Impacts of New Technologies and Policies on Biofuels Production and Trade

Bhima Sastri, Ph.D.
Audrey Lee, Ph.D.
Office of Policy and International Affairs,
Department of Energy, Washington DC
Thomas Alfstad
Brookhaven National Laboratory
Richard Bain
National Renewable Energy Laboratory

November 16-21, 2008
AIChE Annual Meeting

Outline

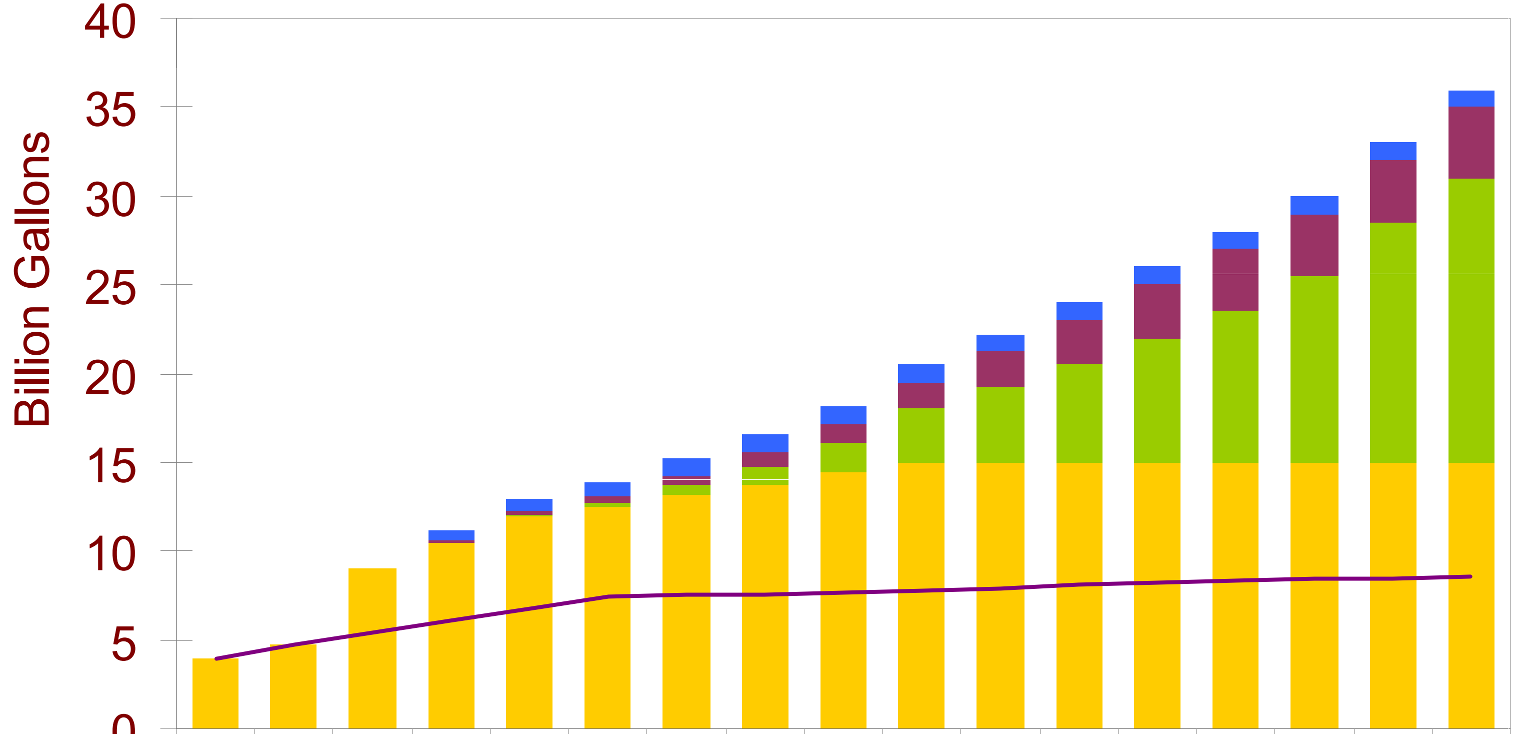
- Policies - U.S. and worldwide
- Model Methodology
- Technologies for Biofuels
- Results
  - Reference Case
  - Scenario Cases
    - CO_2 price, oil price, E20
- Conclusions

Energy Independence & Security Act of 2007

- Renewable fuel standards for feedstocks & GHG emissions:
  - Renewable Fuel: Fuel derived from renewable biomass (Including corn starch)
  - Advanced Biofuel: Renewable fuel (not from corn starch) with fewer GHG emissions
  - Cellulosic Biofuel: Advanced biofuel from cellulose, hemicellulose or lignin
  - Biomass-based Diesel: Advanced biofuel replacing diesel
- Requirements are nested:
  - Firm requirements for cellulosic biofuels and bio-diesel.
  - Advanced biofuels may be all cellulosic and bio-diesel.
  - Renewable fuels may be all advanced biofuels.
- Waivers available – financial buyout for cellulosic biofuels.

