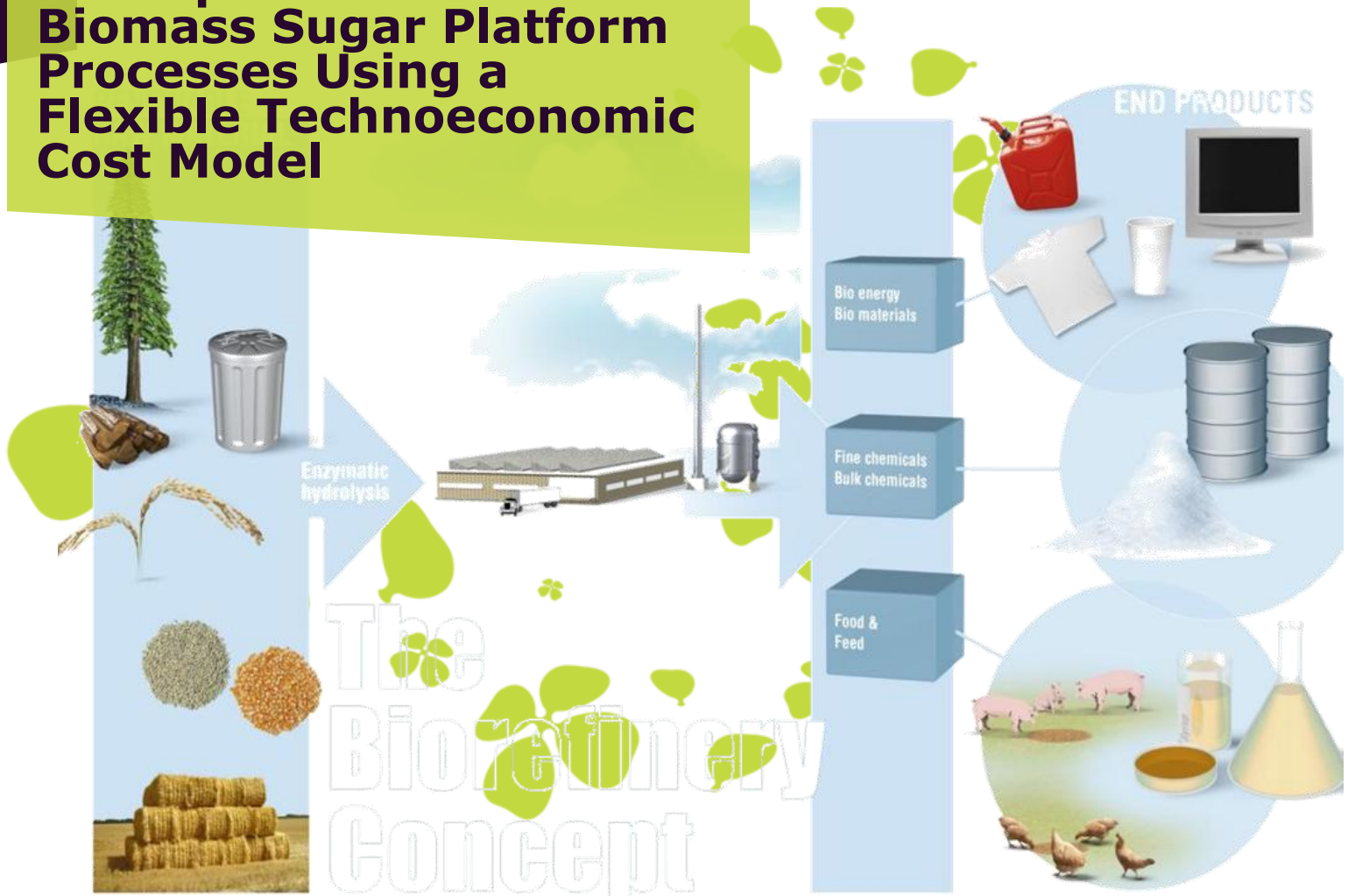
Conceptualization of Biomass Sugar Platform Processes Using a Flexible Technoeconomic Cost Model



Brandon Emme
bemm@novozymes.com
Bioenergy R&D, Novozymes

Why Study Sugar Platform now?

Several open questions to answer

- If industry acceptance of biomass sugars for general use can be realized, can they be competitive with other sugar sources?
- Can a 2G ethanol plant making biomass sugars be competitive with dedicated 2G ethanol plants?
- Is there a winning process concept for making biomass sugars?
- What are biomass sugar processes cost sensitive to?

What are Biomass Sugars Competing With?

