The biochemical conversion platform for advanced biofuels production

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- Introduction to Novozymes
- Global industry status
- California in particular
- A few noteworthy examples
- Barriers to commercialization
- Brazil as the poster child

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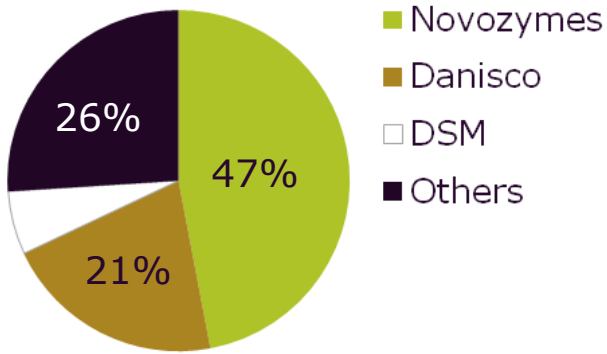
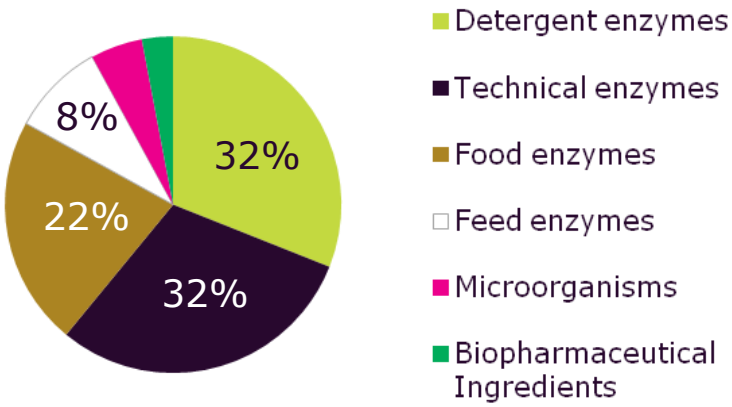
Novozymes in brief

- World leader in industrial enzymes & microorganisms and market leader in all industries where present
- More than 700 products sold in 130 countries in 40 different industries
- Total sales of USD 2 billion in 2012
- 13–14% of revenue invested in R&D
- New products represent around 25% of total sales
- More than 6500 active patents and patent applications

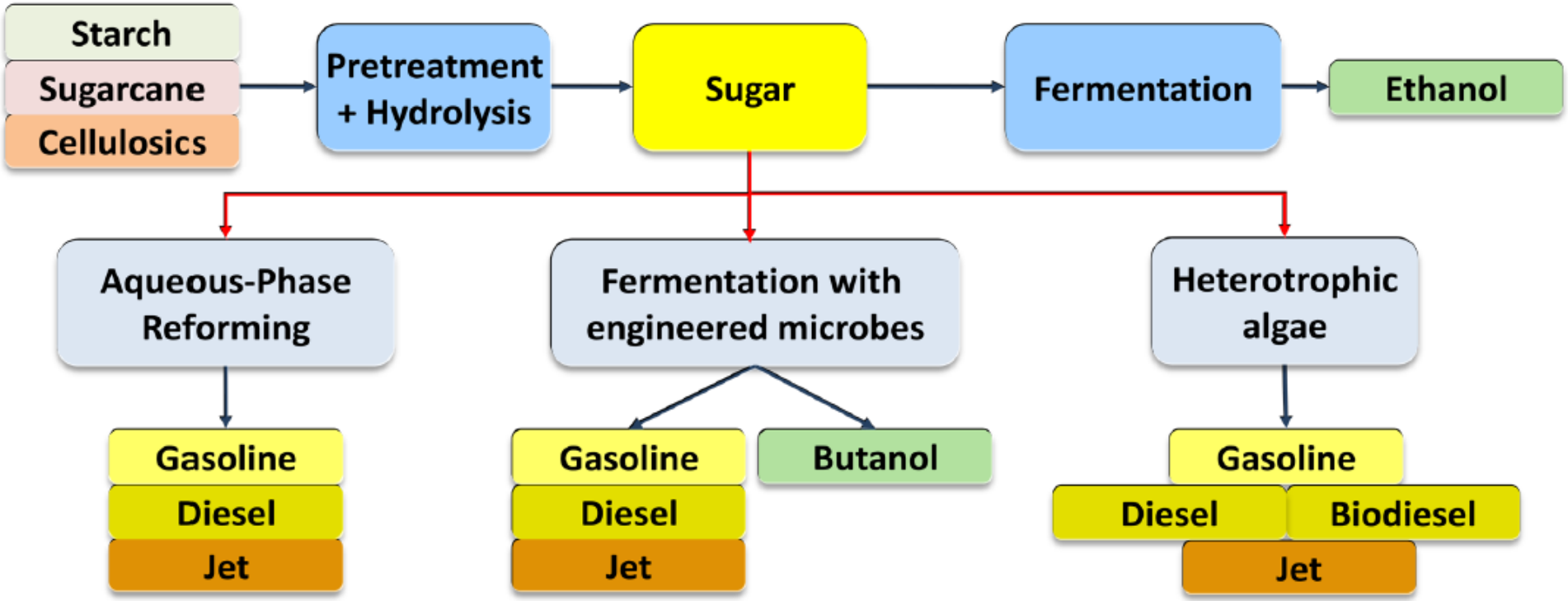
Enzymes for industrial use
Market size ~ USD 4 billion