Energy Independence & Security Act of 2007

Renewable Fuels Standard



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Biomass based Diesel				0.5	0.65	0.8	1	1	1	1	1	1	1	1	1	1	1
Any Advanced	0	0	0	0.1	0.2	0.3	0.5	0.75	1	1.5	2	2.5	3	3.5	3.5	3.5	4
Cellulosic Advanced					0.1	0.25	0.5	1	1.75	3	4.25	5.5	7	8.5	10.5	13.5	16
Any Biofuels	4	4.7	9	10.5	12	12.5	13.2	13.8	14.4	15	15	15	15	15	15	15	15
Old RFS	4	4.7	5.4	6.1	6.8	7.4	7.5	7.6	7.7	7.8	7.9	8.1	8.2	8.3	8.4	8.5	8.6

EISA'07 RFS Restrictions

- **Minimum GHG Reductions:**
  - Renewable Fuel: 20%
  - Advanced Biofuel: 50%
  - Cellulosic Biofuel: 60%
  - Biomass-Based Diesel: 50%
- **Land Use Must Be:**
  - Cleared or under cultivation & non forested prior to EISA'07 (crops)
  - Managed plantations (trees)
- **Feedstocks May Include:**
  - Crops from previously cleared, non-forested land
  - Biomass from private forest lands*
  - Algae
  - Separated yard and food wastes
- **Feedstocks Do Not Include:**
  - Biomass from ecologically sensitive, protected lands
  - Biomass from federal forest lands

*Includes native-American lands, privately held forests and tree plantations

Worldwide National Policies

Country/ region	Gasoline tax	2010 Biofuel tax exemption	Ethanol tariffs	Other, modeled	Other, not-modeled in current study
Australia	$1.40/gal	100%	90¢/gal		
Canada	$0.25/gal	100%	20¢/gal		5% market share by 2010
China	$0.15/gal	100%	0		15% market share 2015
Central & S. America	$0.70/gal	50%	27¢/gal	Subsidy for hydrous ethanol & FFV; Brazil blending requirement of 20-25%	
Europe	$2.80/gal	90%	90¢/gal	5.5% market share 2010 10% market share 2020	
India	$1.90/gal	0%	200%		5% market share by 2015
Japan	$1.85/gal	90%	17%	500 million liters gasoline equivalent by 2010	
S. Korea	$3.02/gal	90%	0		
USA	$0.42/gal	51¢/gal	54¢/gal	36 billion gallons renewable fuels 2022	

MARKAL Model Structure

Energy Technology Perspectives Model

Technology Characteristics
- Energy Sources Used
- Efficiency
- Costs (Capital and O&M)
- Availability

Energy Resources
- Cost and Availability

Energy Service Demands
- By Sector/Region

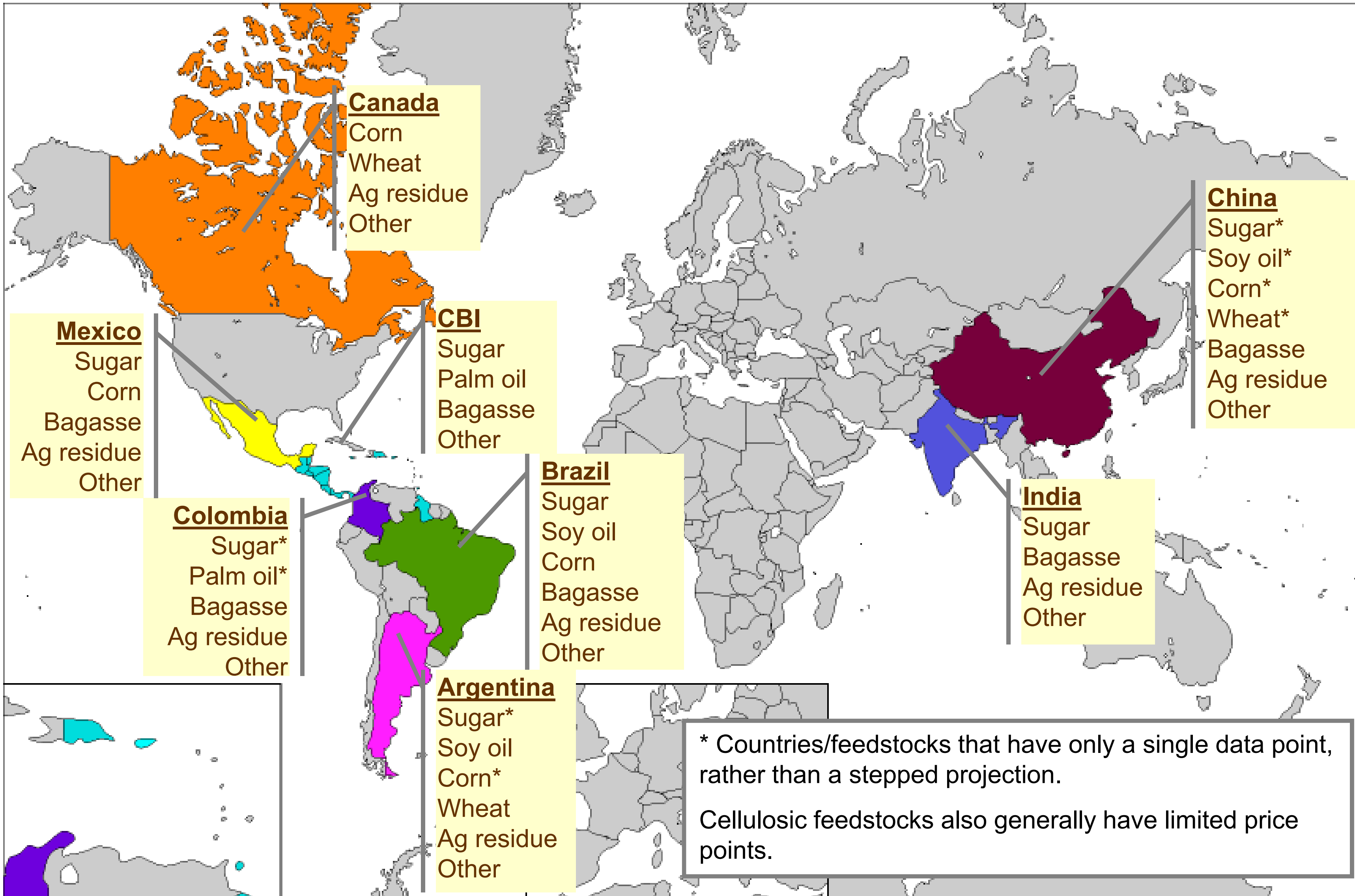
Other Assumptions
- Long-Term Discount Rate
- System Reserve Requirements