Prices increase due to growing industry demand

Fast rise in sugar prices in recent years

Diagram 1: Prices of major raw materials in the starch sector

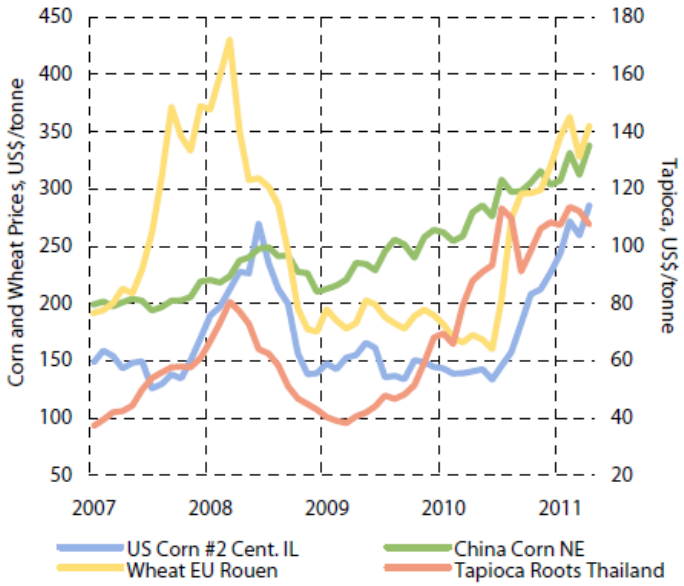
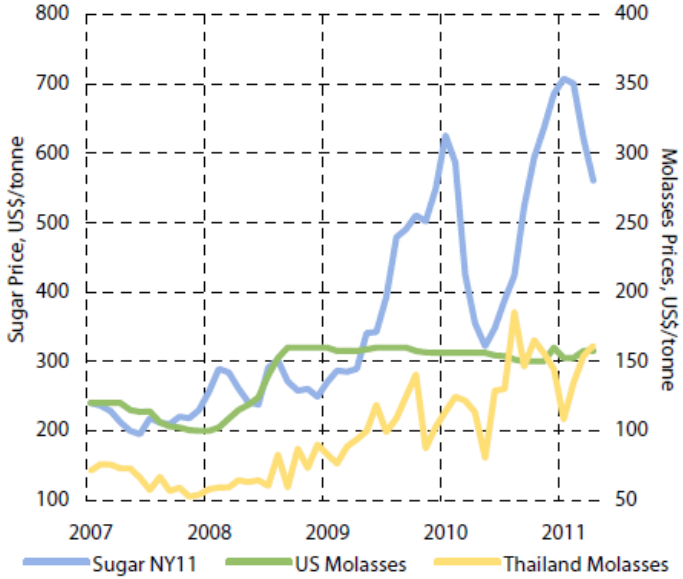


