Towards an Interdisciplinary Approach to Next-Generation Biofuels

Environmental, Techno-Economic, and Governance Perspectives

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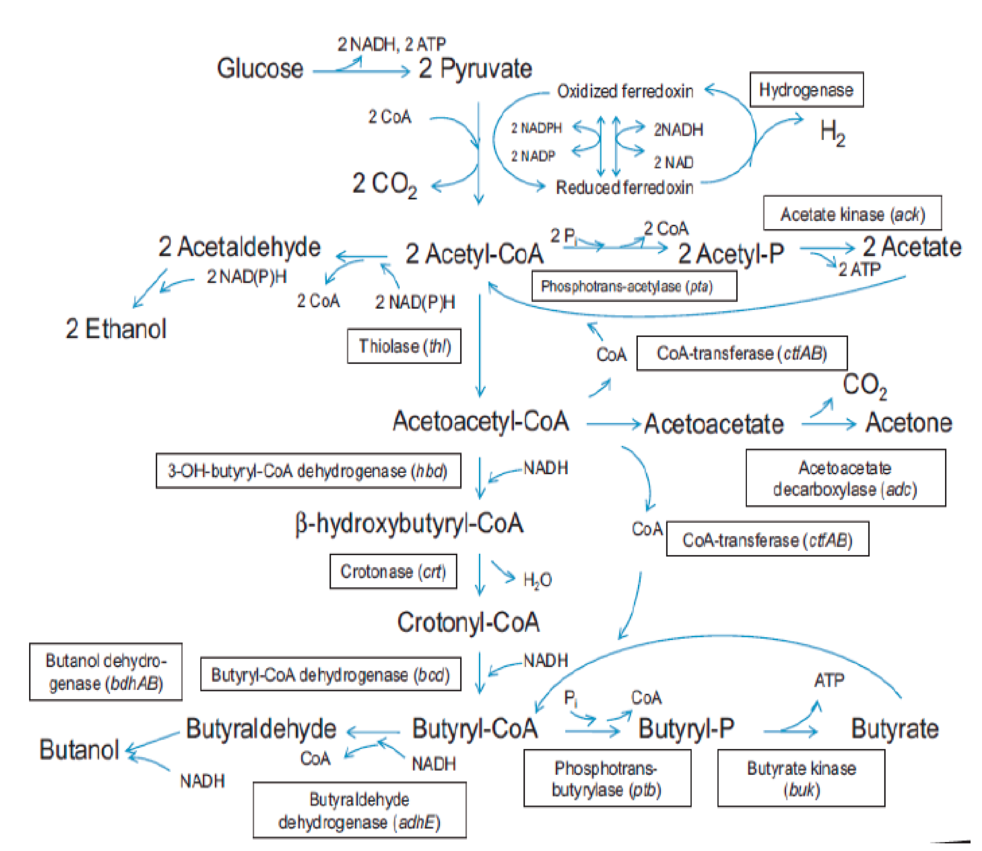
Introduction

Higher-order alcohols are an attractive set of potential fuels due to their high energy content, relative imiscibility in water, and compatibility with native microbial metabolic systems. These factors, along with their early value as platform chemicals and the potential to make use of abandoned ethanol facilities, makes them particularly commercializable - a viable substitute for today's petroleum fuels. But what hazards might these new fuels bring - hazards both conventional and unconventional, anticipated and unanticipated? As we explore these questions, we provide an excellent case study for interdisciplinary learning, Green Chemistry and a critical lens on the nature of 'clean energy' technologies.