Distribution of Novozymes' business revenue



Overview of the biochemical platform



Humbird et al., 2011, NREL Technical Report TP-5100-47764

PROGRESS IS MOST APPARENT IN THE FACT THAT
- A CELLULOSIC ETHANOL INDUSTRY IS EMERGING NOW

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FIBERIGHT 2013
Blairstown, Iowa, US
MSW
6 MGY

MASCOMA 2013
Kinross, Michigan, US
Woody biomass
20 MGY

M&G 2015
NC, US
Energy Crops
20 MGY

INBICON 2009
Kalundborg, DK
Wheat Straw
1.4 MGY

MAABJERG ENERGY
DK
25 MGY

M&G (Beta-Renewables) 2013
Crescentino, Italy
Wheat Straw, Energy Crops
13 MGY

POET 2014
Emmetsburg, Iowa, US
Corn Stover
25 MGY

COFCO/SINOPEC 2013
HeiLong Jiang Province, CN
Corn Stover
15 MGY

Dupont 2014
Nevada, Iowa, US
Corn Stover
30 MGY

CANERGY 2016
Imperial Valley, CA, US
Bagasse
25 MGY

ABENGOA 2013
Hugoton, Kansas, US
Corn Stover
25 MGY

RAIZEN 2014
Piracicaba, BR
Bagasse
11 MGY

GRANBIO 2014
São Miguel dos Campos, BR
Bagasse
22 MGY

ABENGOA 2014
Arance, FR
Agricultural Residue
13 MGY

World Map: ***Public info on large scale plants under planned construction; biochemical conversion (capacity in mio. US gallons per year)***

Activity in California

- **Solazyme** uses heterotrophic microalgae to produce oils from sugar. Sugar source is currently sugarcane or corn-based, but could be cellulosic if inhibitor problems can be solved. Currently concentrating on high-value, relatively low volume "designer triglyceride" market rather than commodity fuels.

- **LS9 and Amyris** use metabolically engineered microbes to synthesize a range of chemicals and potential fuels, currently various fatty alcohols, esters, isoprenoids, biodiesel and jet fuel. Feedstock for microbes can be glycerol or sugars obtained from various sources including (in theory) hydrolysis of cellulosic biomass.

- **Canergy** recently announced a collaboration with Beta Renewables/Chemtex to build a 25 MGPY cellulosic biofuels facility in the Imperial Valley. Scheduled for start of construction in early 2014 and commissioning in 2016. Biomass source will be energy cane (high fiber cousin of sugarcane).

We are witnessing the birth of a new industry - Crescentino, Italy

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- World's first commercial 2G plant, currently operational well before competition
- Initial capacity ~13 MGPY, scalable to 20.
- Licenses expected to be sold in LA, NA and EMEA during 2013
- First 3rd party license closed and operational in Brazil by Q1/Q2 2014