Diagram 2: Sugar and molasses prices

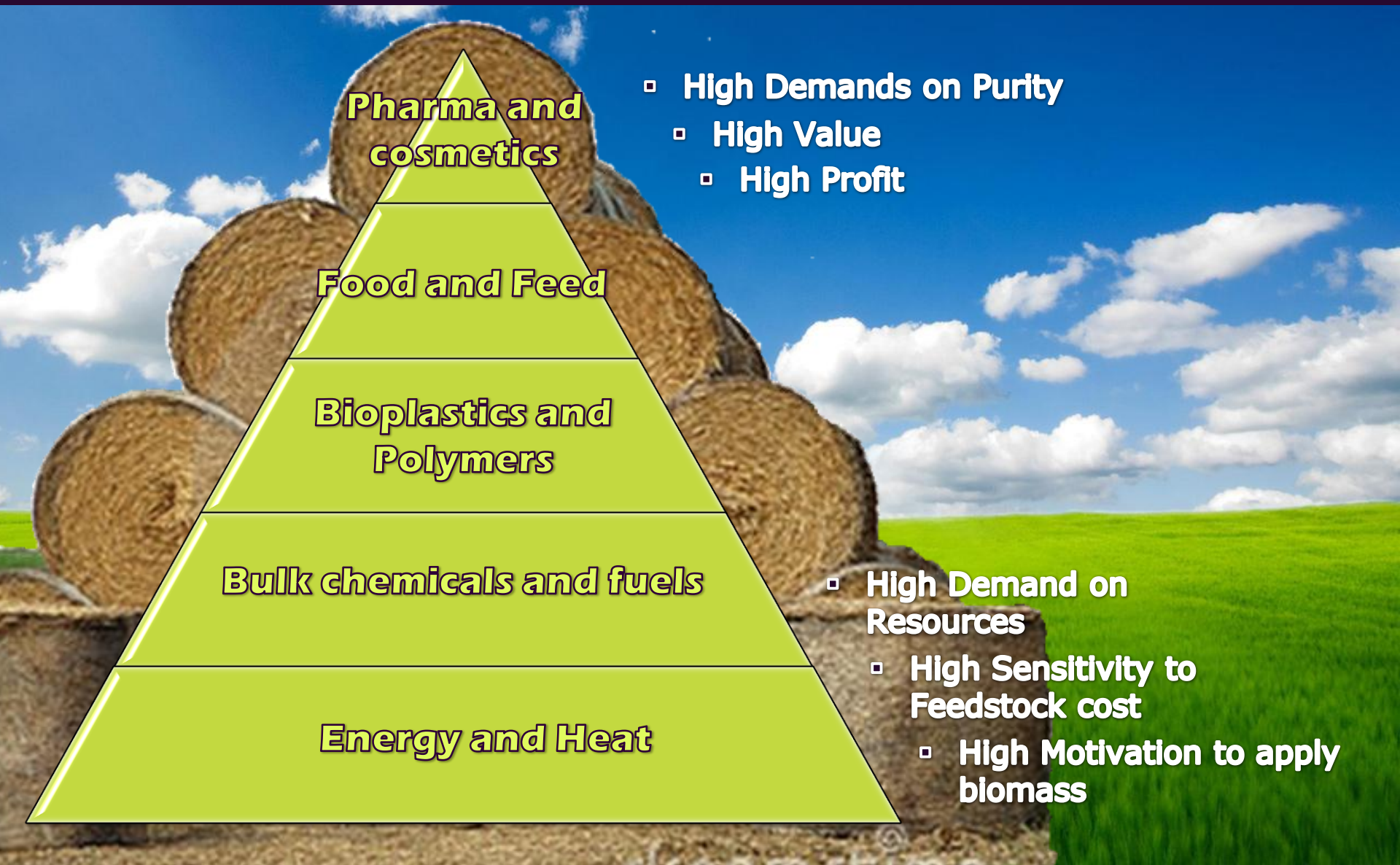


SOURCE: LMC INTERNATIONAL LTD., SUGAR BULLETIN 2011

ON A DRY BASIS, 150 USD/MT MOLASSES EQUATES TO ~400 USD/MT-SUGAR

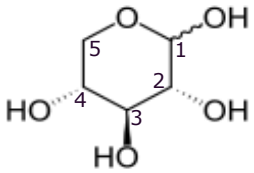
The 2G "Food Pyramid"

