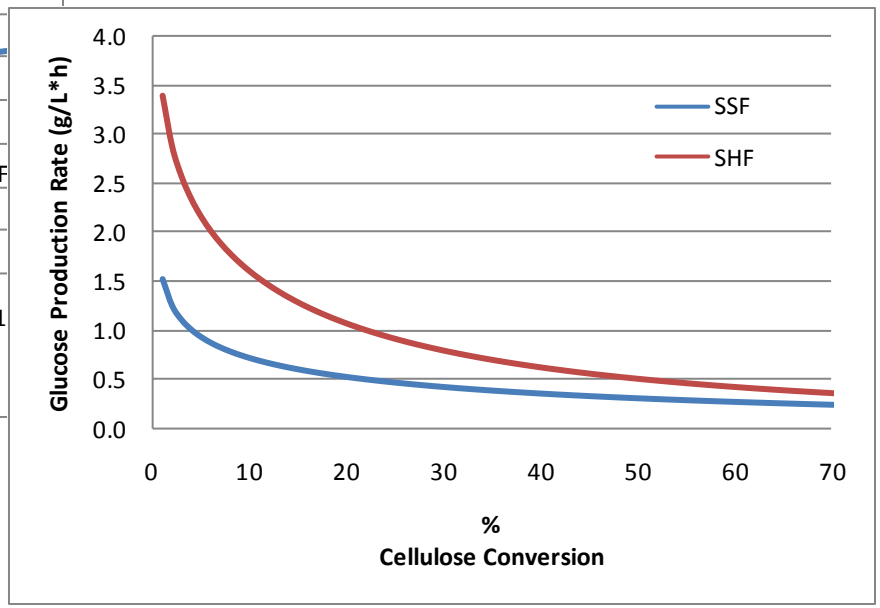


Actual Enzyme Performance
at relevant process conditions*



Dedicated Hydrolysis (SHF) vs.
Combined Hydrolysis and Fermentation (SSF)

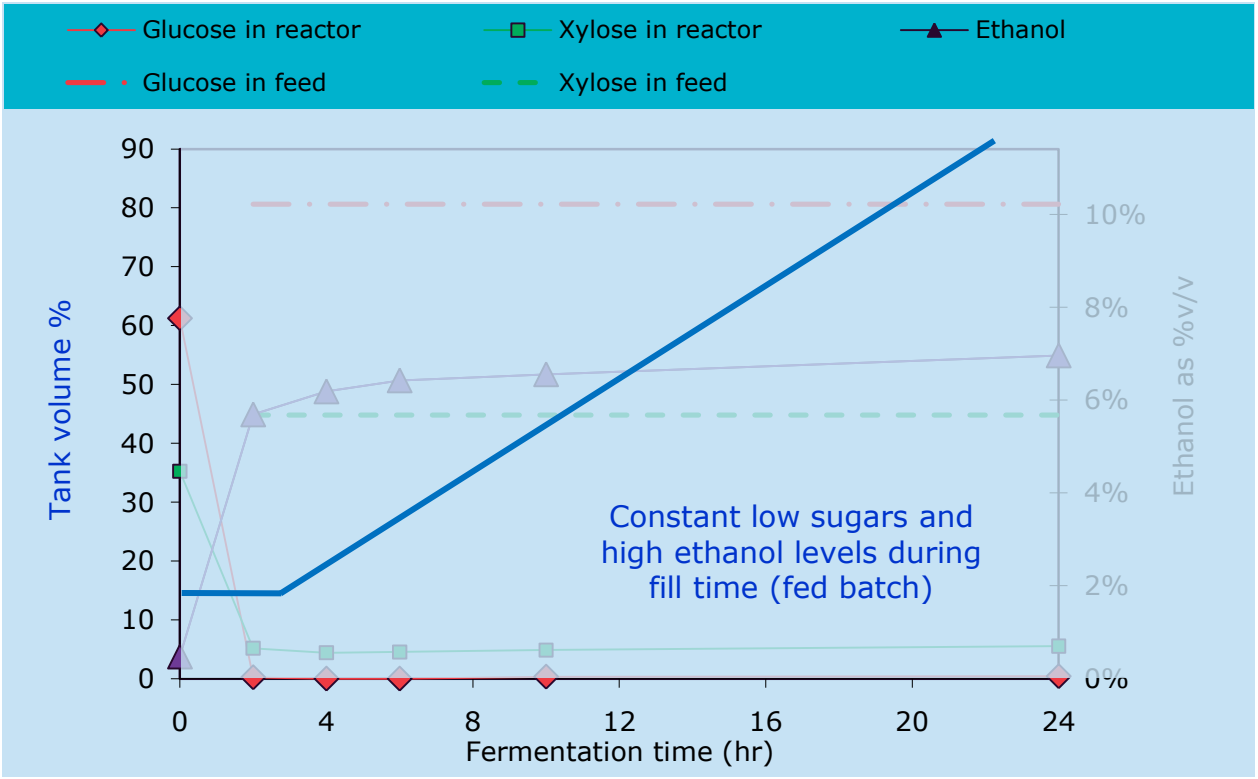




* High Solids (20%), uwPCS, Reactor scale, Newest enzymes (NS22074)

