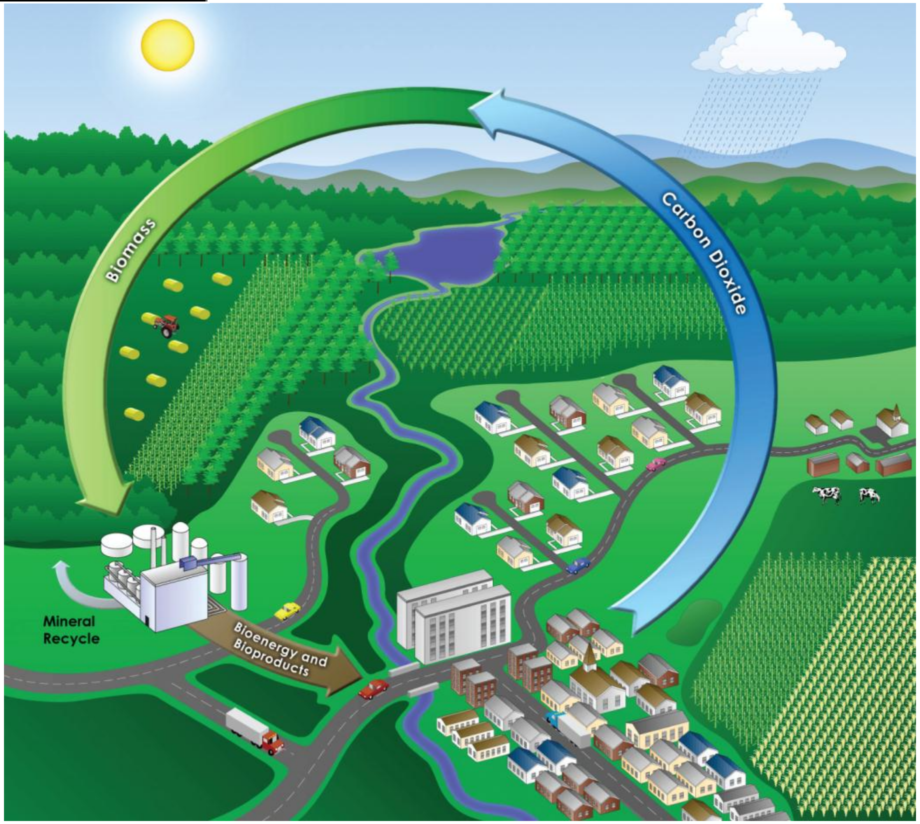
Development of Cellulosic Biofuels

FAPESP
BIOEN-BIOTA-PFPMCG-SCOPE Joint Workshop on Biofuels & Sustainability
26/02/2013 - FAPESP - São Paulo

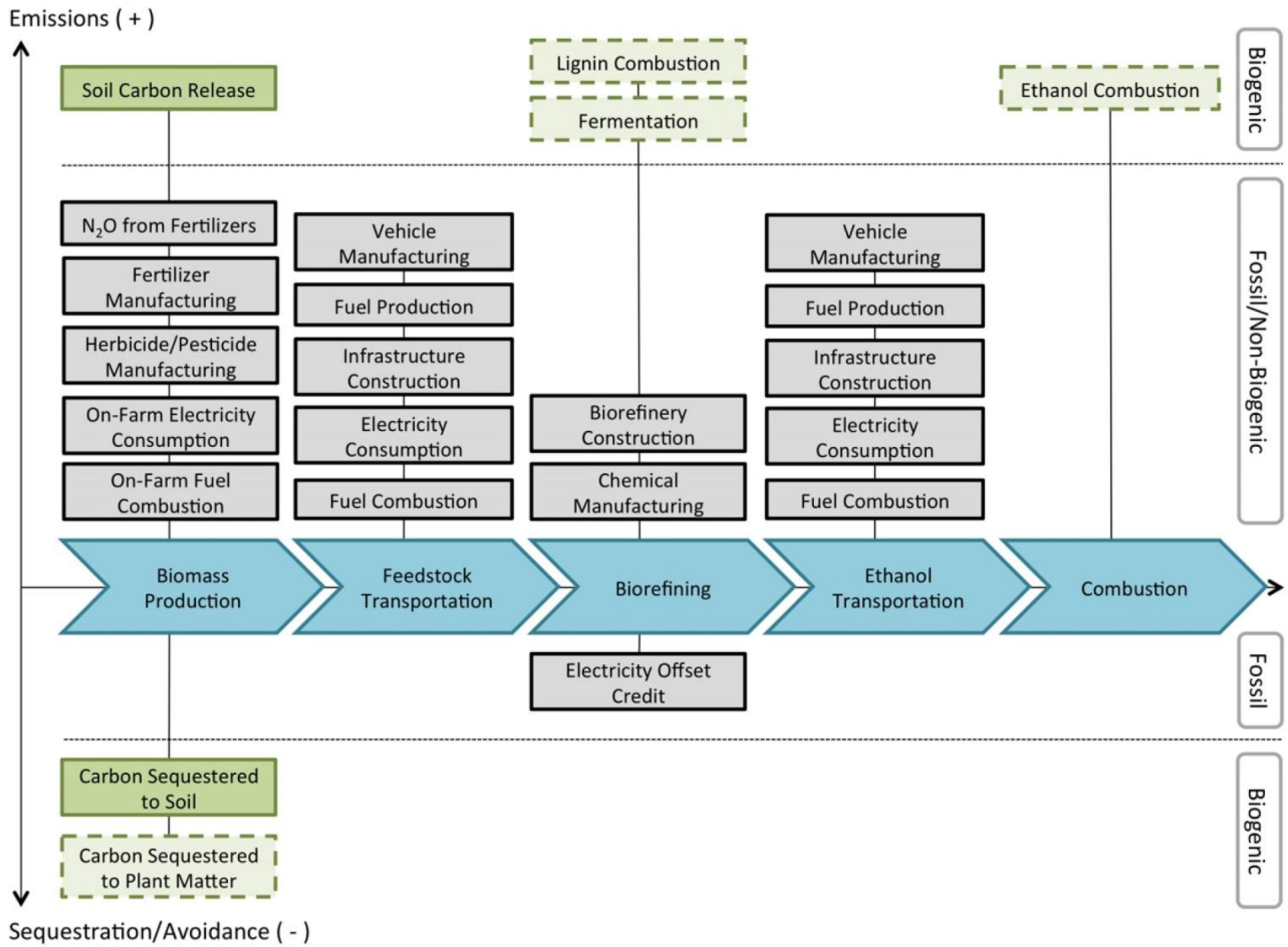


Chris Somerville
Energy Biosciences Institute
UC Berkeley, LBL, University of Illinois

The Energy Biosciences Institute

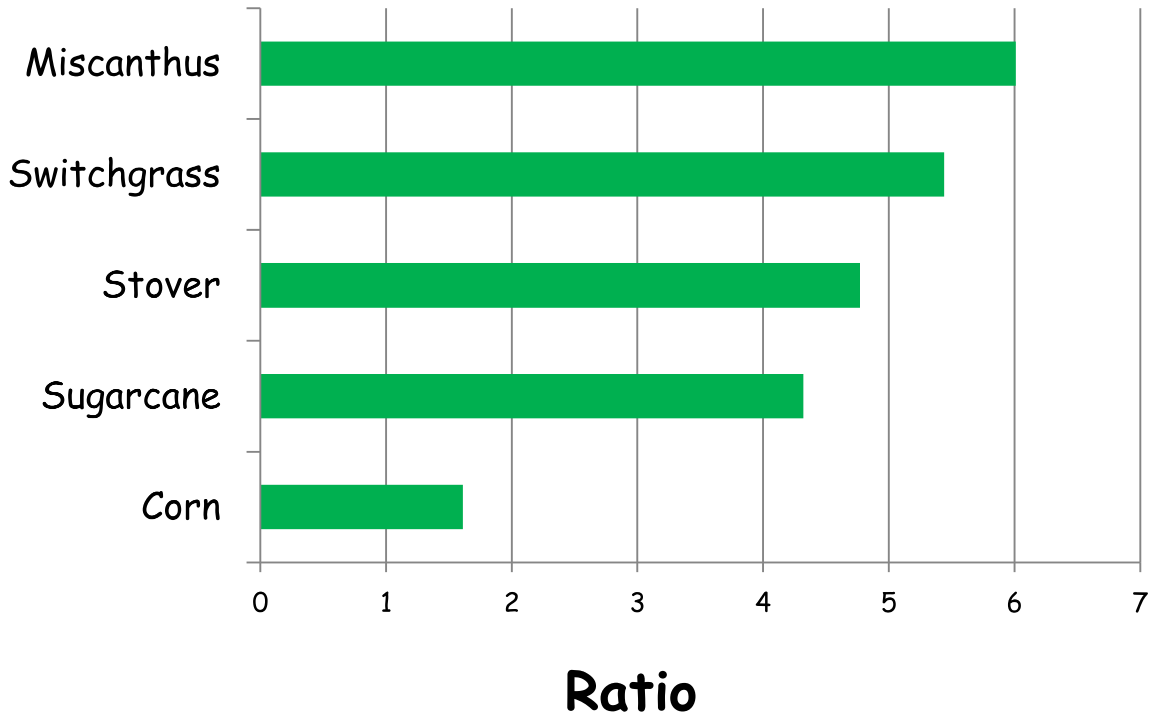
- $500M committed over 10 years
- Research mandate to explore the application of modern biological knowledge to the energy sector
  - Cellulosic fuels
  - Petroleum microbiology (eg., corrosion, souring, reservoir flow, remediation…)
  - Bio-based chemicals