Other Constraints
- Max. CO_2 Emissions by Time Period

Dynamic LP Optimization

Technology Mix for Each Time Period That Satisfies Energy Demand Given Constraints

Updates to ETP Model-Feedstocks



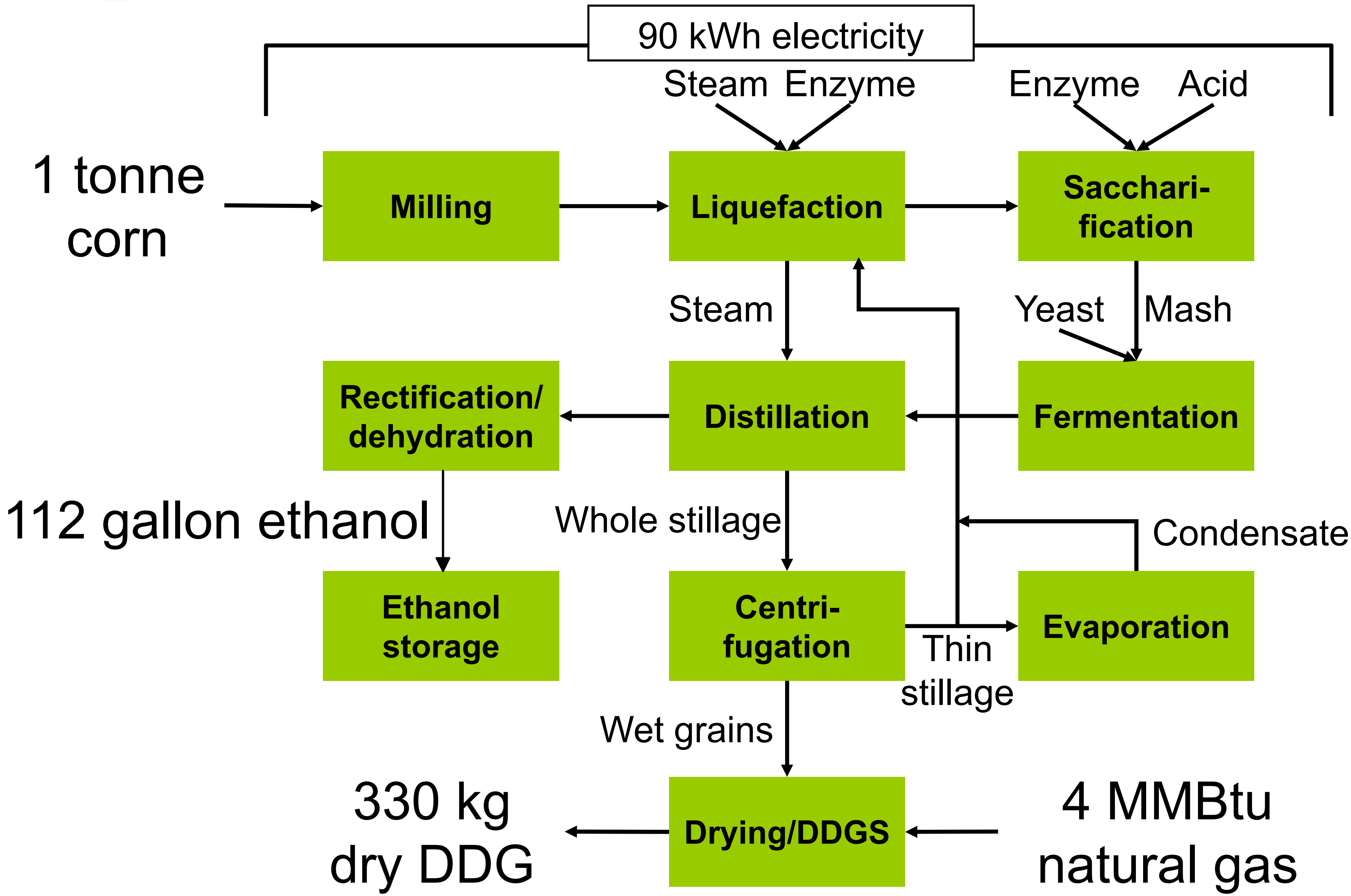
Updates to ETP Model-Technologies

Feed stock	Source	Conversion Technology	Product	Distribution/ Consumption
Sugar	Sugarcane	Sugar-ethanol mill	Ethanol	• New distribution infrastructure required • Consumption limited to E10 for most of existing vehicle fleet • Higher blends (i.e. E85) can be used in small portion of fleet
Starch	Corn Wheat	Dry mill	Ethanol	
Cellulose	Bagasse/other agricultural residues	Biochemical conversion	Ethanol	
	Forestry residues	Thermo-chemical alcohol synthesis	Ethanol/ higher alcohols	
	Energy crops	Fischer-Tropsch synthesis	Distillates, naphtha	• Products are refining feedstocks • Compatible with conventional fuel infrastructure
Oil	Oil Palm Soybean	Transesterification	Biodiesel (FAME)	• Can be blended with petrodiesel at high ratios in most applications