Fast Fermentation Demonstrated

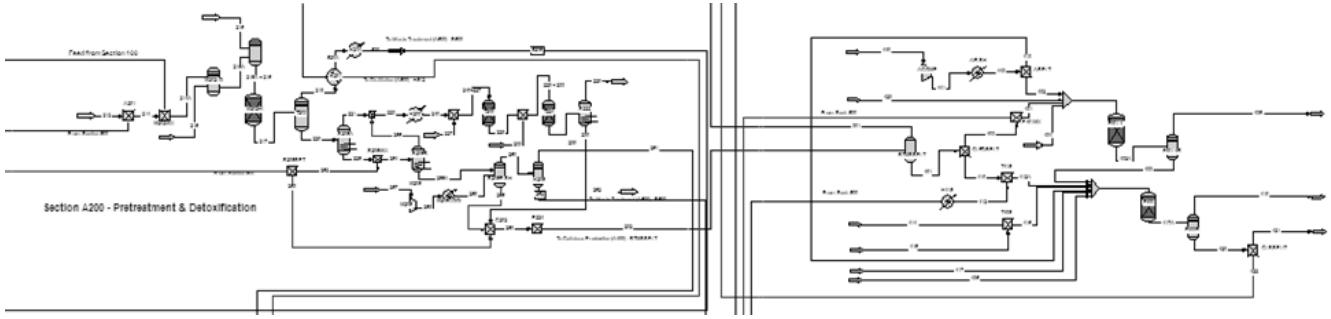
Fed-batch, simultaneous C6 & C5 fermentation, 20% TS uwPCS using Nedalco Yeast at 20 g-cells/L



Fast Fermentation in only 24 hr achieving 86% ethanol yield from glucose and xylose

Setting Direction for Application R&D in Novozymes

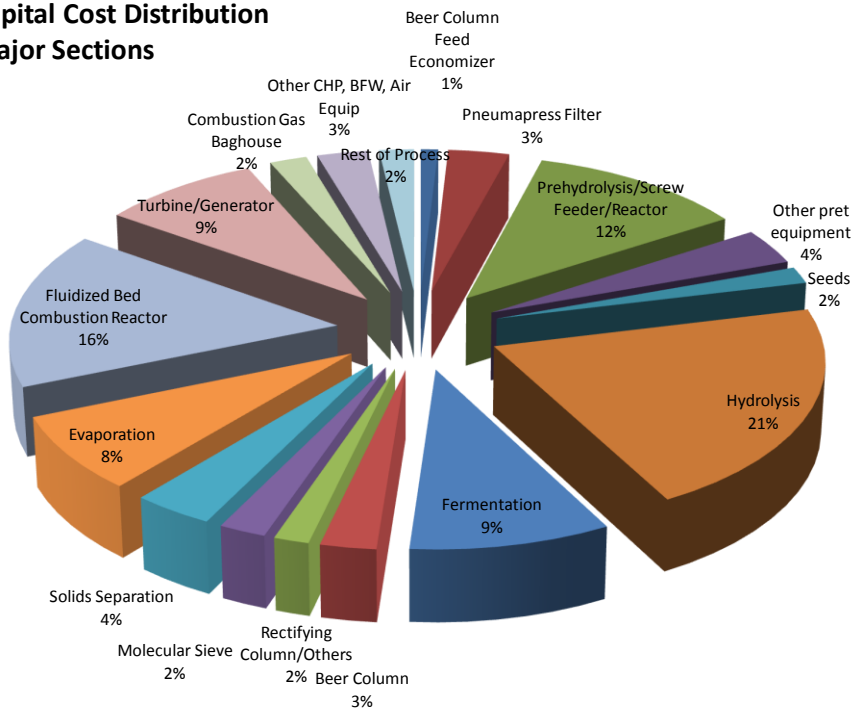
Holistic approach supported by process modeling



Key Assumptions for Holistic Cost model

-Stand-alone facility in USA
-Nth generation plant
-Corn stover feedstock
-2000 dry-ton feedstock/day
-Dilute Acid Pretreatment
-Self-sufficiency in heat/power
-Excess energy exported as electricity
-IRR 10%, NPV 20yr
-Plant gate ethanol cost
-No subsidies