A Balance of Quality Cost to Volume and Profit Margin

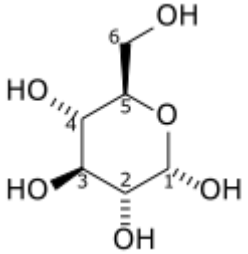


Not All Sugars are Created Equal

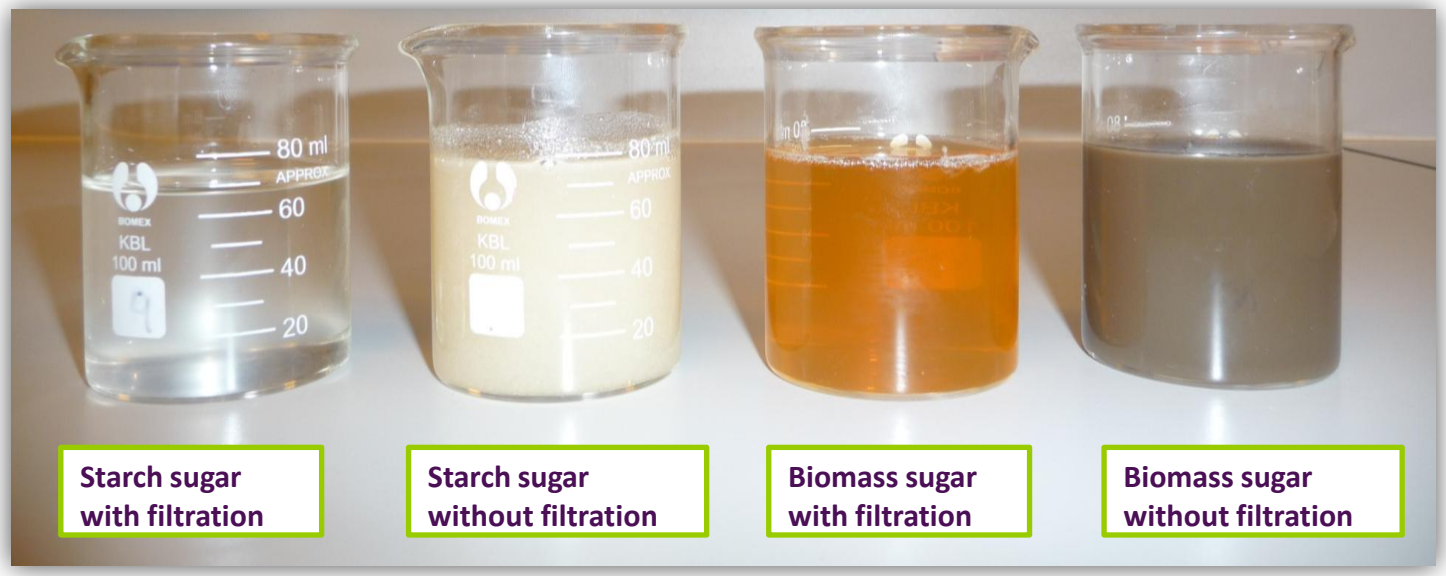
Quality Aspect of the Sugar Cost



5-carbon sugar
D-xylose



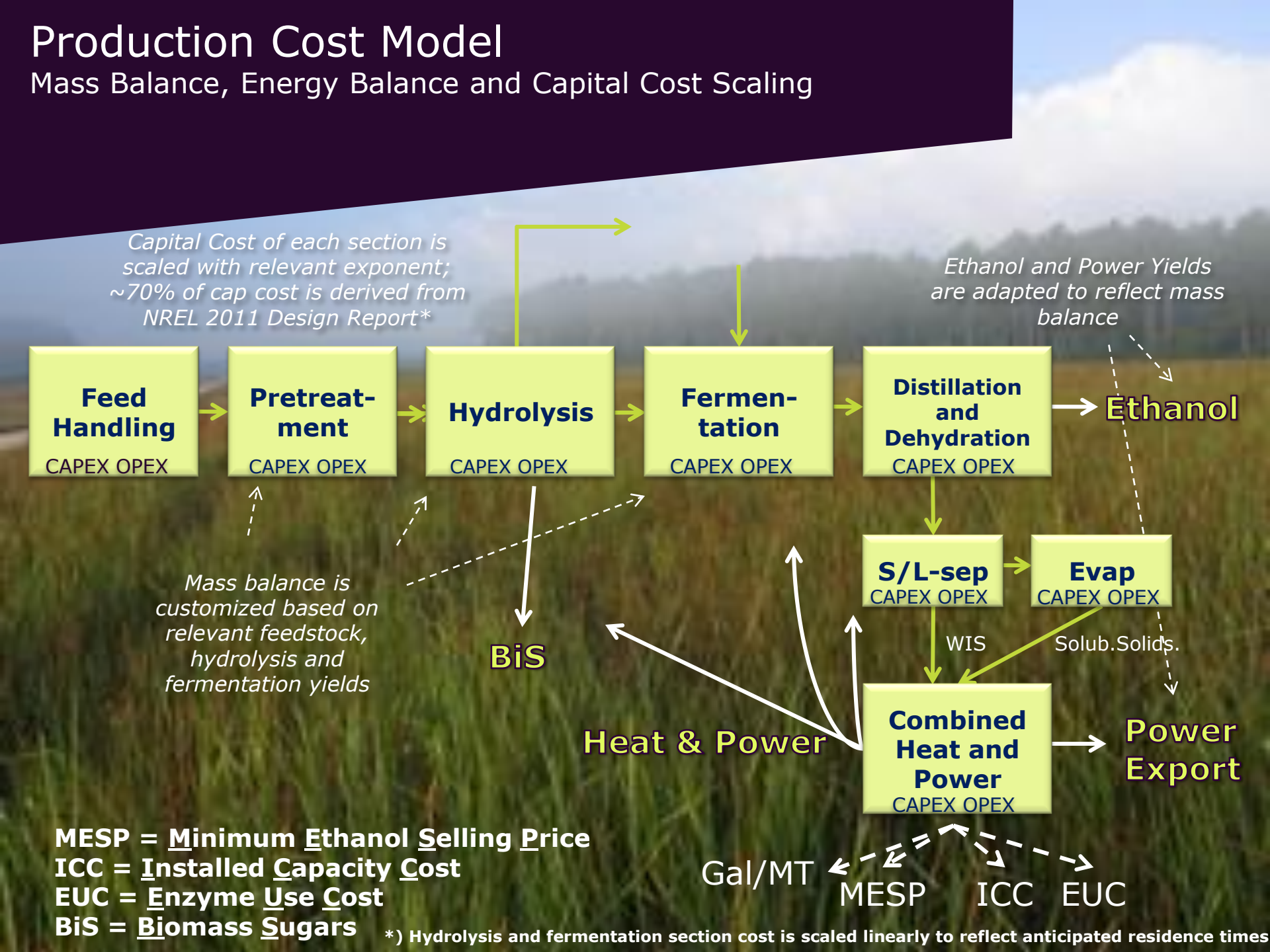
6-carbon sugar
D-glucose



	Starch Sugar	Biomass Sugar	Extra cost
Solid/Liquid Separation	N/A	Necessary for organic acids production and catalytic reactions	Sugar yield loss and Capital cost
Sugar Concentration	75 wt%	10 wt%	~$100/MT through filtration and evaporation to 75%TS
Sugar Purity	Quite clean sugar	Mixture of C5 and C6 sugars Many unknown compounds toxic to strain or catalyst	Fermentation yield reduction