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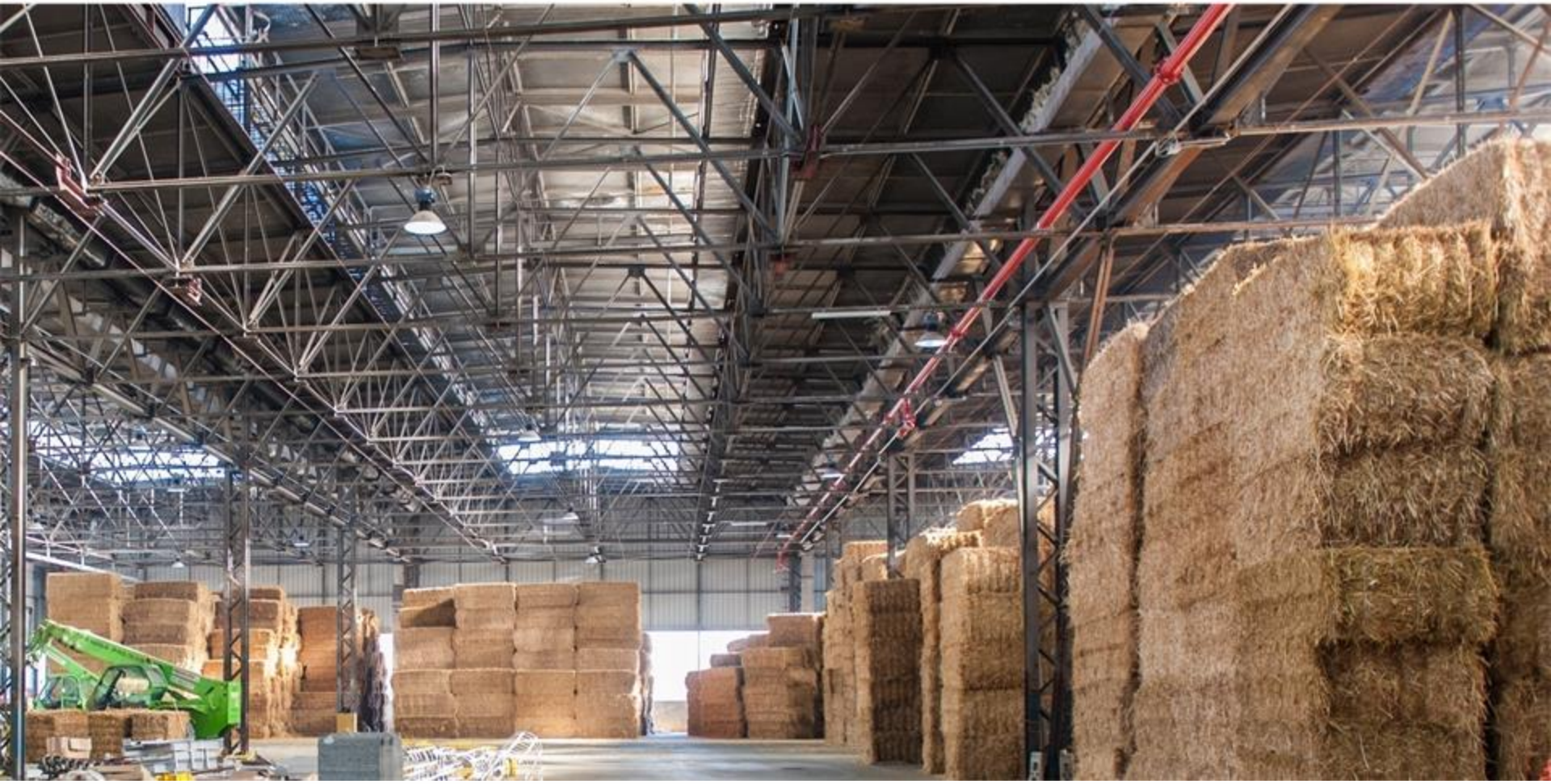
Feedstock storage - Crescentino



It will require 5-6 truck loads of biomass per hour when running at full capacity. Initial feedstock wheat straw.

Relevance of Crescentino to California

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- The same technology will be used to build the Canergy biorefinery in the Imperial Valley.

- One of the near-future feedstocks for Crescentino will be *Arundo donax* (giant cane), a plant that grows well in California. It is drought resistant and has minimal tillage, fertilizer and pesticide requirements.

- Northern Italy is the largest rice-growing region in Europe and rice straw is slated to be a future source of biomass at Crescentino.

Fiberight - MSW TO BIOFUELS

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- Every year about 250 million tons of municipal solid waste are generated in the US. This represents a potential for production of 5 billion gal of fuel.
- Fiberight, based in VA, is utilizing the biopulp fraction (~25% of MSW) to produce cellulosic sugars and then fermenting to ethanol. The pulp solids left over are used to generate various co-products such as fertilizer, pressed panel boards, road materials and animal absorbents.
- A pilot facility in VA has demonstrated the commercial feasibility of the approach.
- Fiberight has obtained a $25 million loan guarantee from the USDA to build a commercial facility in Iowa. A total of $50 million will be invested with construction to begin later this year. Expected capacity is 6 MGPY.
- If successful, they are targeting expansion to communities with populations of 100,000 or more in a 5 mile radius, particularly if they have high trash disposal costs and/or landfill limitations.