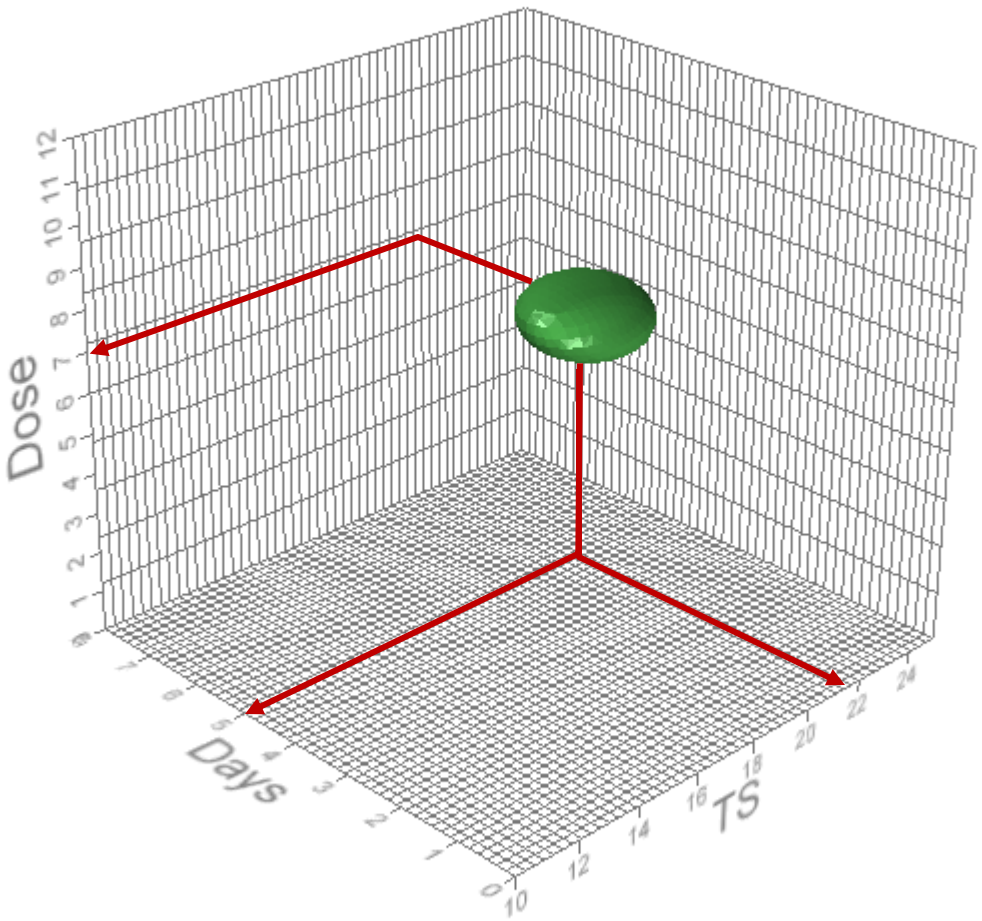
Capital Cost Distribution Major Sections



Note: build on from the NREL Aspen model

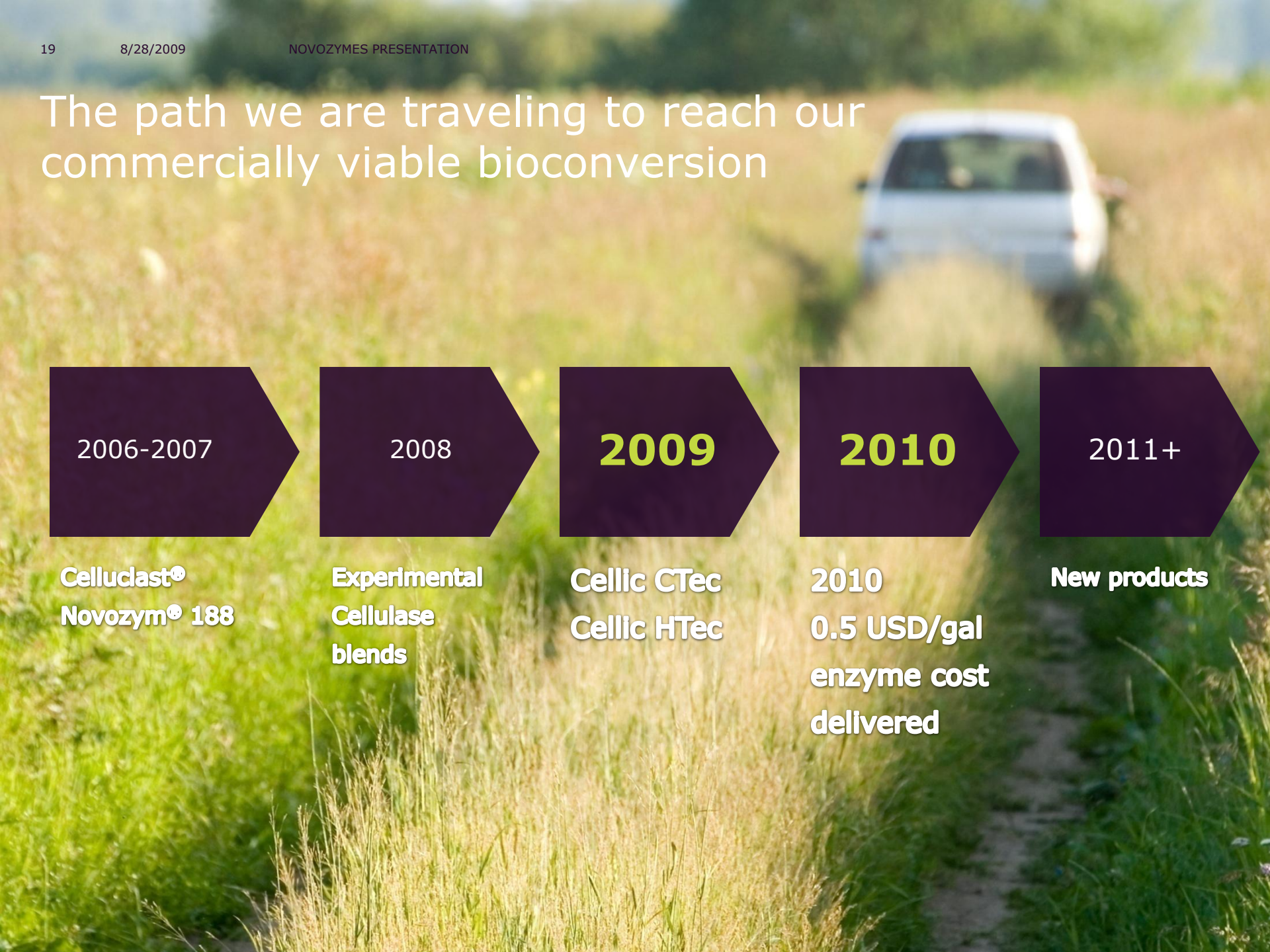
Process Assessment of Best Commercial Process Layout