Scope of life cycle analysis of GHG emissions from production of lignocellulosic ethanol



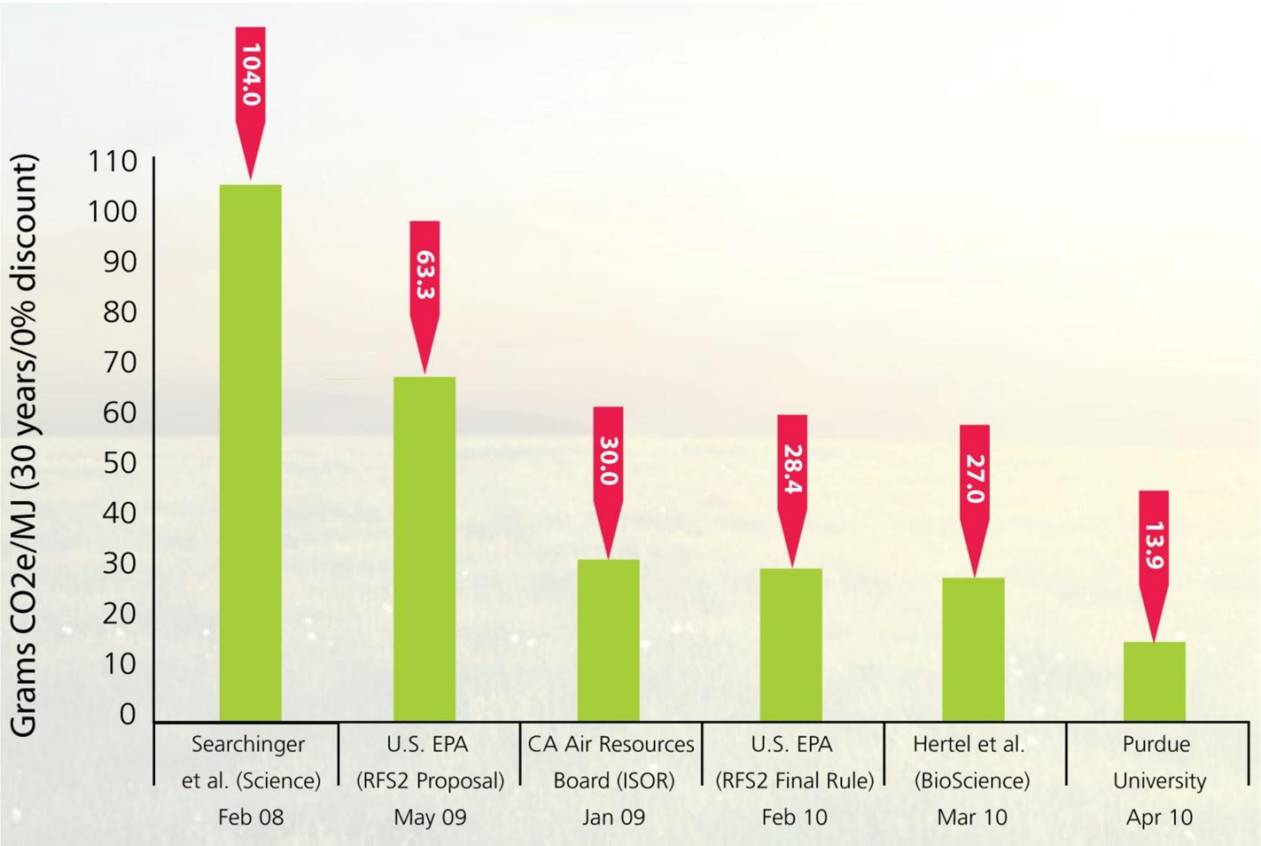
Scown et al Environ. Res. Lett. 7 (2012) 014011

Net Energy Yield of Biofuels



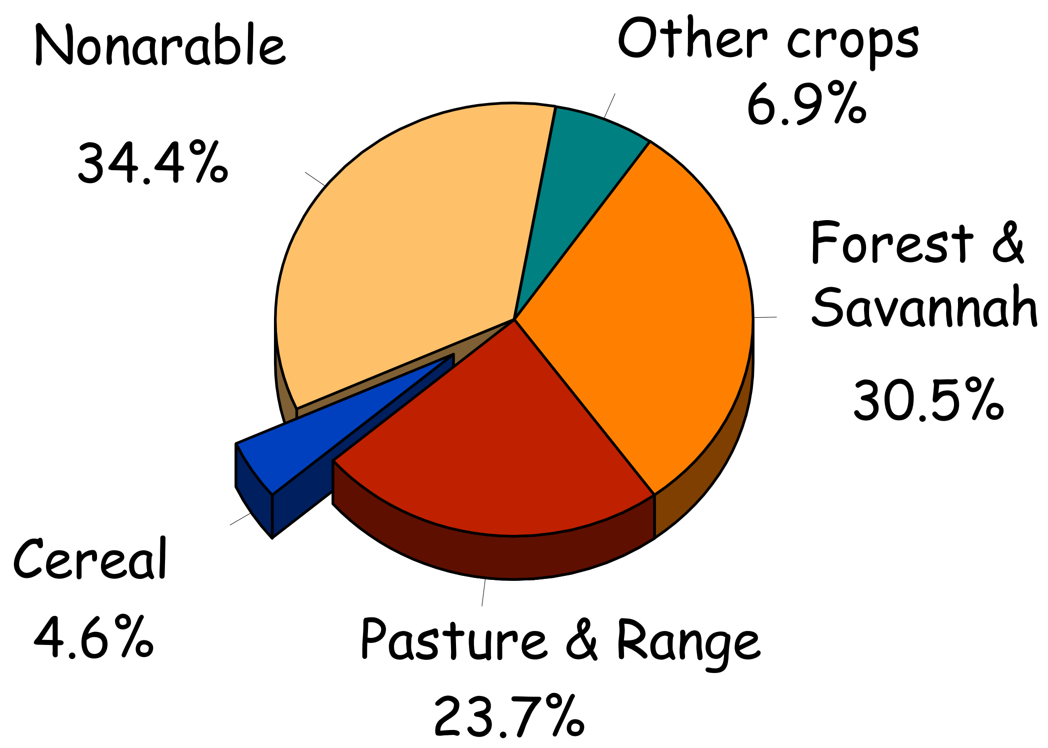
Wang et al., Env. Res. Lett7, 045905

Magnitude of ILUC effects uncertain
(ILUC = indirect land use change)



