Cellulosic and Advanced Biofuels

(Other than Cellulosic Ethanol)

Presentation to Oregon's Department of Environmental Quality

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Overview

- Describe the challenges of using corn-based ethanol and cellulosic ethanol
- Summarize our volumes analysis for RFS2
- Summarize the potential role of other cellulosic biofuels in the future
- Questions

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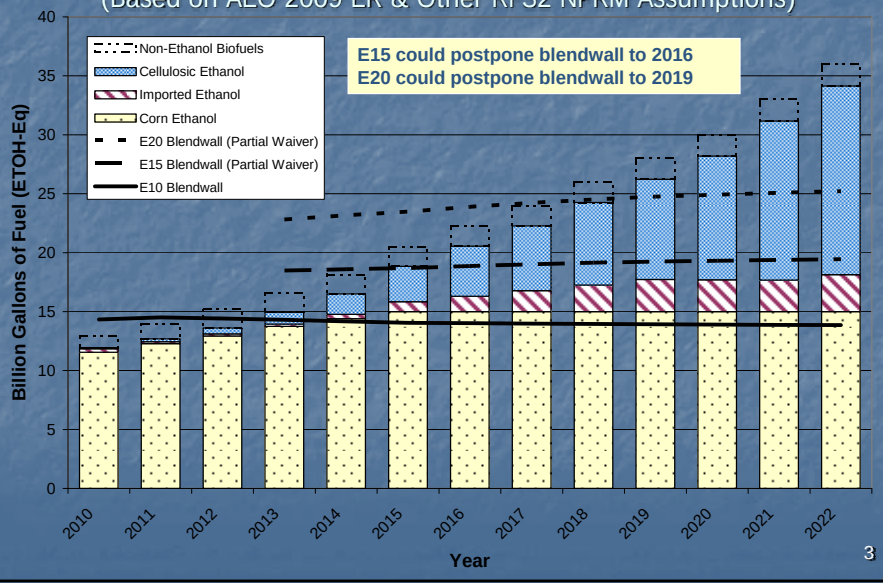
Ethanol Faces Issues with "The Blendwall"

(Based on AEO 2009 ER & Other RFS2 NPRM Assumptions)



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Fuels That Are Transparent to the Marketplace Have an Advantage

- **Mid-level blends, by themselves cannot reach the RFS2 mandated volumes – or go beyond**
- **E85 economics makes cellulosic ethanol a tough sell**
  - We estimate that in 2014
    - If crude is priced at $89/bbl, ethanol would have to be priced < $1.38/gal for refiners to choose to purchase it (compared to $1.83 ethanol today)
  - Although highly dependent on crude prices
    - At $116/bbl, ethanol could be priced at $2.14/gal
  - Chicken/egg issues prominent for dispensing E85
- **Conversely, lower barriers of entry into the marketplace for renewable gasolines, diesels, jet fuels that can be used in the existing fleet and fuel infrastructure without modification**

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The Holy Grail of Fuels

- **Low GHG emissions**
- **High energy content**
- **Low cost**
- **Target fuels (diesel/jet) whose demand is increasing, as opposed to gasoline which is decreasing**
- **Compatible with existing vehicle and fuel infrastructure**
- **No meaningful sustainability issues**
  - Competition for prime lands
  - Food vs Fuel
  - Sensitive habitats
  - Etc.
- **SCALE: Able to replace very large percentages of crude oil**

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2022 Cellulosic Biofuel Volumes

- RFS2 FRM Analysis: Primary Control Case assumed more cellulosic diesel fuel than cellulosic ethanol

	Billion Gallons												
	Ethanol				Biodiesel				Renew Diesel		Cell Diesel		
Ethanol Scenario	Corn	Cell	Imp	Total ETOH	Fuel-Grade Corn Oil	From FOG	Algae	Virgin Veg Oil	Non-CoPro	CoPro	BTL	Other	Total Renew Fuel
Low-ETOH	15.00	0.25	2.85	**18.10**	0.15	0.23	0.50	0.38	0.15	0.00	1.96	7.30	**28.77**
Mid-ETOH (Primary)	15.00	4.92	2.85	**22.77**	0.15	0.23	0.50	0.38	0.15	0.00	1.96	4.56	**30.70**
Max-ETOH	15.00	16.00	2.85	**33.85**	0.15	0.23	0.50	0.38	0.15	0.00	0.00	0.00	**35.26**
Max-ETOH (NPRM)	15.00	16.00	3.14	**34.14**	0.15	0.00	0.00	0.66	0.19	0.19	0.00	0.00	**35.33**

In addition to primary control case, we also assessed high-ethanol and low-ethanol cases as sensitivity cases

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Many Companies Pursuing Cellulosic Diesel & Advanced Hydrocarbons

Biochemical
- Amyris
- Bell Bioenergy
- Terrebon
- LS9
- Swift Fuels

Other
- Virent[Sh]

Biomass-to-Liquids
- Baard
- Flambeau River Biofuels
- Gulf Coast Energy
- Clearfuels/Rentech
- Choren/SunFuels
- TRI
- Renewable Energy Institute

Depolymerization/ Pyrolysis
- Cello
- Envergent
- Dynamotive
- Green Power
- Kior
- Petrobras

Oil Company Investments: Sh=Shell

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Potential for Cellulosic Biofuels

(Other than Ethanol)

Biochemical Diesel
- Easier water separation compared to biochemical ethanol
- Potential for lower capital and operating costs

Biomass-to-Liquids (syngas and FT reactor)
- Well understood technology
- Very capital intensive – difficult to fund in current economic environment

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Potential for Cellulosic Biofuels

(Other than Ethanol)

Depolymerization/Pyrolysis

- Two step process – depolymerization and then repolymerization/upgrading
- Low to moderate capital costs
- May be able to utilize existing refinery capital to upgrade biocrude

Other (Virent)

- Reforming of sugars based on refining technology

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Potential for Cellulosic Biofuels

(Other than Ethanol)

Renewable Diesel Fuel

- Additional companies (Neste, Syntroleum, UOP etc.) pursuing FOG-based renewable diesel

Free fatty Acids to Fuel

- Endicott pursuing biodiesel from waste free fatty acids
- Potential for many billion gallons of biodiesel

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Some of the Companies Pursuing Algae-Based Biofuels

- Algenol
- Aurora Biofuels
- Bio Algene
- Biolight Harvesting
- BioProcess Algae LLC
- Cellana[Sh]
- Kent BioEnergy
- Live Fuels
- Martek Biosciences
- OriginOil
- Petroalgae
- Petrosun
- Sapphire Energy
- Solazyme[BP]
- Solix Biofuels[Val]
- SunEco Energy
- Synthetic Genomics[BP,EM]
- XL Renewables

Oil Company Investments: BP=British Petroleum, EM=Exxon Mobil, Sh=Shell, Val=Valero

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Potential for Biofuels sourced from Algae

- Currently estimated costs are very high
  - One reason for the high costs – humans are growing the feedstock, not mother nature
- Attraction: Algae growth per acre is potentially very high – could supply ALL of US transportation fuel demand
- Challenge: CO_2 sources are not located near best algae growing sites in the US

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What Would You Like to Know?

Thank you

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