Production Cost Model

Mass Balance, Energy Balance and Capital Cost Scaling



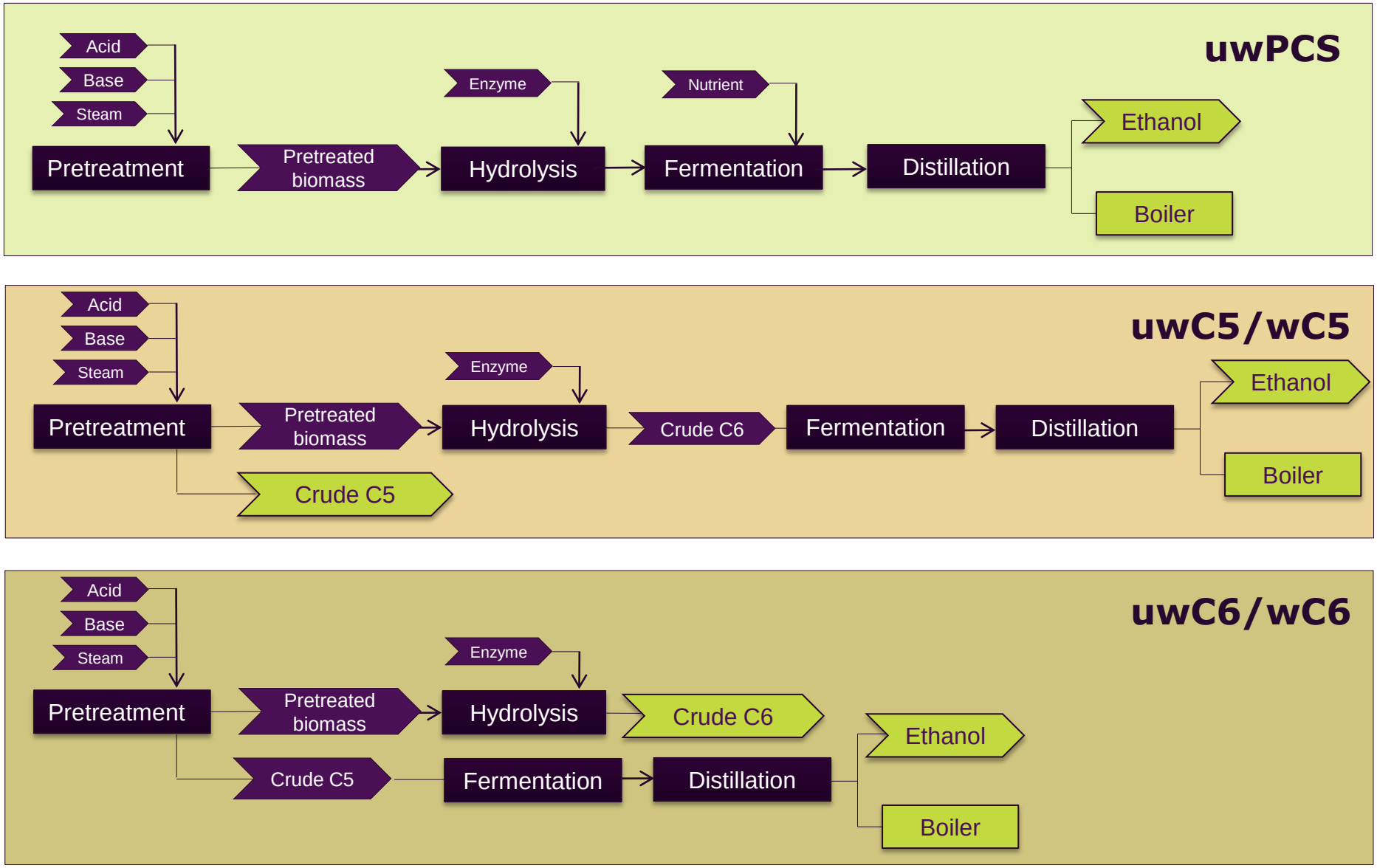
MESP = Minimum Ethanol Selling Price
ICC = Installed Capacity Cost
EUC = Enzyme Use Cost
BiS = Biomass Sugars