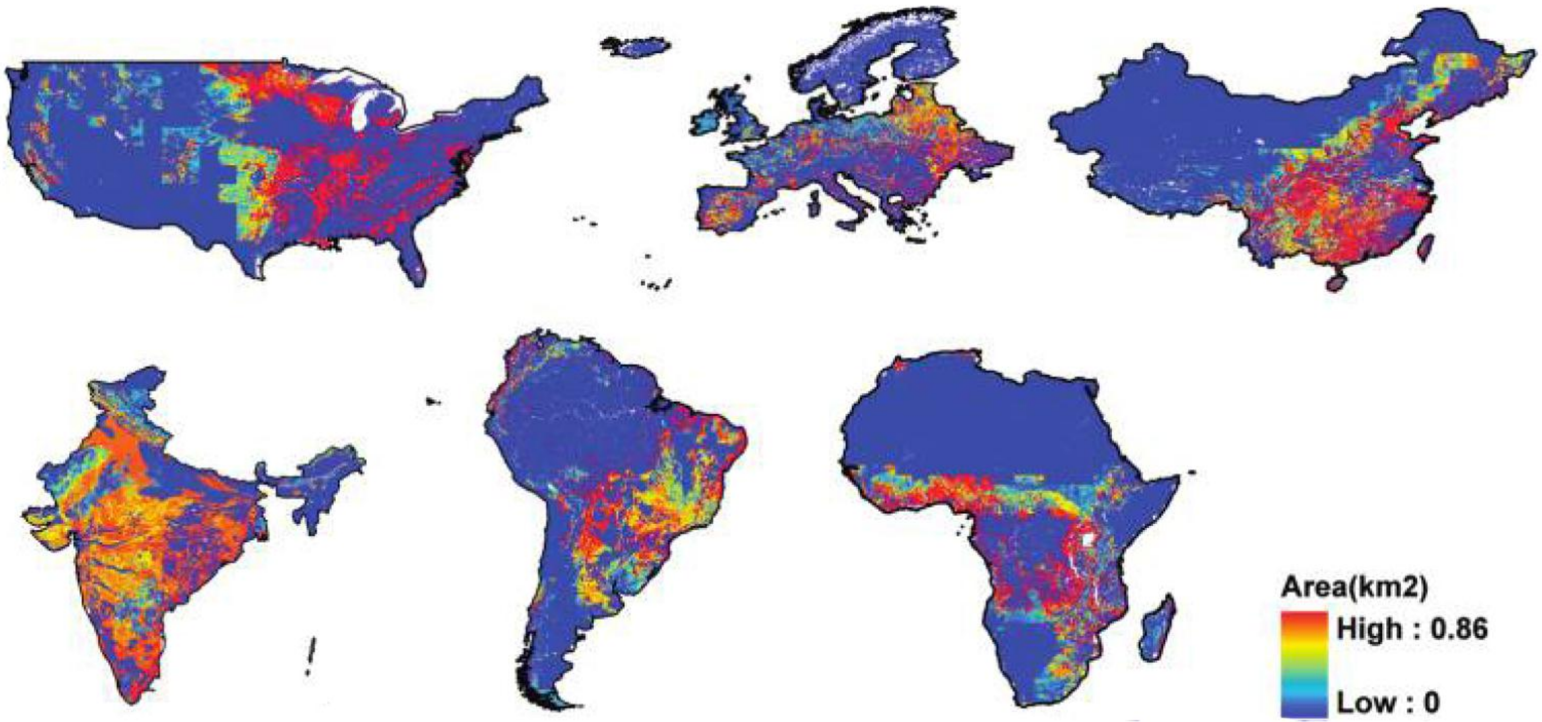
Source: RFA, 2011

Land Usage



AMBIO 23,198 (Total Land surface 13,000 M Ha)

More than 1.5 billion acres of degraded or abandoned land is available for cellulosic crops



Cai, Zhang, Wang Environ Sci Technol 45,334

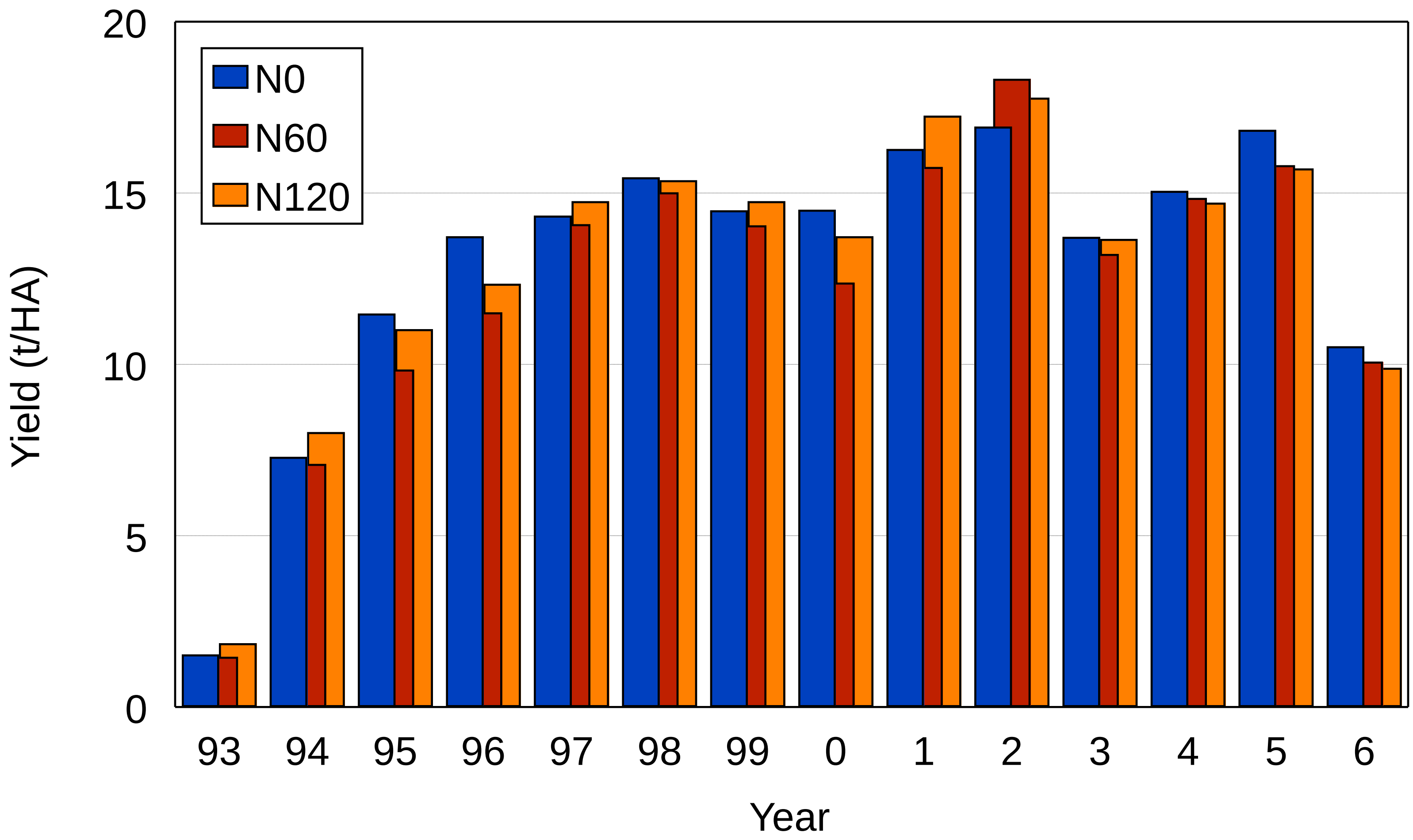
Campbell et al., Env. Sci. Technol. (2008) 42,5791

Miscanthus gigantaeus: An energy crop

Yield of 26.5 tons/acre observed by Young & colleagues in Illinois, without irrigation

Courtesy of Steve Long et al

Response of Miscanthus to nitrogen fertilizer



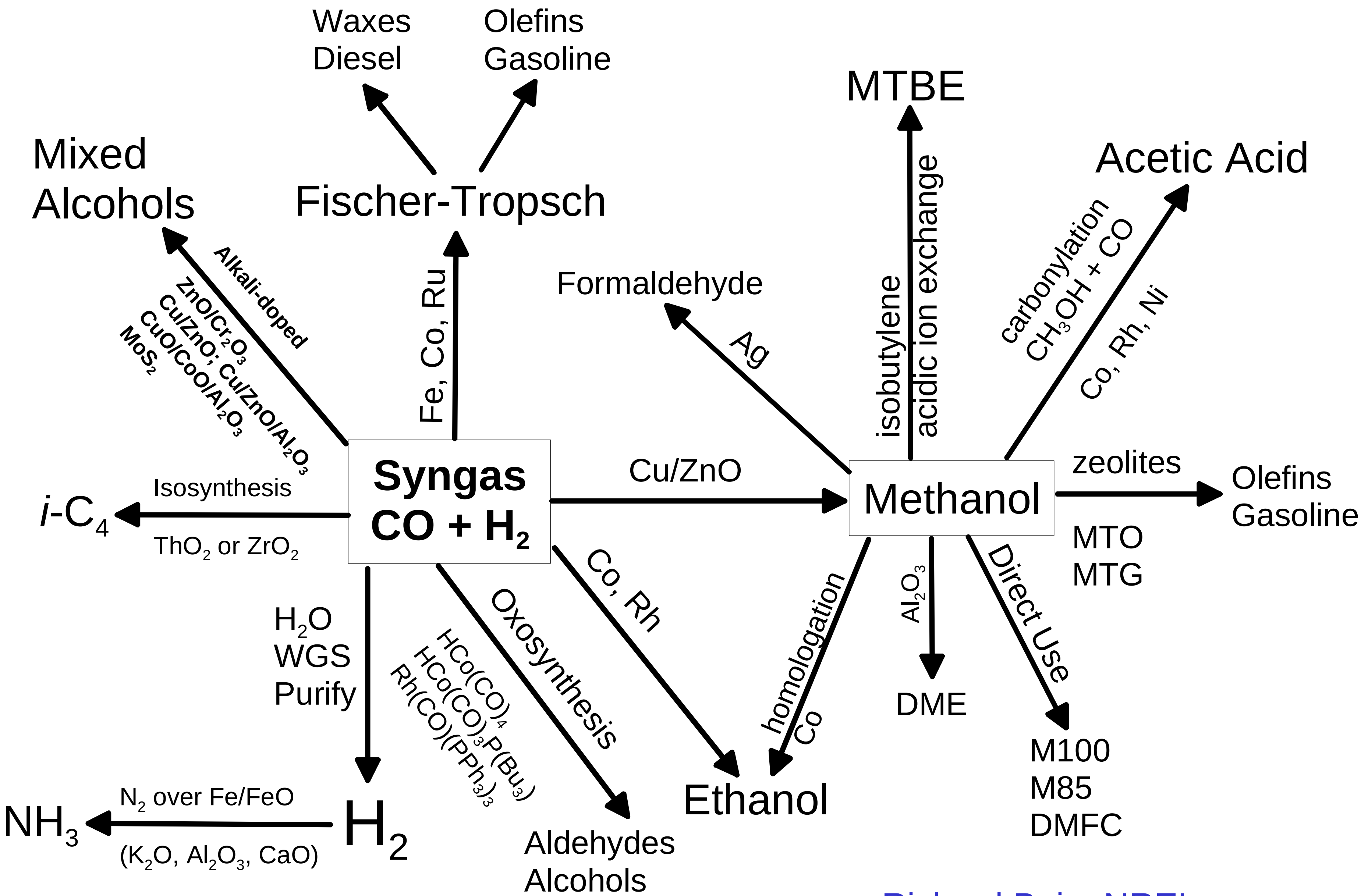
Christian, Riche & Yates Ind. Crops Prod. (2008)