Example of a holistic model approach



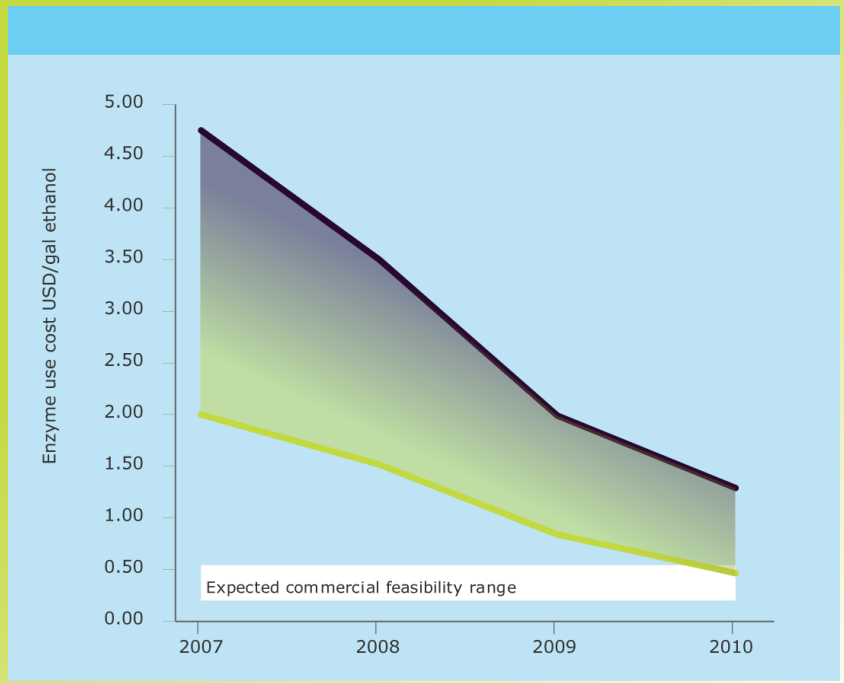
isosurface plot with Min EtOH Selling Price = 2.80