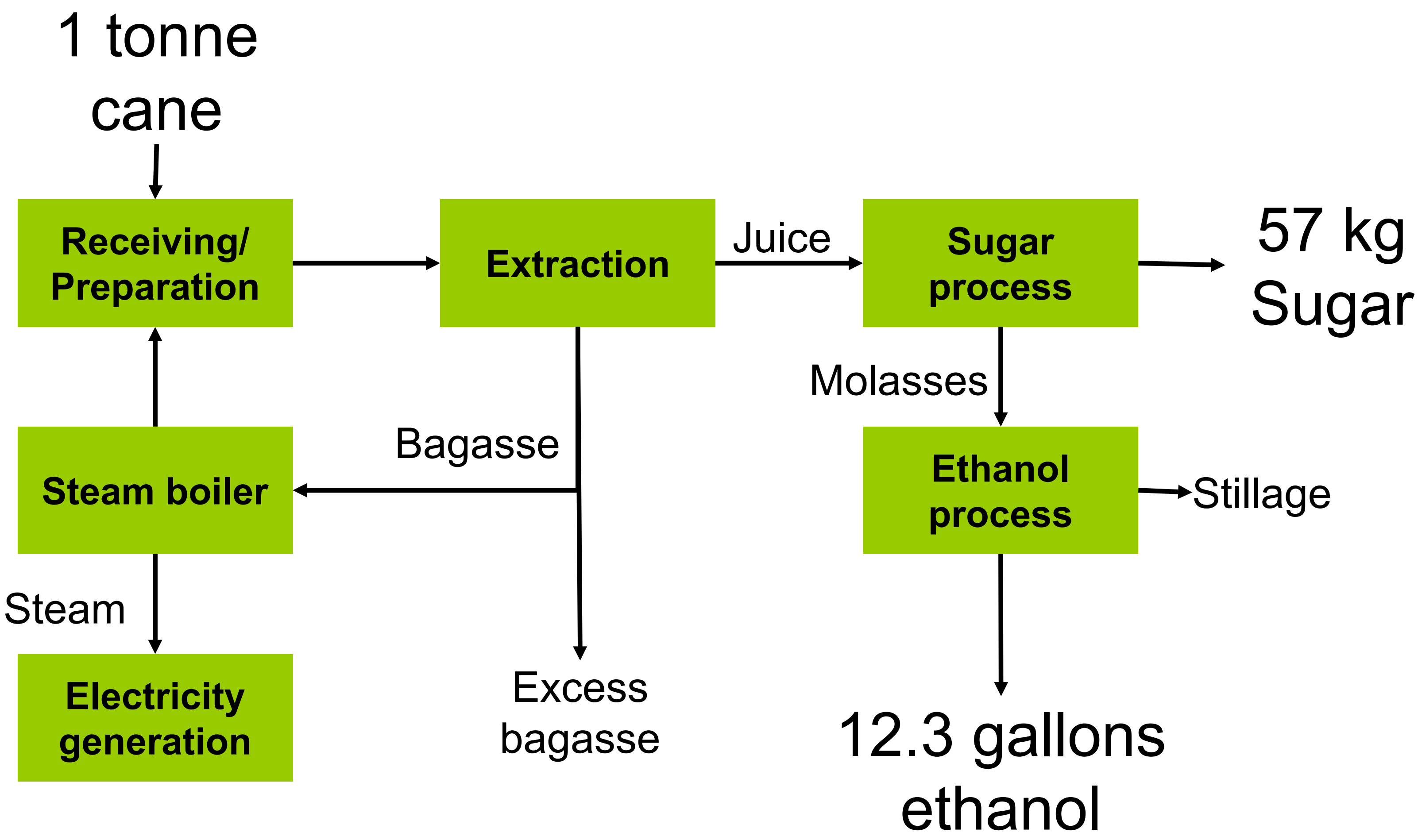
Conversion Technologies

- Ethanol
  - Sugarcane
  - Dry Mill – Corn, Wheat
  - Thermo-chemical Process for Cellulosic Feedstocks (Alcohol Synthesis)
  - Biochemical Process for Cellulosic Feedstock
- Biodiesel
  - Soy Oil
  - Palm Oil
- Biomass-to-Liquids products
  - Thermo-chemical Process for Cellulosic Feedstocks (Fischer-Tropsch)