Desert plants can greatly expand the availability of land for biomass production

(Agave in Madagascar)

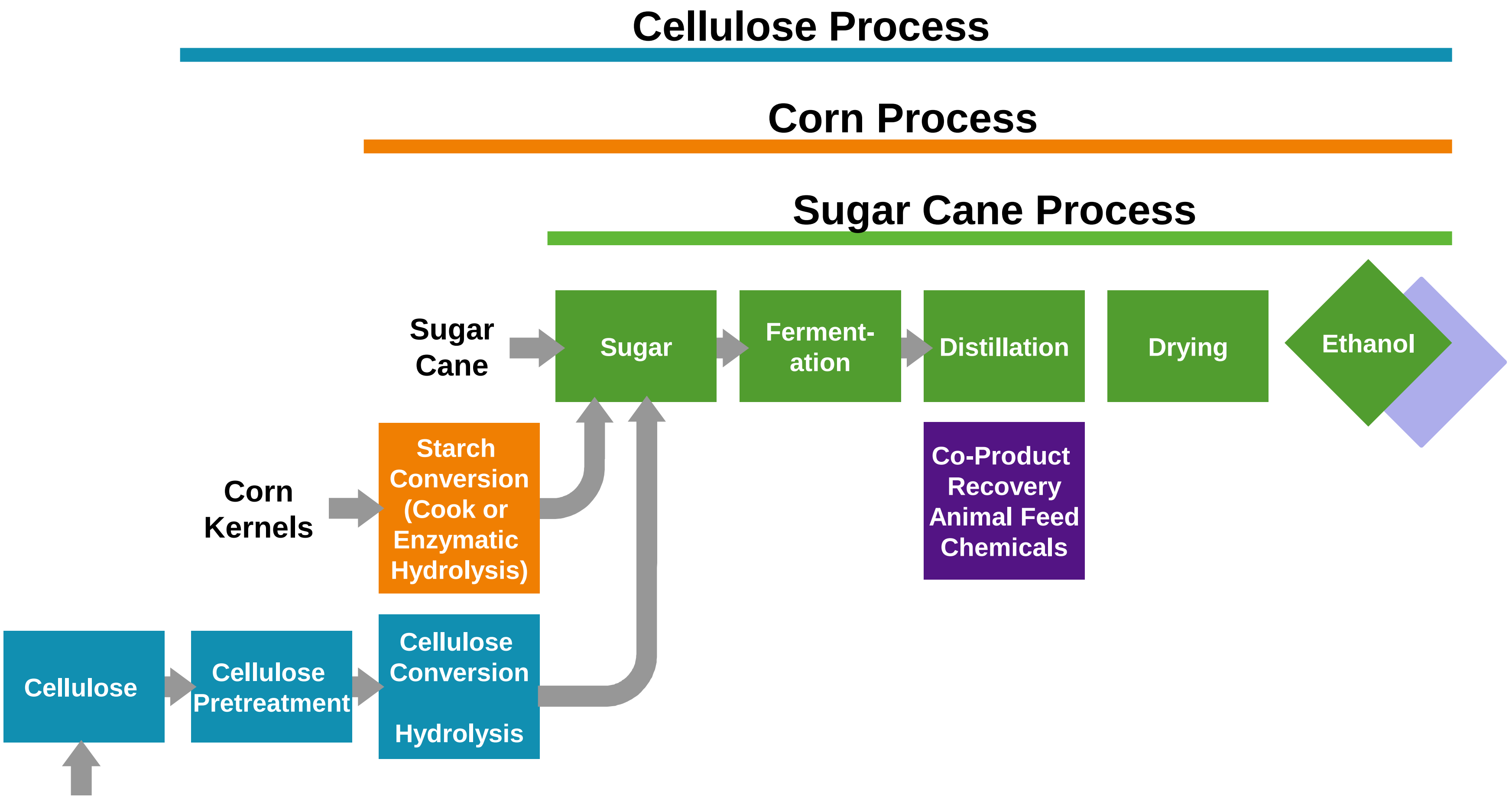
Borland et al. (2009) J. Exp. Bot. doi:10.1093/jxb/erp118