The path we are traveling to reach our commercially viable bioconversion

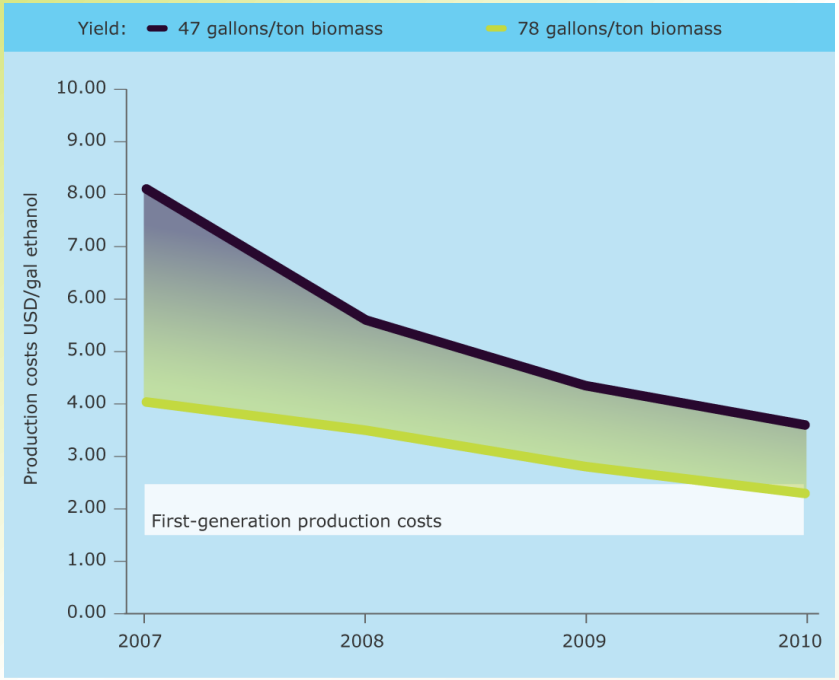


Novozymes' Cellic® product family is enabling commercial viability

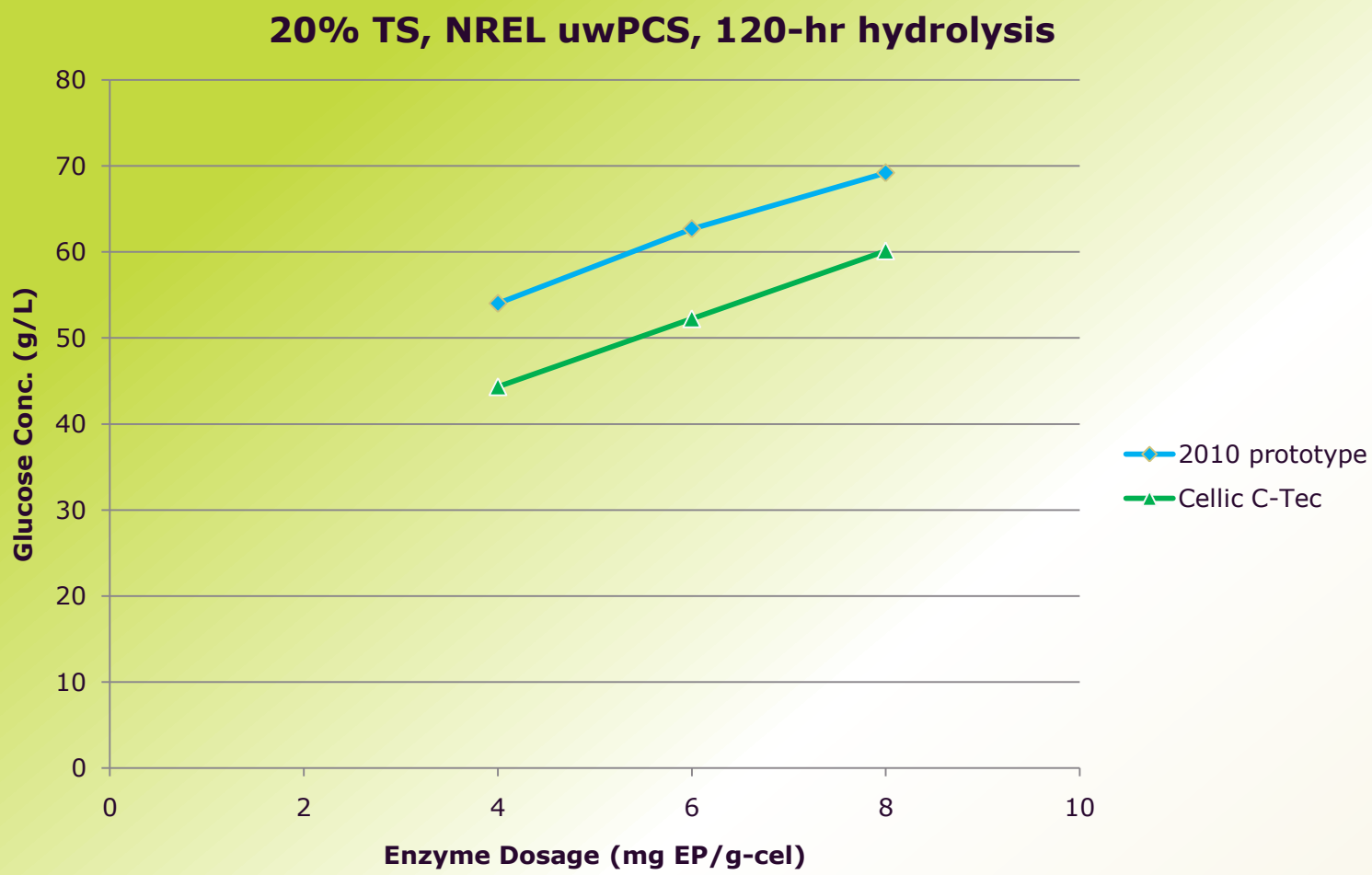
Enzyme costs are becoming a smaller and smaller percentage of the total process costs