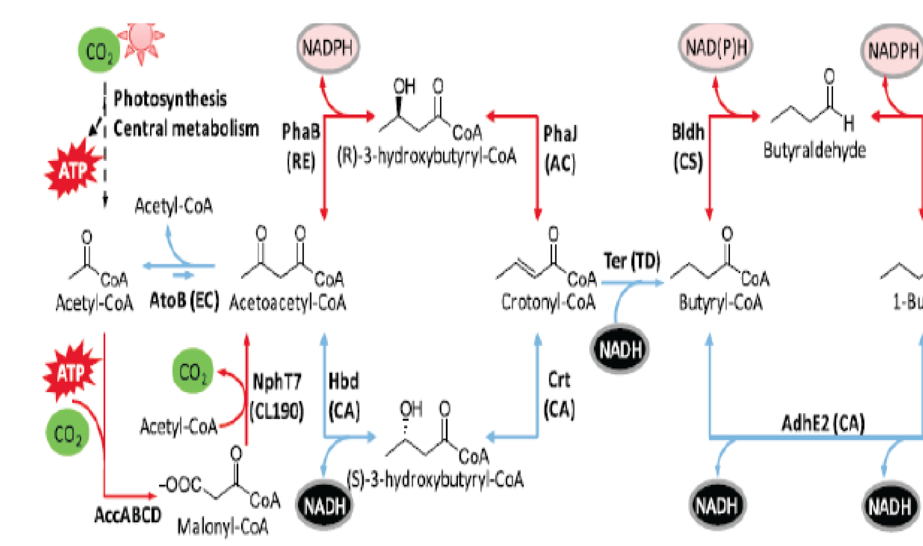
Higher-Order Alcohols

Compound	Energy Content	Water Solubility	KOW	Highest Reported Titers	Acute Human Hazard	Chronic Human Hazard	Ecological Hazard
isobutanol	27.3 MJ/L	8.7 g/100ml	.76	50 g/L	Irritation, otherwise Low	Low	Low
hexanol	.59 g/100ml	.59 g/100ml	2.03	0.21 g/L	Irritation, otherwise Low	Low	Low
pentanol	28 MJ/L	2.5 g/100ml	1.55	9.5 g/L	Irritation, otherwise Low	Low	Low
ethanol	21 MJ/L	7.9 x 10^3 g/100ml	-0.31	>37 g/L	Irritation, otherwise Low	Low	Low
gasoline	32 MJ/L	Low	5.18	n/a	CNS effects	Evidence of CV effects; carcinogenic byproducts during production	High, particularly during production

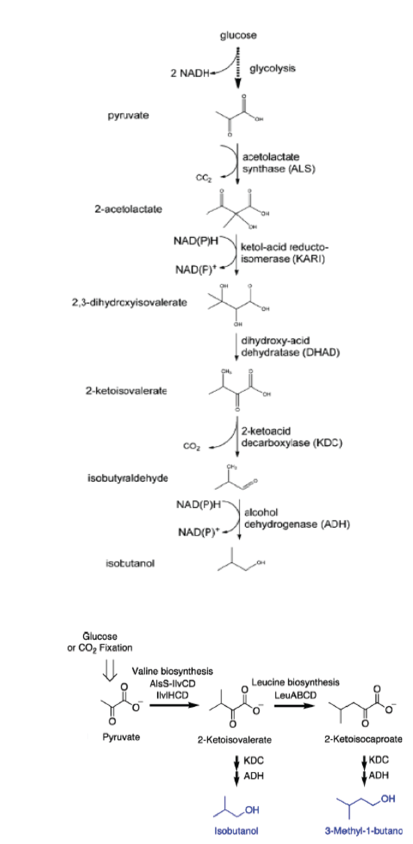
ABE (Clostridia)



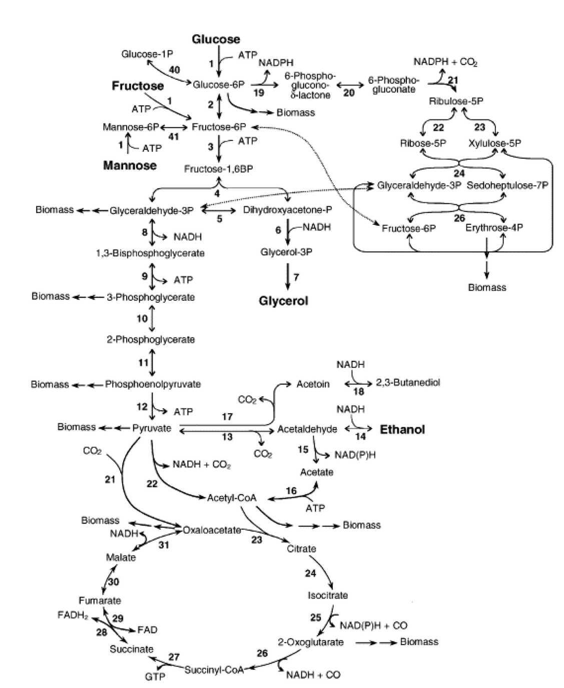
Cyanobacteria



Designed Pathways in E. coli, Yeast



Carbon Metabolism



Commercial Landscape

Gevo - Est 2007. Retrofitting ethanol plants for capital-light isobutanol mfg. Drawing revenue from lucrative market for isobutanol as platform chemical. Component of Coca-Cola's biobased PET bottle, for instance. See lawsuit with Butamax. Continuous separation.

Butamax - Est 2009. Joint Venture between DuPont and BP. Current potential capacity 500 million gallons per year.

Joule - Est 2007. Producing alcohols and other fuels with cyanobacteria. Only inputs are CO_2, water, sun. Relies on a complex engineered tanks, but targeting $1.28/gallon production.

Saffron Eagle - Est 2012. Jay Keasling spin-off out of JBEI. Production of pentanol.

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Barriers to Science Informing Policy

Political Inertia - Carbon Tax or Tradable Permits

Monitoring/Measurement Difficulty - Confidential Business Information

Quantification of Impact - Fertilizer Runoff

Incomplete Scientific Agreement - Endocrine Disruptors

Ethical Considerations - Genetically Modified Organisms

Challenges

Technical

- Shunting carbon metabolism to alcohol production without disrupting organism growth
- Energetics (NADH/NADPH)
- Separation of alcohol from growth media
- Scale-up engineering
- Process Modeling

Governance

- Regulation of Non-traditional risks such as bioengineering requires different structures and approaches compared with past efforts.
- Balancing trade-offs among non-commensurate hazards operating over a variety of scales in time and place, with potential threshold effects and other non-linearities.
- Balancing efforts to accelerate technology development with the need to proceed cautiously and with confidence that new problems are not being created with new technology.
- Understanding when and how new technological tools such as biotechnologies may require different property rights protections or different types of regulatory oversight.

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