Summary of Syngas-Liquids Processes



Richard Bain, NREL

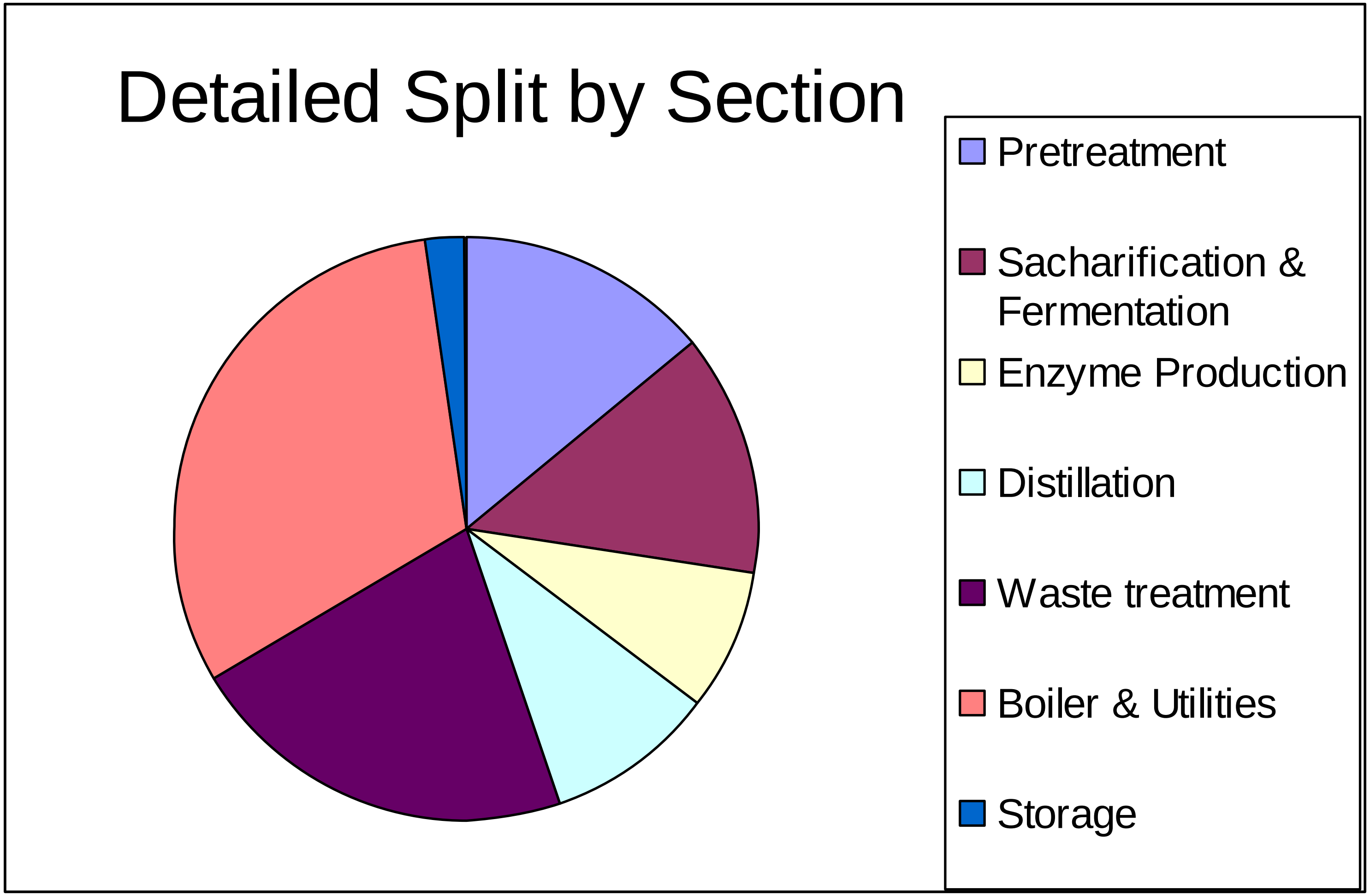
Ethanol Production Schemes



- Miscanthus
- Switchgrass
- Forest Residues
- Ag Residues
- Wood Chips

Slide Courtesy of Bruce Dale

Breakdown of Capital Costs for NREL Biorefinery

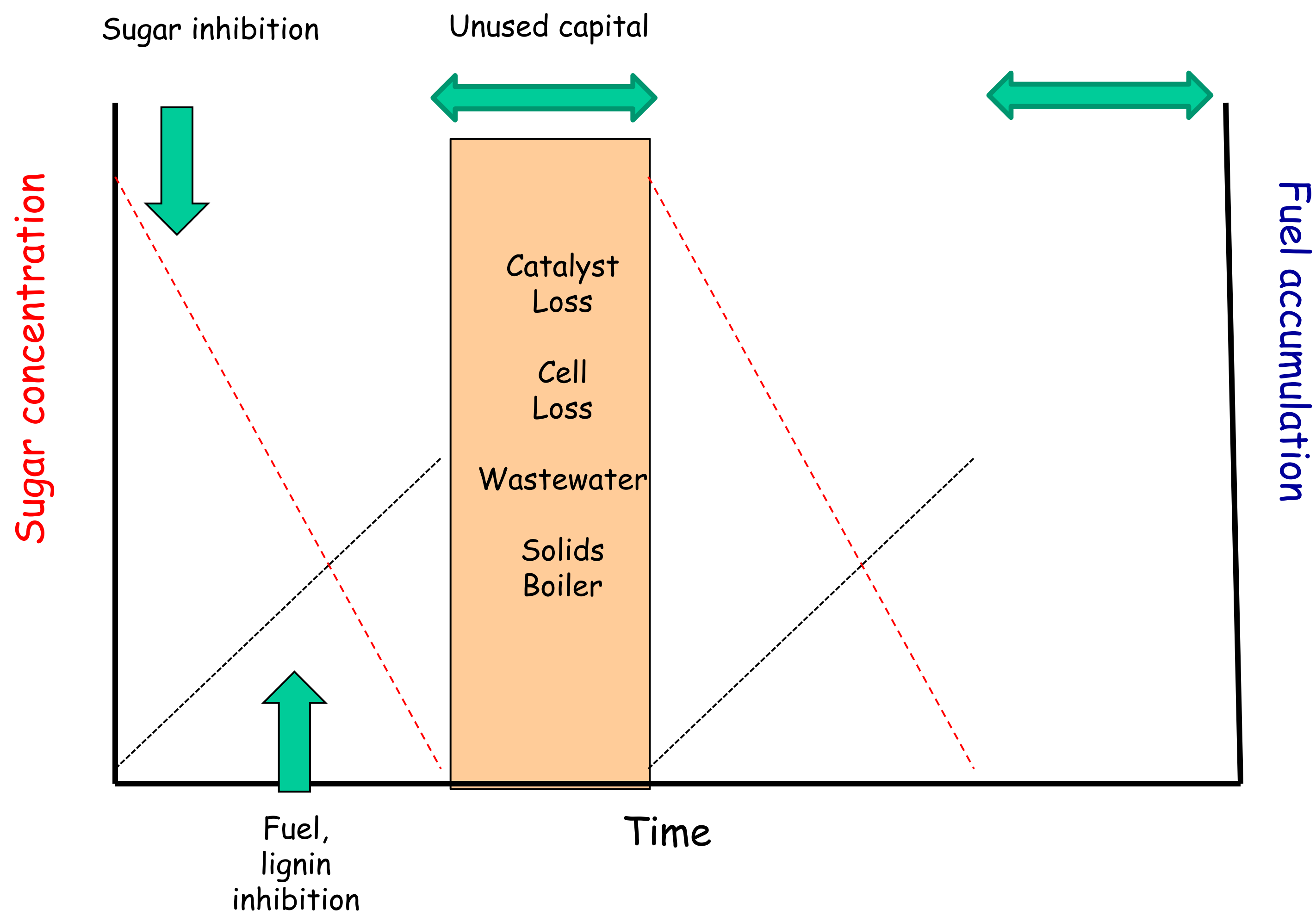


Source : Paul Willems from NREL design, May 2011

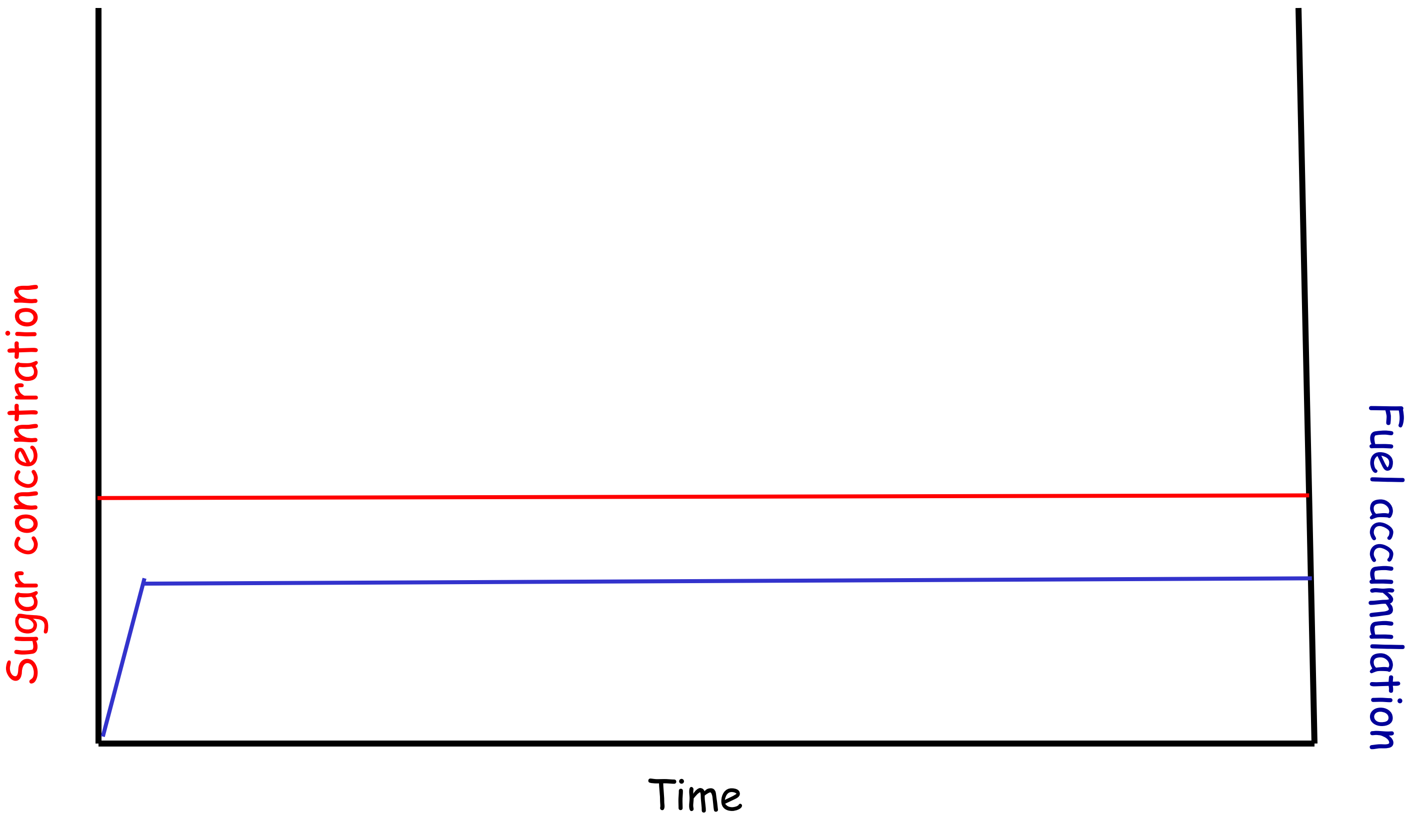
Strategies for reducing costs

- Reduction in capex
  - Minimize number of unit processes, minimize residence time, minimize down time, eliminate solids boiler, minimize wastewater
- Reduction in opex
  - Operate under optimal conditions (sugar, fuel, nutrients, temperature…), minimize enzyme inactivation, recycle enzyme, maximize longevity, control contaminaion

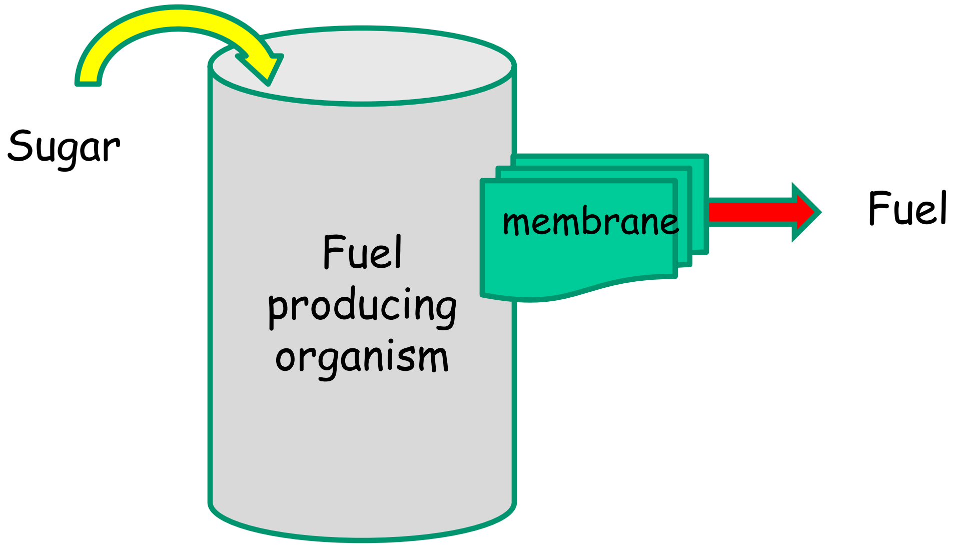
Batch processes have many inefficiencies