***) Hydrolysis and fermentation section cost is scaled linearly to reflect anticipated residence times**

Process Options

Biomass to Crude Sugars Using Dilute Acid Pretreatment

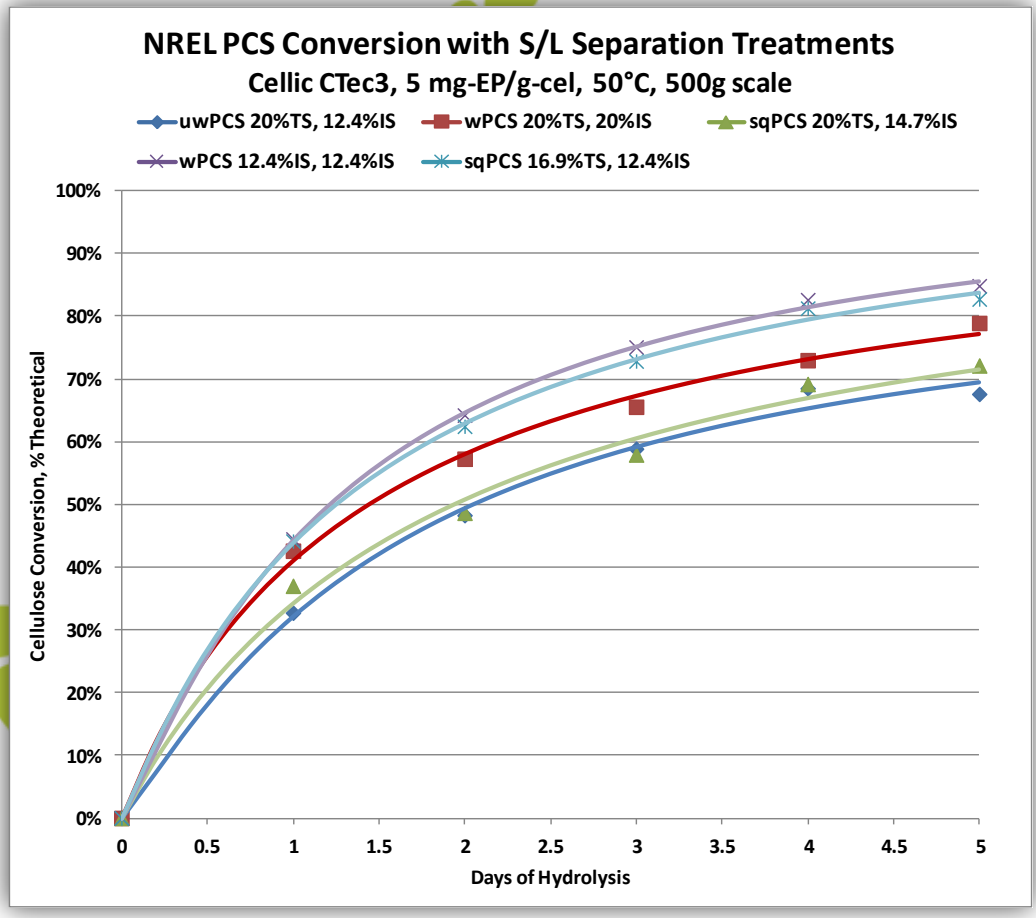
novozymes® Rethink Tomorrow



Hydrolysis Data

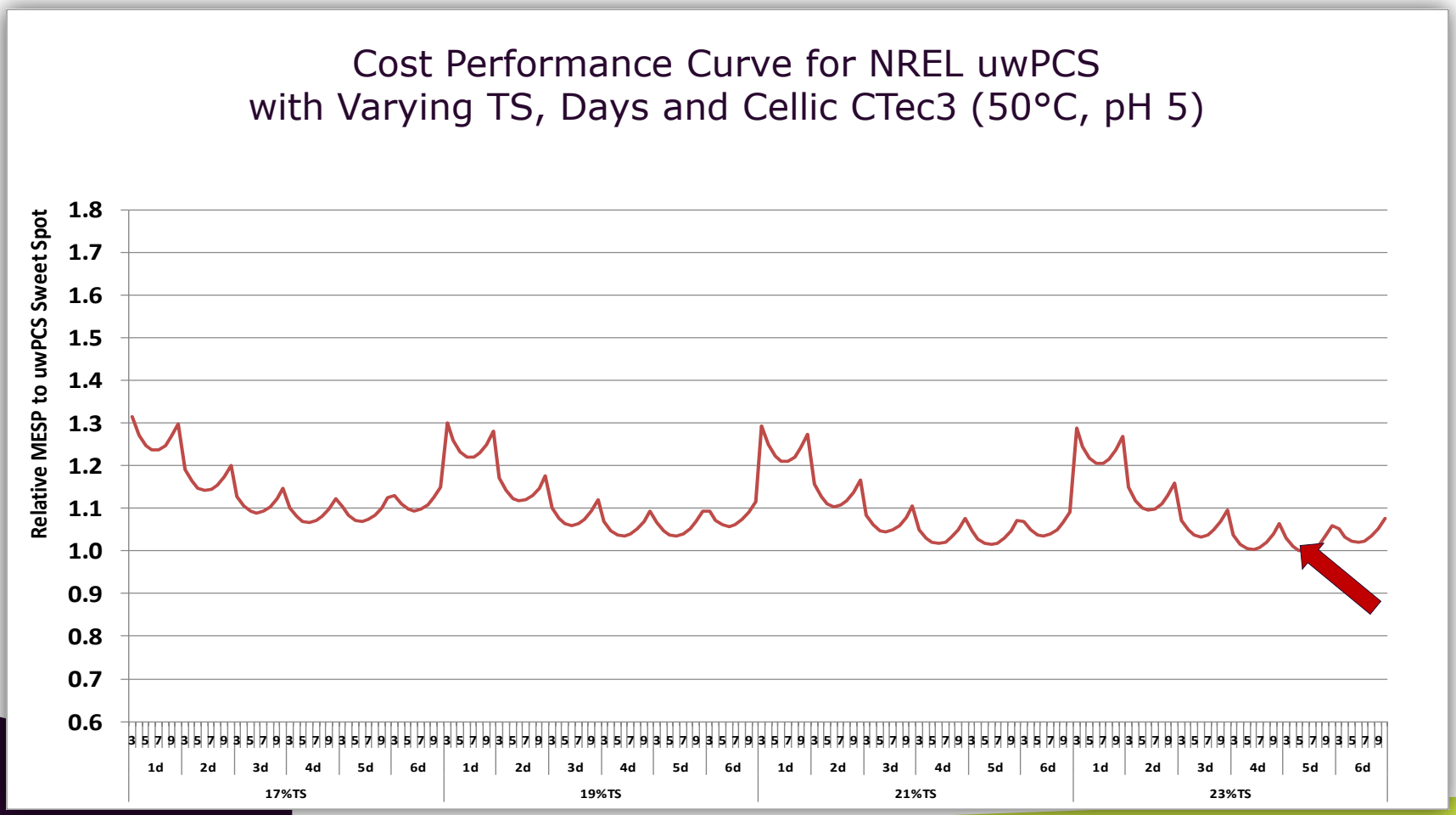
Whole Slurry & Washed vs. Squeezed with CTec3