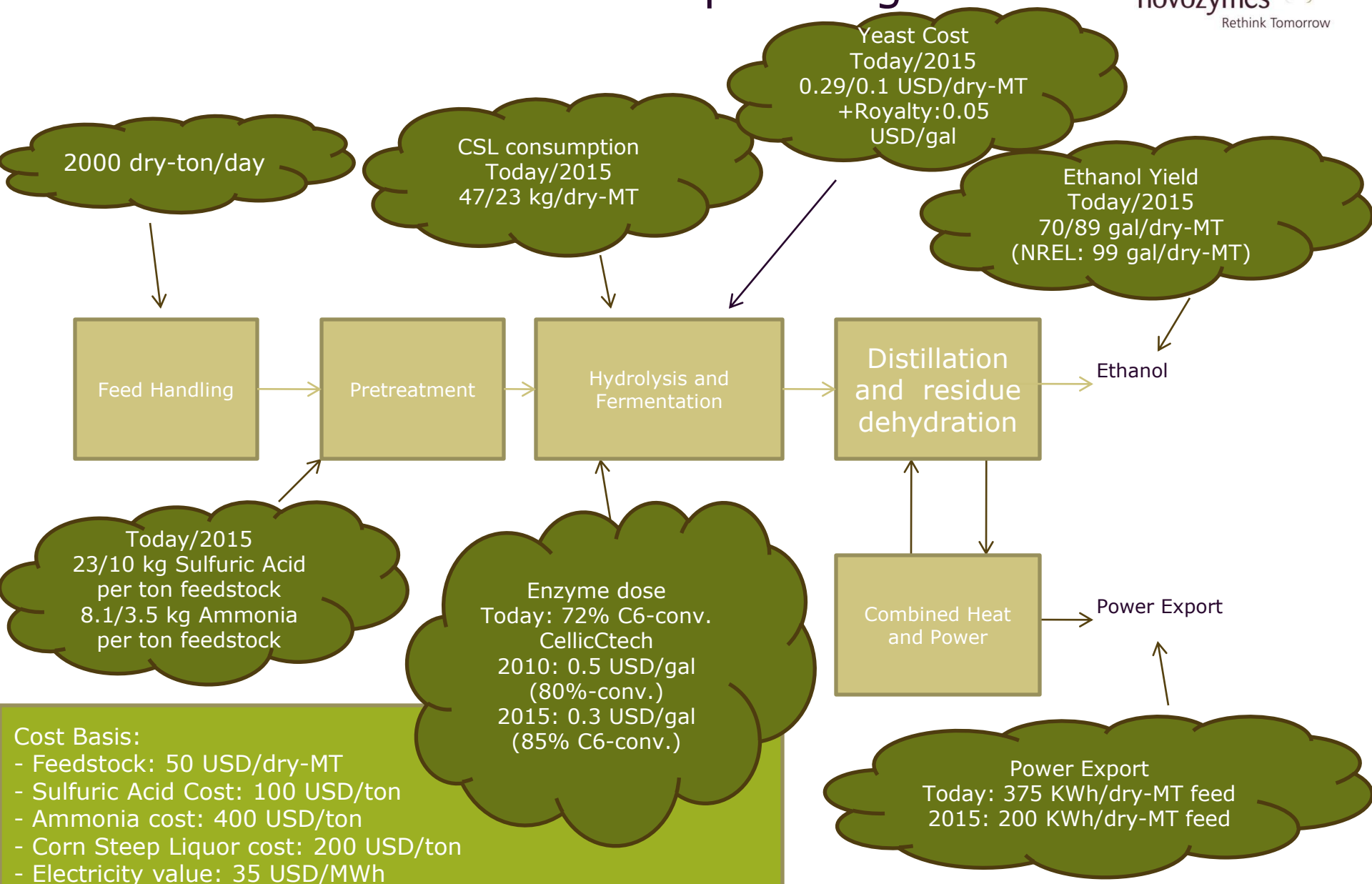
Production costs are coming in line with corn based ethanol costs