An ideal process



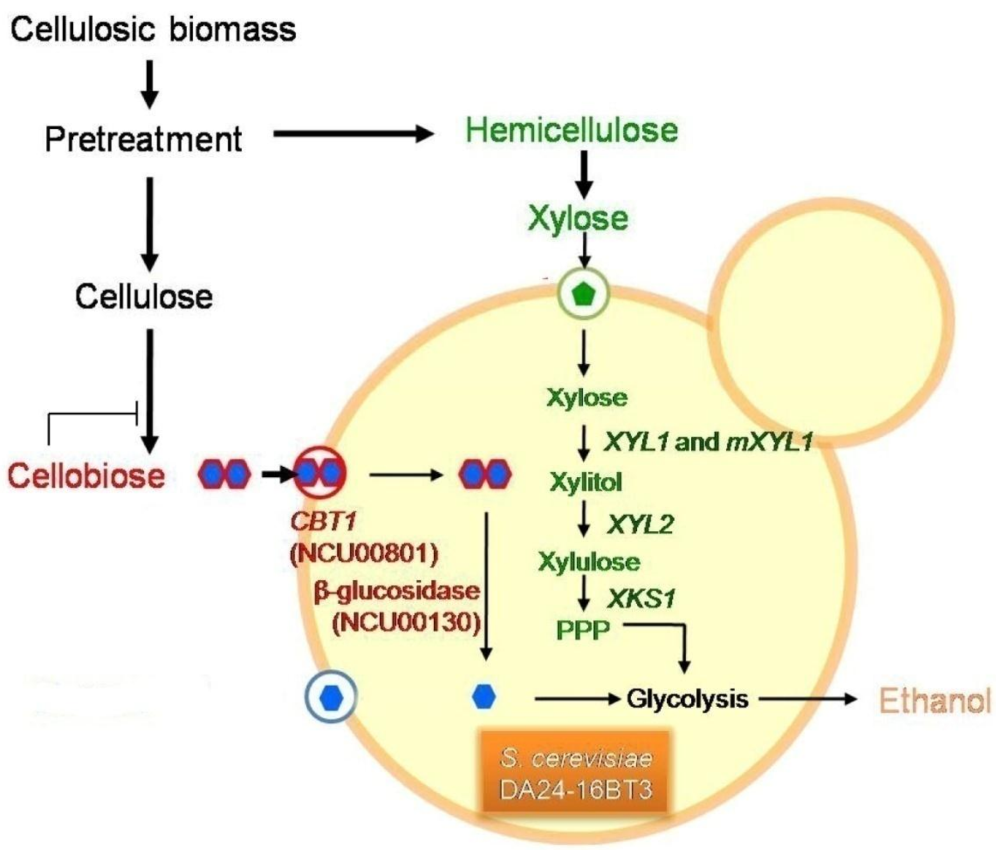
Plugged reactor concept based on continuous removal of fuel

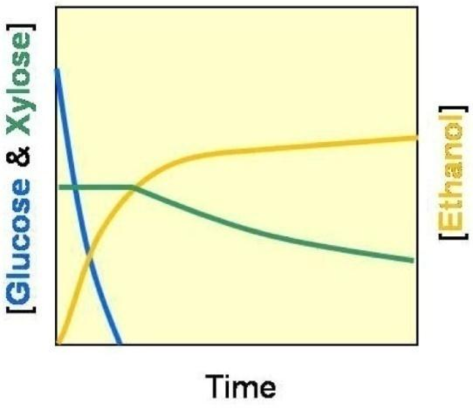


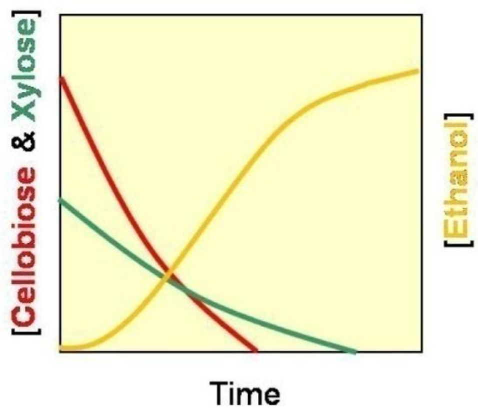
Major challenges to continuous process

- Remove all lignin without losing sugar
- Simultaneous utilization of all sugars
- Continuous fuel removal
- Hygiene

Use of cellobiose instead of glucose allows simultaneous conversion of xylose to ethanol