- Cellic enzymes give superior performance even at low efficiency S/L separation
- Cellic can reduce or eliminate need for washing steps during separation



Sweet Spot Results

Cellic CTec3 is able to reduce dilution water in the process

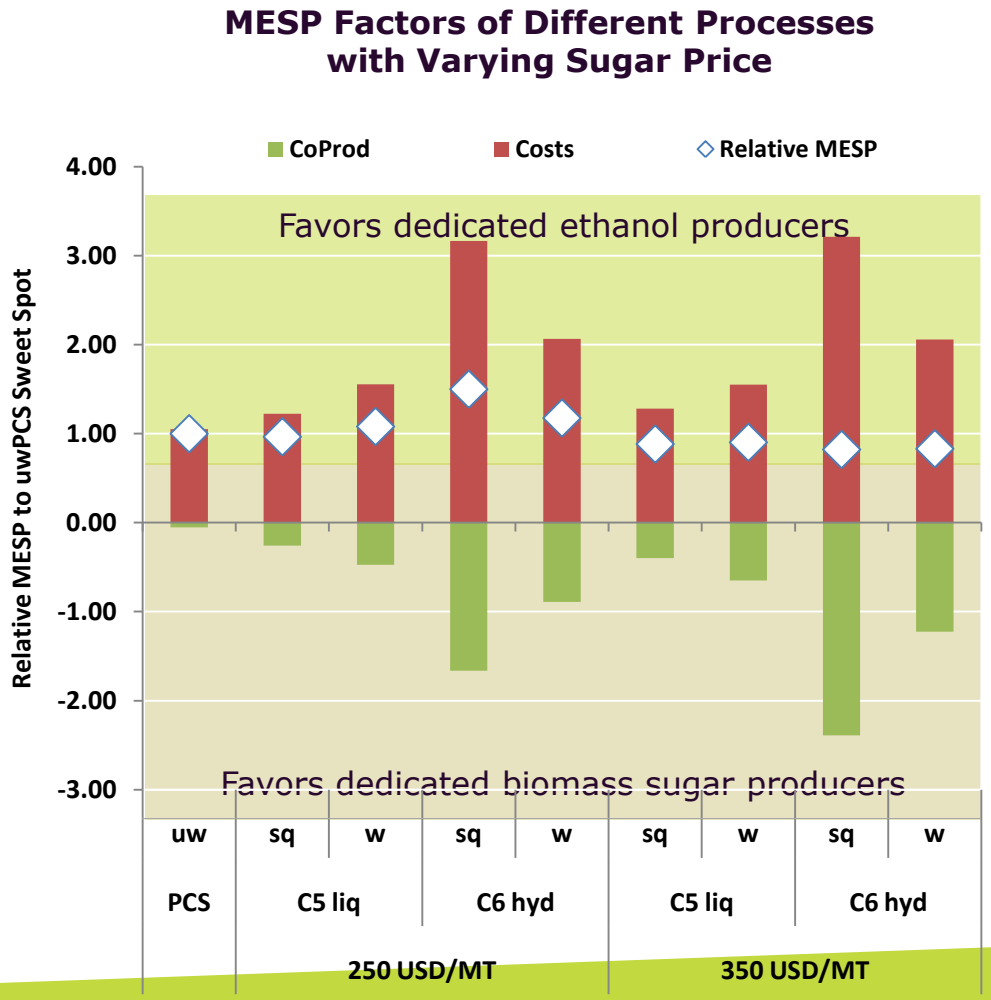


CONSISTENT LOWEST MESP WITH 4-5 DAYS OF HYDROLYSIS

Sweet Spot Results

C6 Hydrolysate Processes are More Sensitive to Market Price

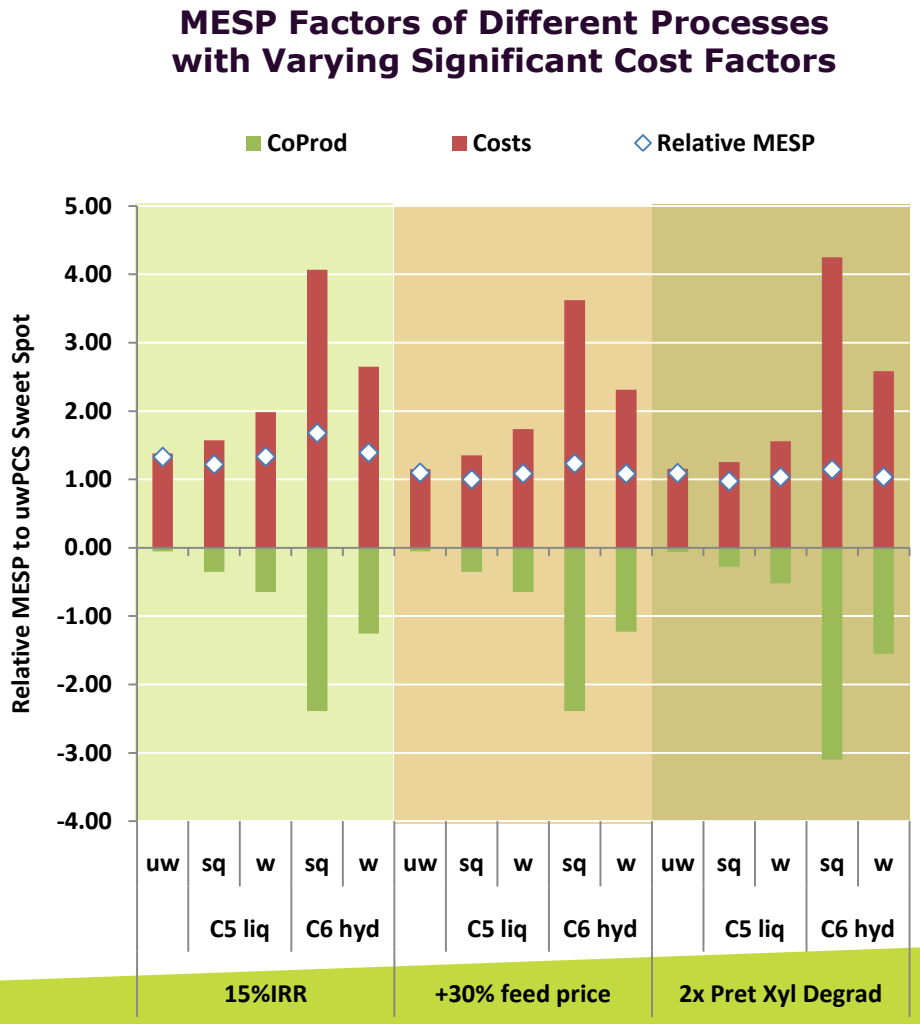
- Tipping point for crude biomass sugars in the area of 300 USD/MT



BASE CASE CONDITIONS: 2000 MT/DAY, 7%IRR, DILUTE ACID PRET, WHOLE SLURRY HYDROLYSIS, C5 FERM

Sweet Spot Results
IRR, Feedstock & Pretreatment

- Profitability requirement impacts cost sensitivity
- Feedstock and Pretreatment have small effect on process differentiation



BASE CASE CONDITIONS: 2000 MT/DAY, 7%IRR, DILUTE ACID PRET, WHOLE SLURRY HYDROLYSIS, C5 FERM

Take Aways

- Biomass sugars can be an effective way to improve the cost picture for 2G Ethanol
- 2G separation technology does not need to be too sophisticated to make biomass sugars as a coproduct
- Specific quality requirements for biomass sugar will drive purification and microorganism development
- C6 to Sugars with C5 to Ethanol is a more interesting case, but more sensitive to cost fluctuations

Thanks

Xin Li
Lorraine Putnam
Haiyu Ren
Sarah Teter
Niels Fischer
NREL

16/10/2012