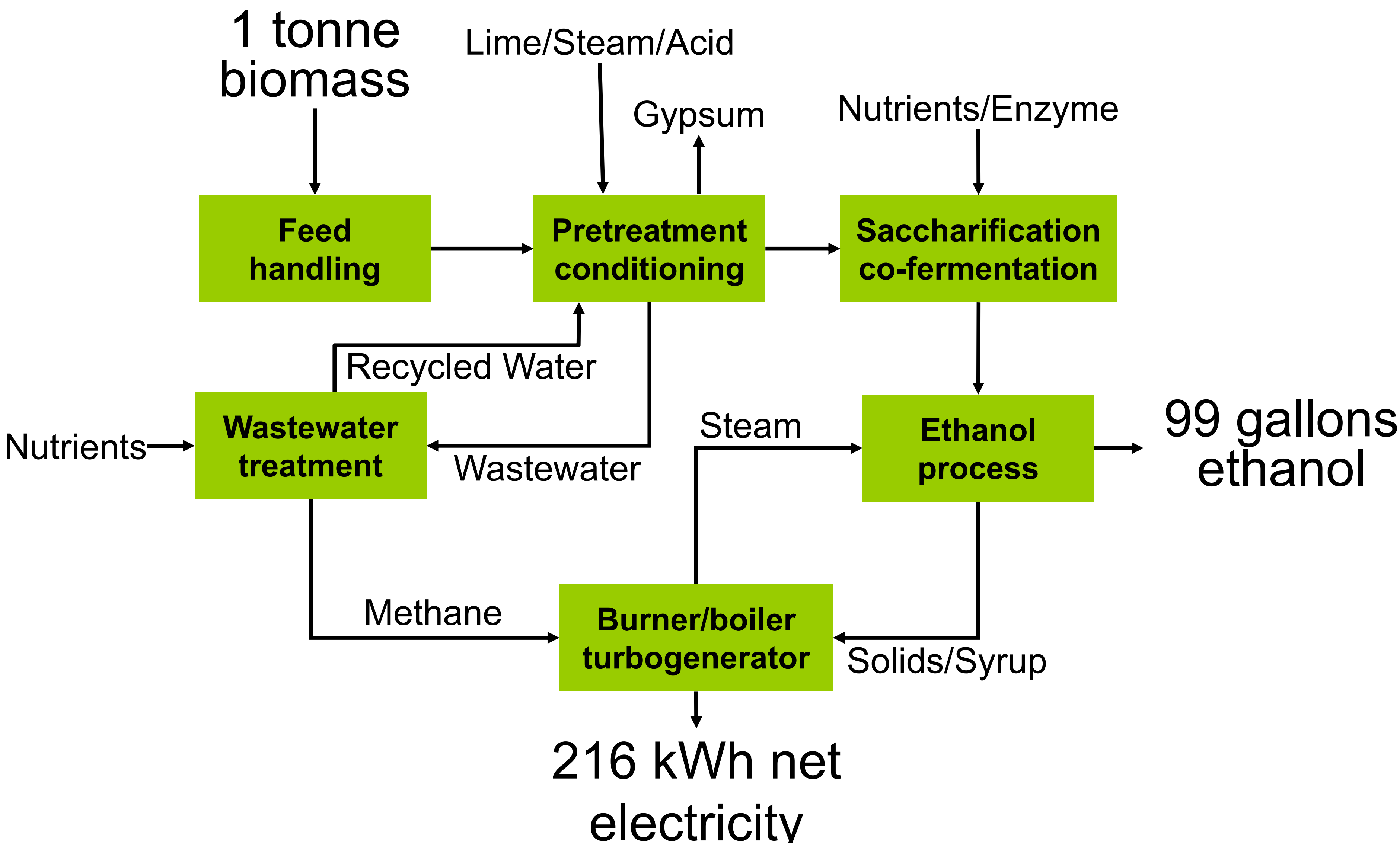
Dry Corn Mill



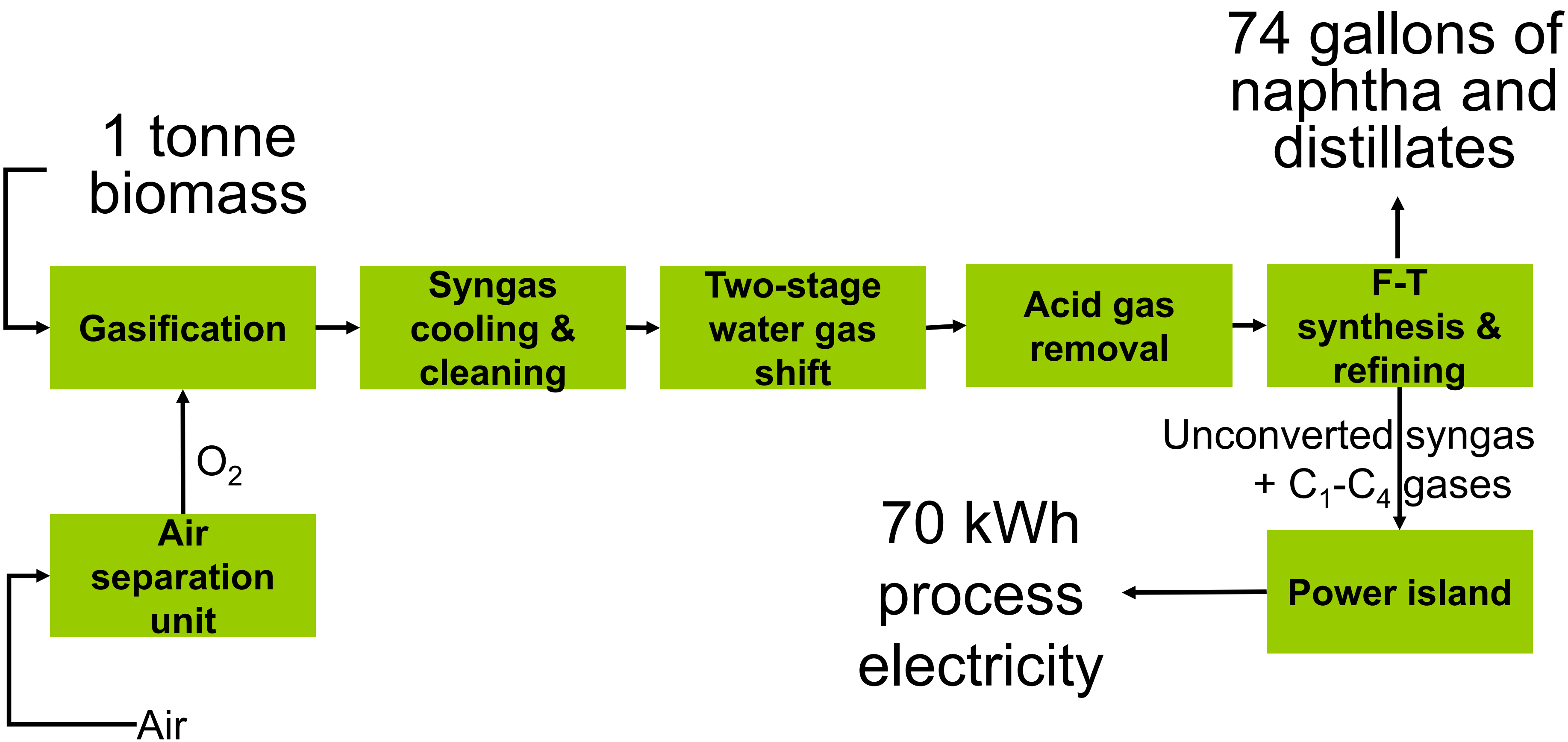
Sugarcane Mill



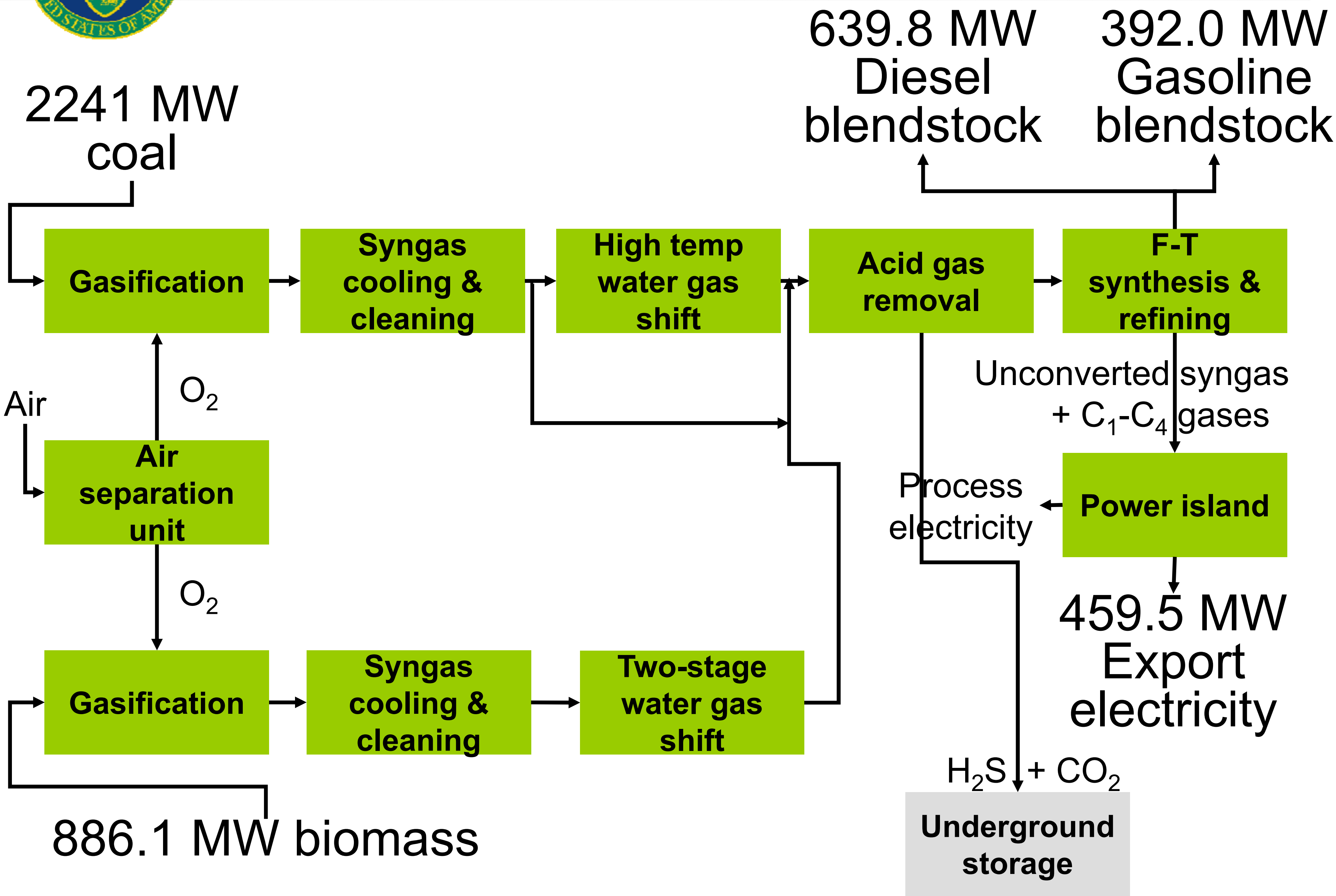