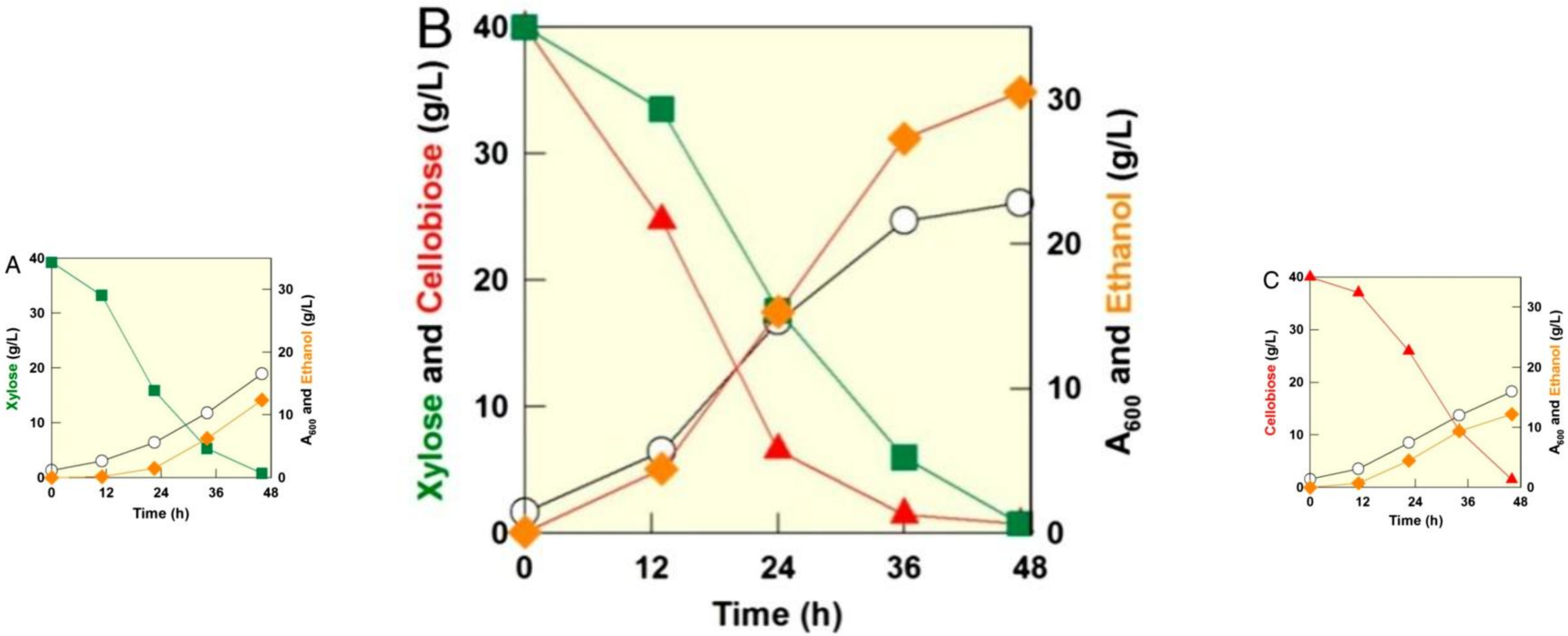






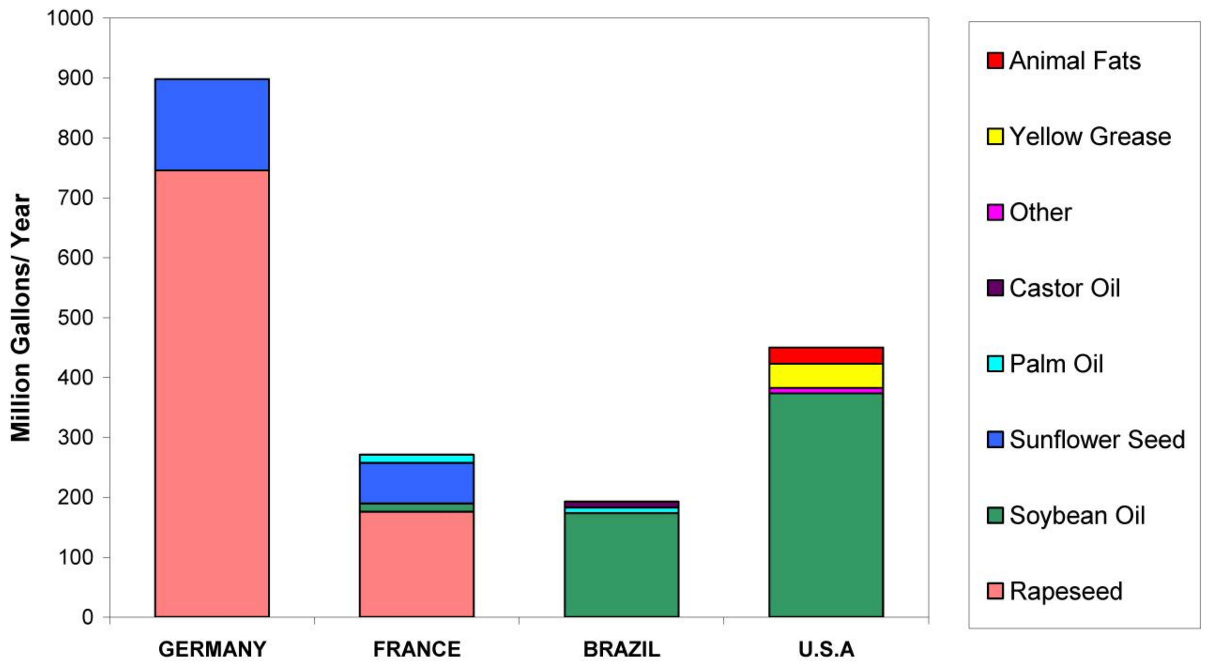
Ha et al *PNAS 2011 108 (2) 504-509*

Simultaneous fermentation of pentose and hexose sugars

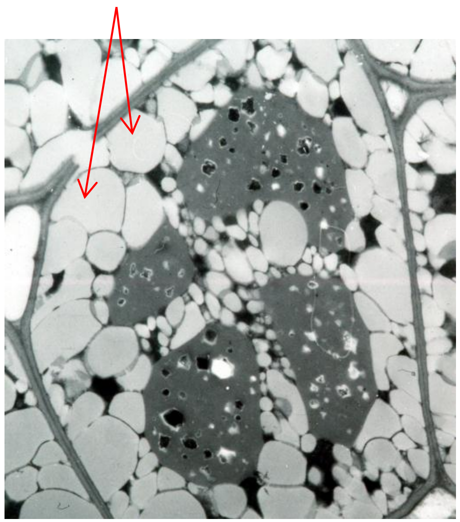


Ha et al PNAS *2011 108 (2) 504-509*

Sources of biodiesel



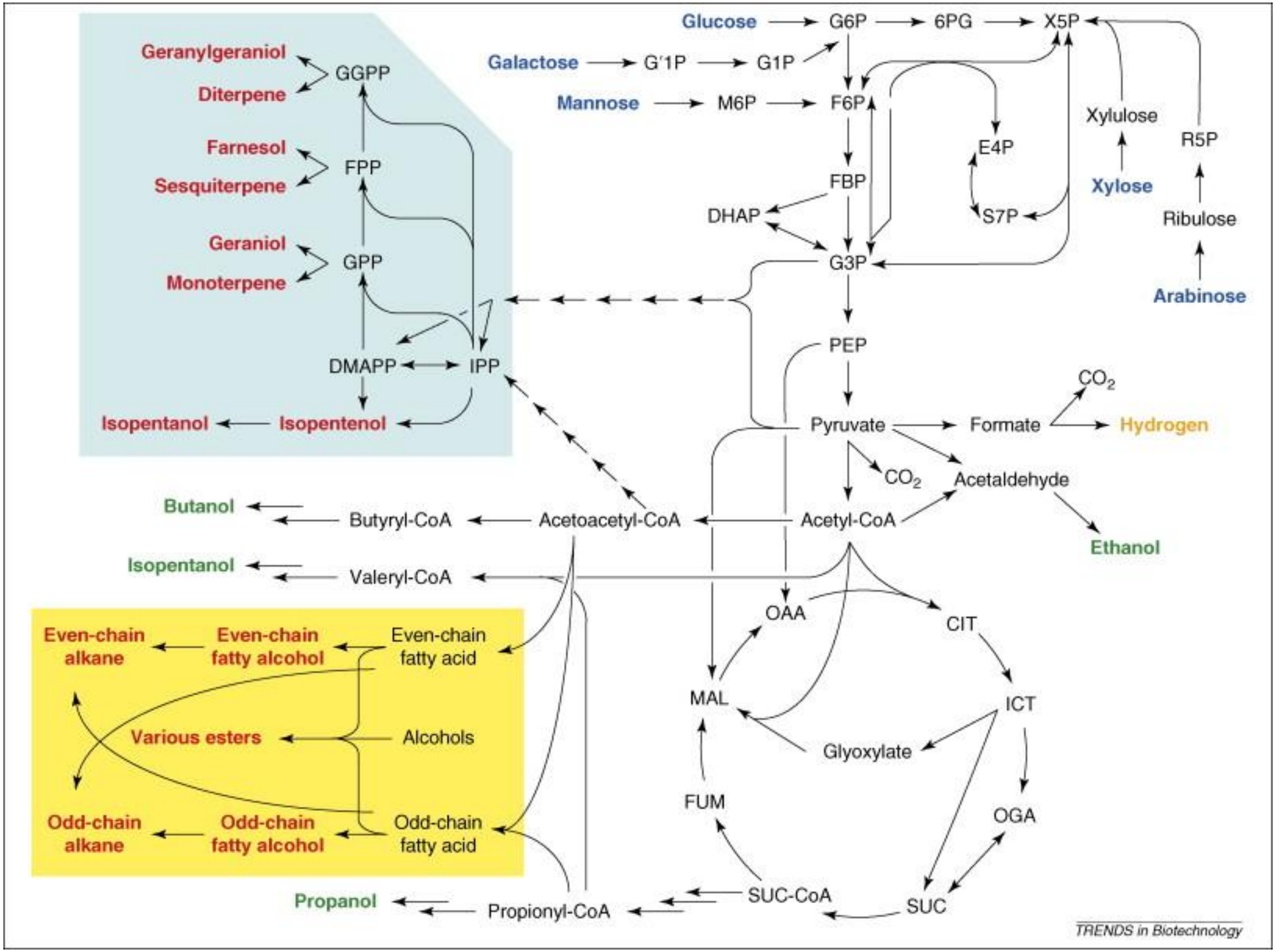
Triacylglycerol



Electron micrograph of a cell in an oilseed cotyledon

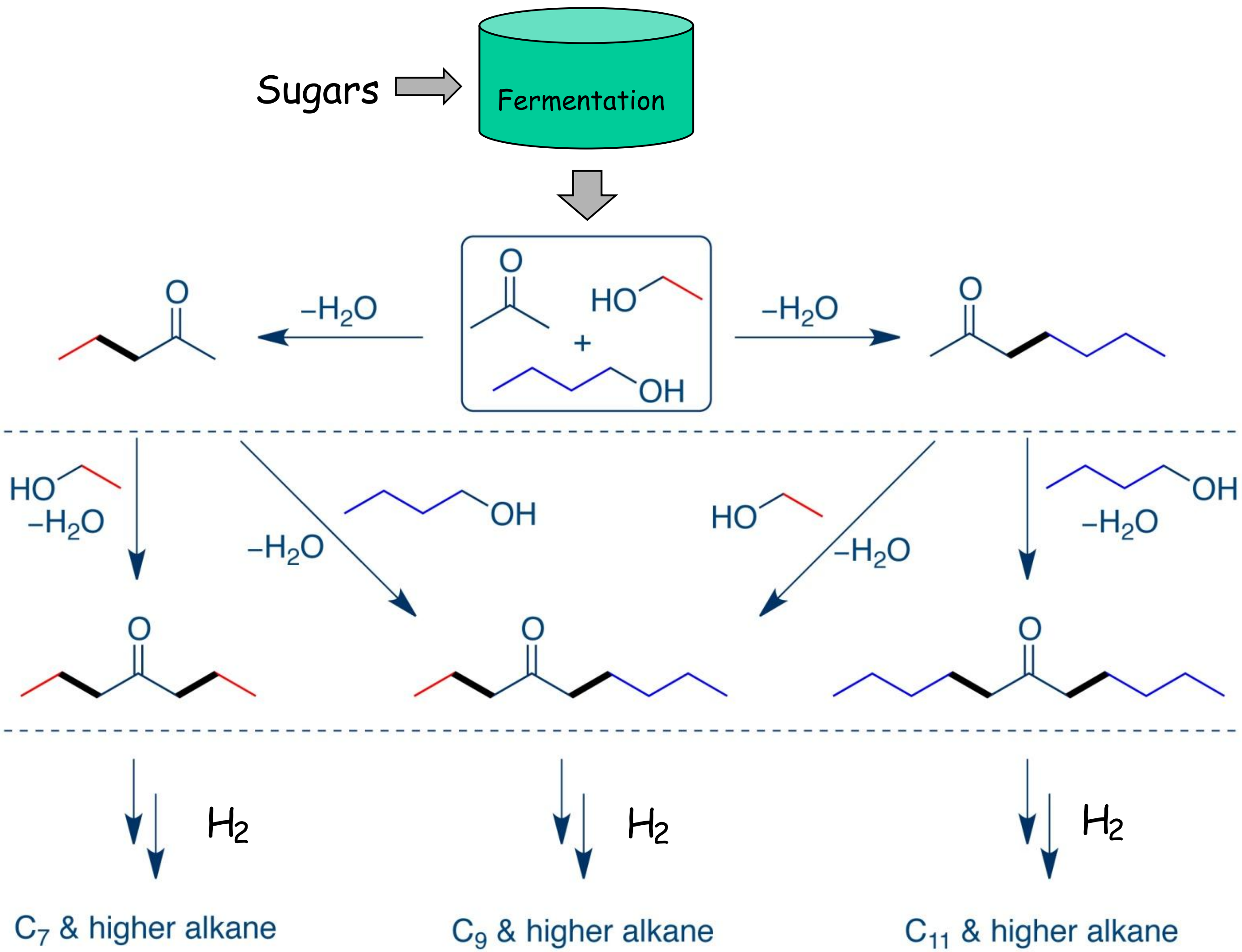
CRC Report AVFL-17

Routes to potential fuels



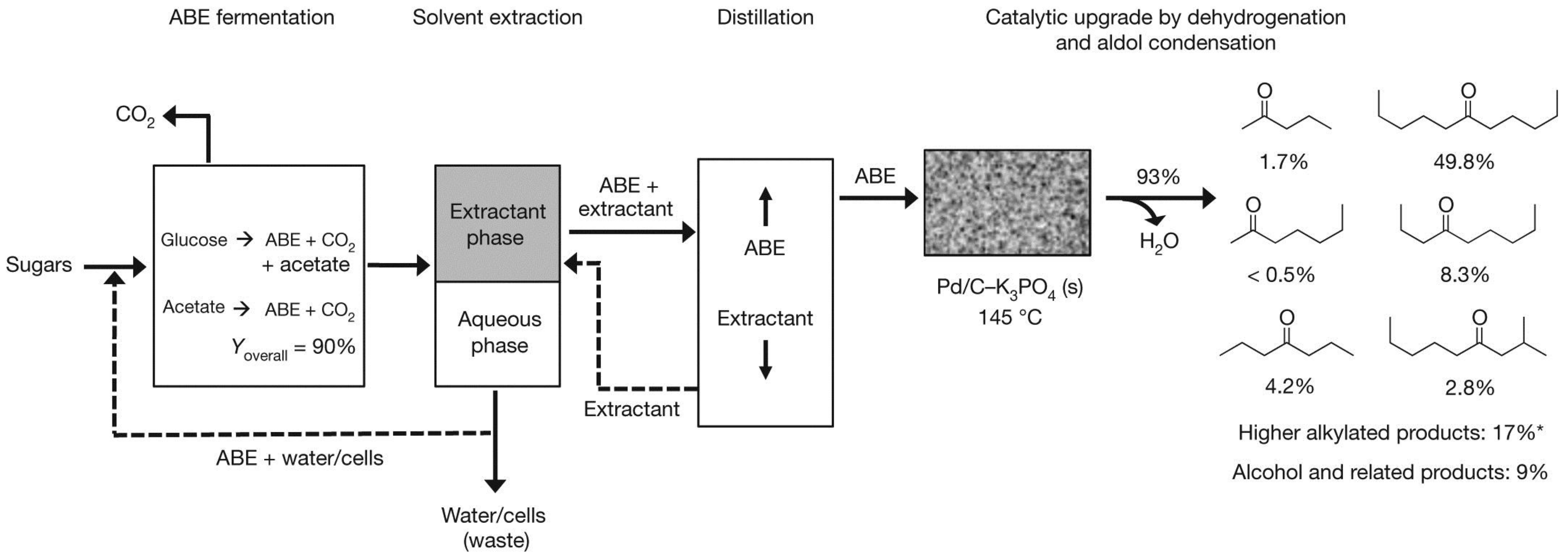
Fortman et al, Trends Biotechnology 26,375

An example of hybrid fuels



Toste et al, Nature 2012