Barriers to commercialization

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- **The "blend wall" -** adoption of E15 has been negligible due to concerns (real or imagined) of potential vehicle damage and effects on small engines. Given the recent decrease in overall gasoline consumption, the ethanol requirements for E10 in the US can be met with corn ethanol alone.
- **Infrastructure -** the blend wall could be surmounted through increased use of E85, but that is hampered by a lack of pumping infrastructure and flex fuel vehicles outside of the Midwest (about 4.5% of the light vehicle fleet is flex fuel).
- **"Loopholes" in the RFS -** the RFS mandates a certain amount of "advanced" biofuel (e.g. cellulosic ethanol and biodiesel) be blended into the fuel supply (2.75 billion gal in 2013). Brazilian sugarcane ethanol qualifies as an advanced biofuel whereas corn ethanol does not. Ironically, this has led to the importation of Brazilian ethanol (490 MGal in 2012) into the US despite an abundance of cheaper domestic corn ethanol.*
- **High capex for cellulosic biofuels plants -** first generation plants of commercial size are costing upwards of $300 million with a capex of $6 to $12 per gallon (depending on technology employed). Much of the capex arises from the pretreatment equipment, wastewater treatment and boiler for energy production.

*A bill was recently introduced in the US Senate to close this loophole.

Barriers to commercialization

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- **Feedstock supply and logistics -** how and where to grow sustainably, how much will it cost, and how to get it to the biorefinery
- **Pretreatment expense -** most cellulosic biomass requires expensive pretreatment to overcome its recalcitrance to enzymatic hydrolysis
- **Enzyme cost -** while great strides have been made, more can be done

Brazil as the poster child for cellulosic ethanol

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Government Direct Incentives:

- Starting May 1st, **increase in mixing anhydrous ethanol into gasoline** from 20% to 25%.
- **Cut in Ethanol taxes** PIS (Social Integration Program) and COFINS (Contribution to Social Security Financing) summing up to **$.25 per gal of ethanol** (10% of the retail price). **Generate a tax waiver of around $500 million** in 2013.
- Reduction of interest rates for a BNDES (National Bank for Economic and Social Development) line **from 9.5% to 5.5% per year**. With **$2 billion credit for the renovation and creation of new sugarcane plantations**.
- Also lower interest rates for **ethanol storage from 8.7% to 7.7%, per year**. Resources of around **$1 billion** credit from BNDES.
- **Starting in, 2014 illegal to burn the sugarcane field residue**. Mechanical harvest becomes mandatory and **increases the amount of biomass in the fields** (15 tons per ha of straw).
- **Energy prices being pressured down** by President Rousseff herself (**16% decrease** for the industry).

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Government Indirect Incentives:

- **BNDES Debt arm** has already committed more than **$1 billion** in financing lines for 2G projects in a program launched in 2012 (**PAISS I**) and is going to launch this year a new program (**PAISS II**) for more than **$1.5 billion.**
- **BNDESpar** (Equity arm) has invested **$300 million,** acquiring **15% of GranBio** and according to our clients **will invest about the same amount split into 2 more Brazilian companies this year acquiring a 10 to 20% equity stake of each**.
- **FINEP**: Research funds of **$500 million** from the government - willing to finance 2G projects with science based technical innovations.

The Industry's Moment:

- **Venture Capital funds and Private Banks,** such as TPG and Itau BBA **have already committed capital** to participate in 2G projects in Brazil. For example, TPG has committed **$200 million**.
- **60% of the industry doesn't have room to grow more cane plantations** due to consolidated agricultural areas and **must seek alternatives to add value to their existing assets**. 2G is a potential solution.

Brazilian players getting more concrete…

Started construction of 1st 12 MGPY plant in Alagoas

Plans to build a Demo Plant of 7 MGPY in 2014 with Guarani or São Martinho.

Announced partnership with Inbicon and the intention of building a Demo Plant in 2014.

TMO is investing an initial $30 million with Brazil's Usina Santa Maria to open a 2.5 MGPY cellulosic bioethanol plant in 2014.

Solid Pipeline being built

Announced the construction of 10 plants and the production of 500 MGPY of 2G EtOH in 10 years

Will start building a Demo Plant of 1 MGPY in 2013, aiming to sell licenses to sugar & ethanol players in 2016

QUESTIONS?