Improvements vs. Cellic-C-Tec in the pipeline

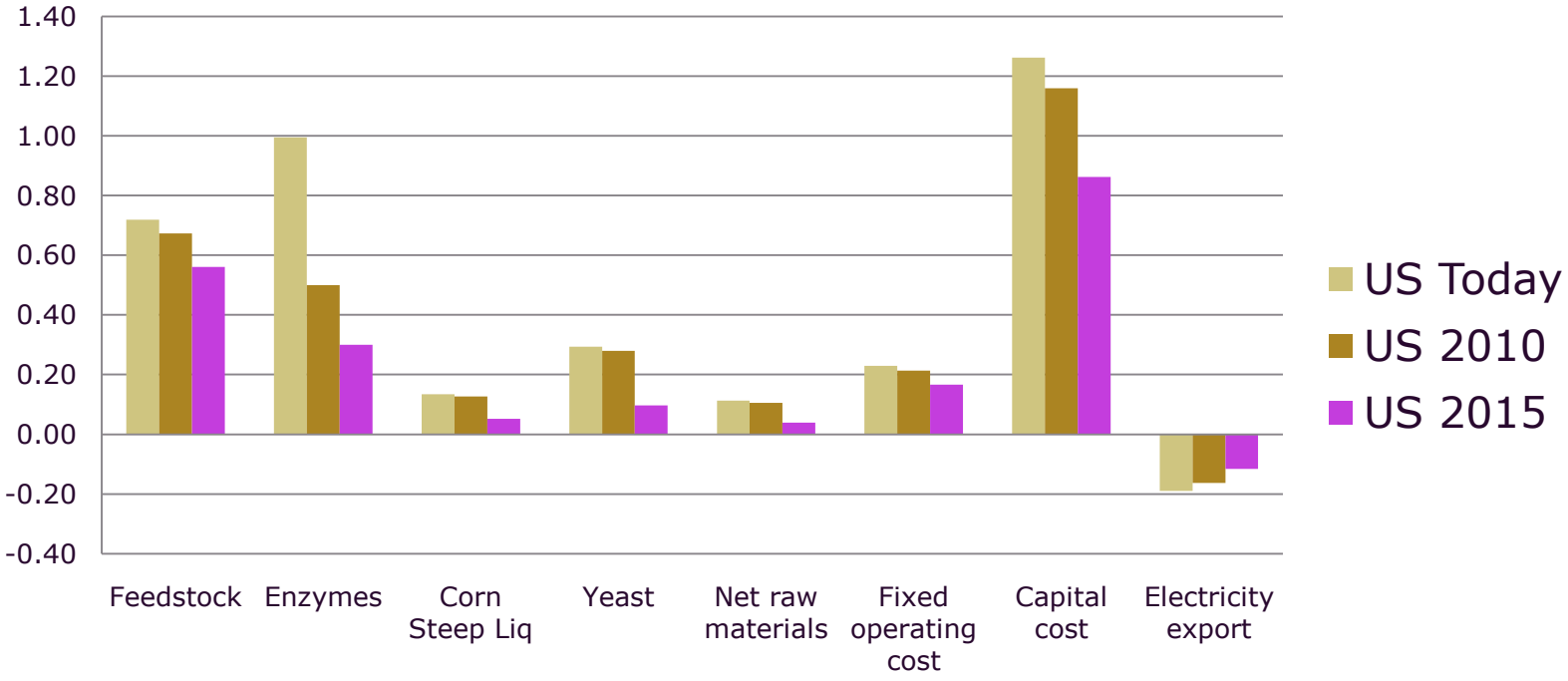


Main Production and Consumption Figures



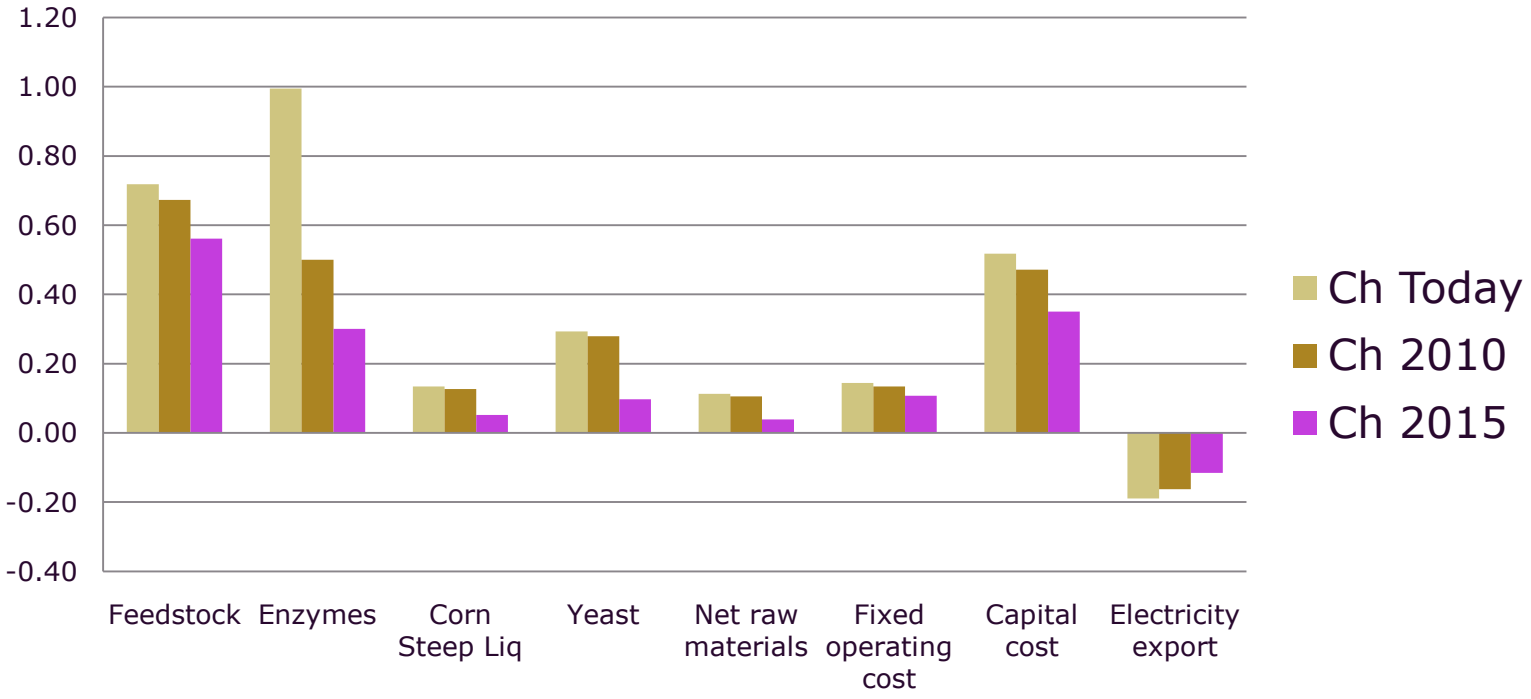
US, Production Cost Estimate

Case	MESP (USD/gal)	Yield (gal/dry-ton)
Today	3.6	70
2010	2.9	75
2015	2.0	89



China, Production Cost Estimate

Case	MESP (USD/gal)	Yield (gal/dry-ton)
Today	2.7	70
2010	2.1	75
2015	1.4	89



llenges remain to be addressed

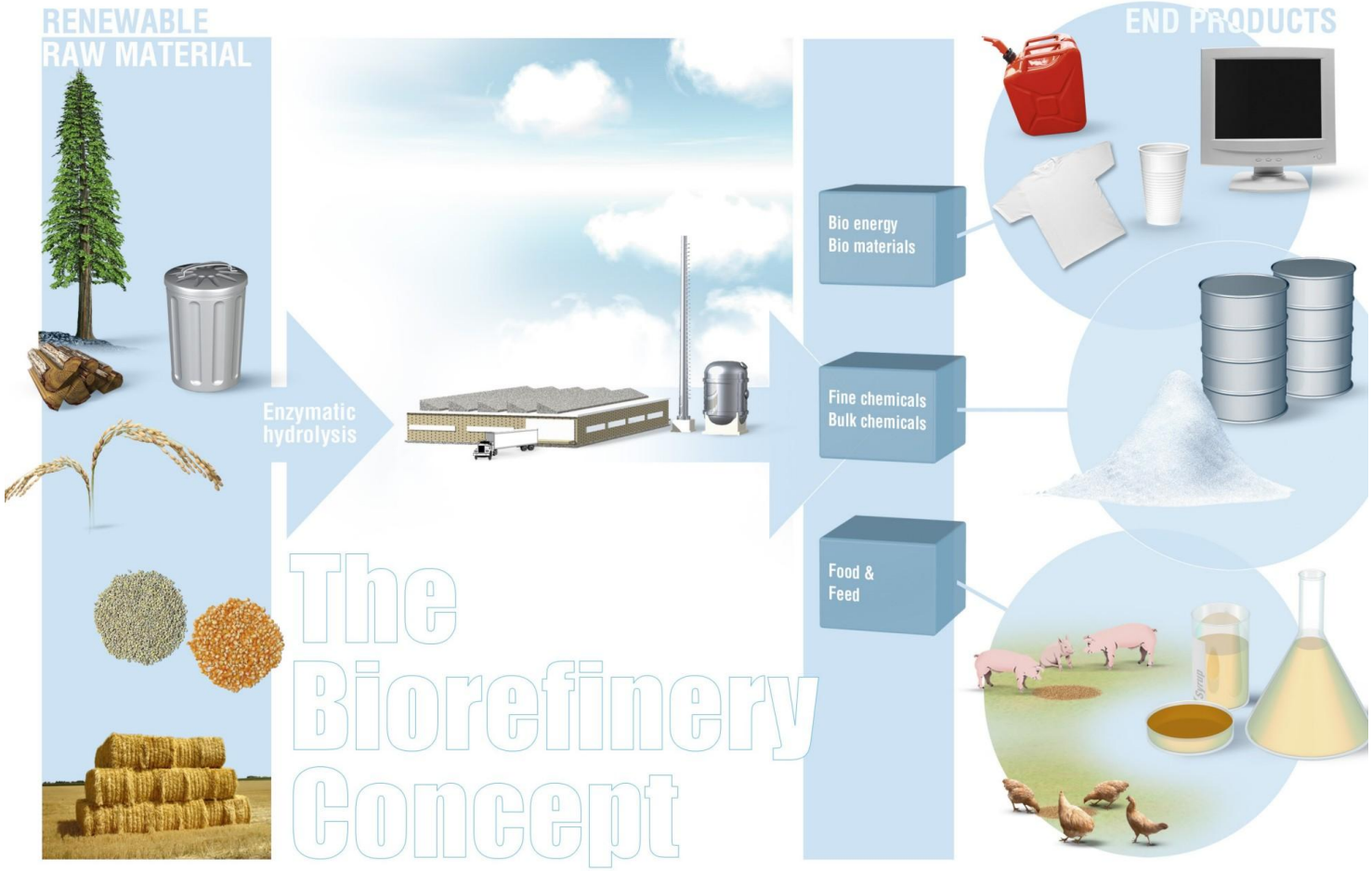
Overriding challenge is to get from pilot to industrial scale due to the capital requirement – technology is there – but +200 MUSD in a 20-30 MGY facility is putting a lot money at risk

Feeds	ent	Enzyme hydrolysis	Fermentation	Products** Co-products
Selection – collection – storage	Physical	–0.18/ cess tric)	Cellulose & hemicellulose conversion	**Critical cost factors:** Concentration
Broad spectrum of viable feedstock	Thermo-chemical			Purity
Infrastructure required	Removal of toxic by-products	inves	olysate tolerance	Value
Quality affects pretreatment	**Critical cost factors:** Capital cost Digestibility Yield of C5 sugars Fermentability	Hydrolysate to	tors:	
Critical cost factors: Collection cost Density		**Critical cost factors:** Enzyme volumes Enzyme price		

For Novozym
Further enzyme i
Enzyme scale-up
Reduction in capital cost

* NZ current enzyme cost estimates = USD 1.00–1.50/gallon of cellulosic ethanol
** Estimated current total production cost = USD 3–4/gallon of cellulosic ethanol

Bioethanol is only the first step toward a biobased society



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Thank you for your attention !

And thanks to all my good colleagues in preparing the presentation - in particular

Mads Torry Smith, Cynthia Bryant, Johan Mogensen, Paul Harris, Anders Lau Tuxen, Carsten Lauridsen

And thanks to

U.S. DEPARTMENT OF ENERGY

for support to

enzyme improvement efforts