A Process Scheme for Production of ABE-Diesel

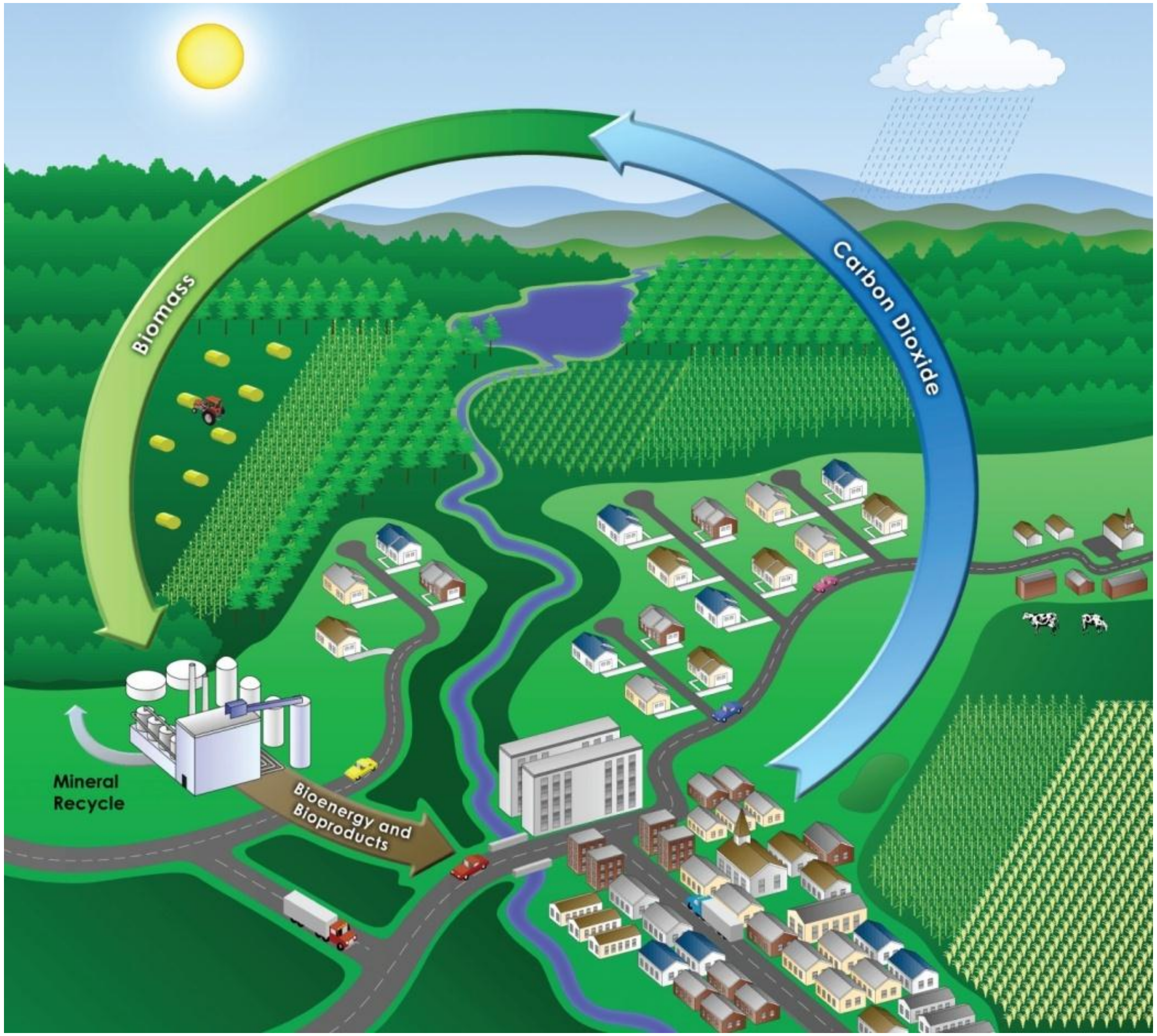


Workshop
March 11

Anbarasan, Baer et al, Nature doi: 10.1038/nature11594 (2012)

Concluding comments

- Biofuels *can* have significant net GHG benefits
- There is significant underutilized land available for expanded biomass production
- We will see a gradual transition from feed crops to cellulosic biofuels (and sugarcane)
- There are are many opportunities to fundamentally improve the efficiency of production and diversification of biofuels
- Drop-in and "hybrid" fuels will expand the types of fuels and extend supply



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