Bio-chemical Conversion



Thermo-chemical Conversion

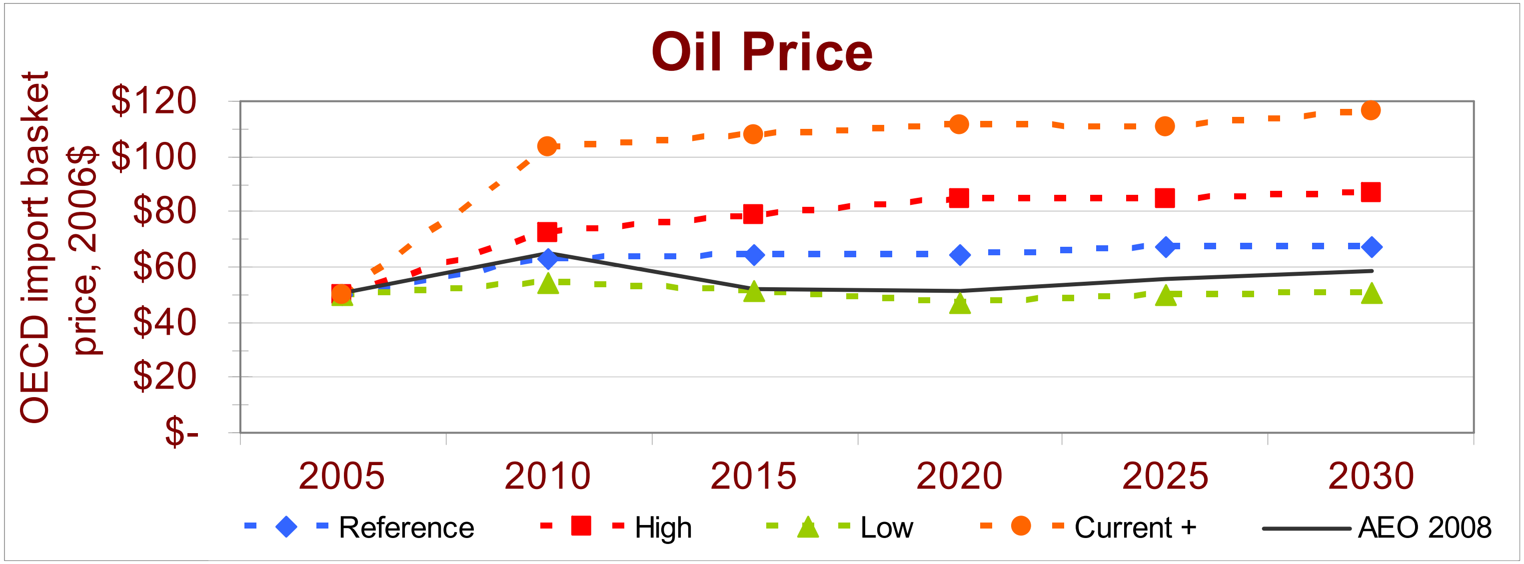


Thermo-chemical Conversion



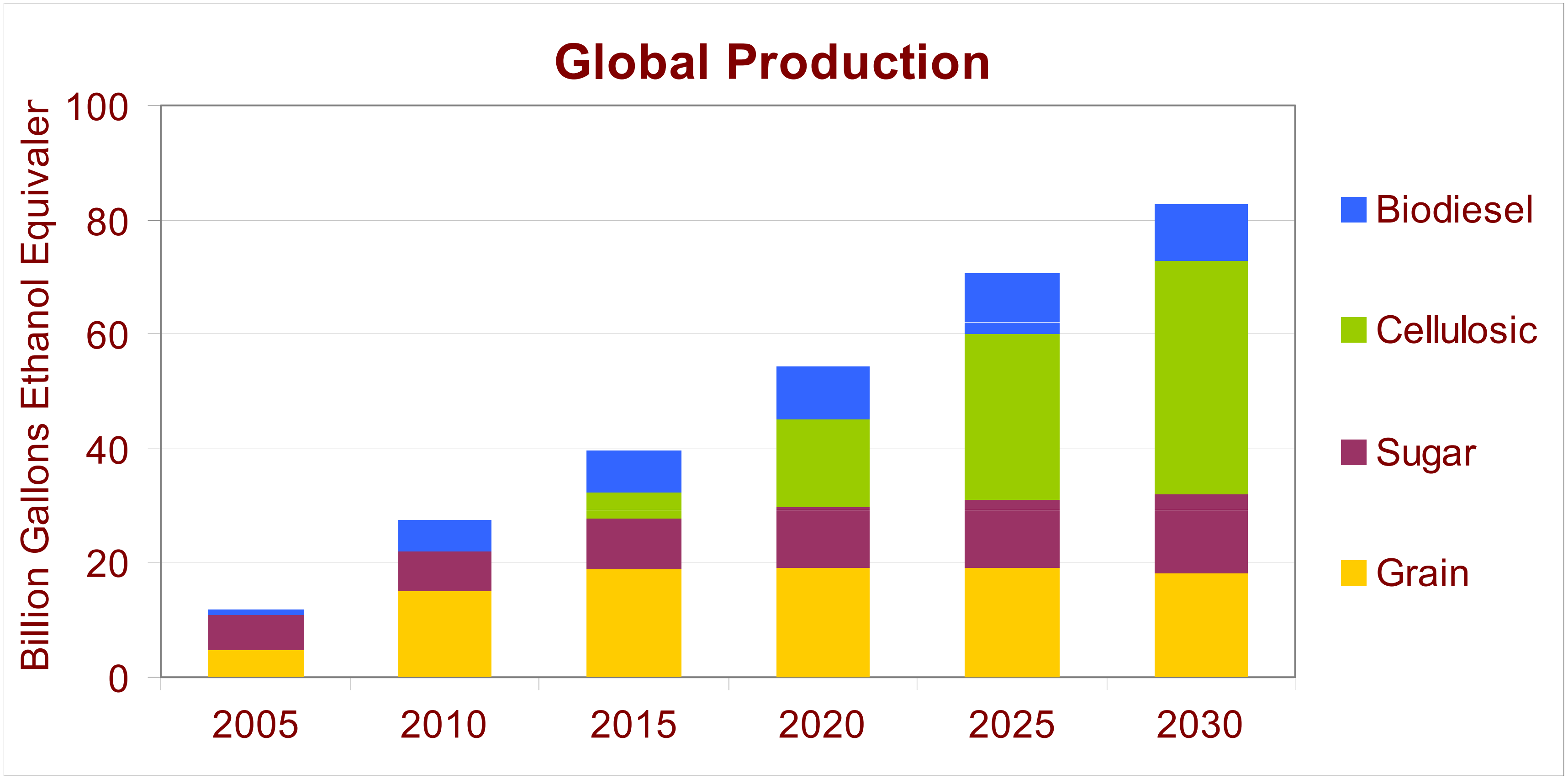
Reference Case Assumptions

- EISA Renewable Fuel Standard
- $1.01/gallon cellulosic biofuel subsidy extended until cost competitive
- $1.00/gallon biodiesel subsidy
- Blenders' ethanol credit of $0.51/gallon and Tariff of $0.54/gallon expire in 2010
- Includes existing national biofuels policies worldwide



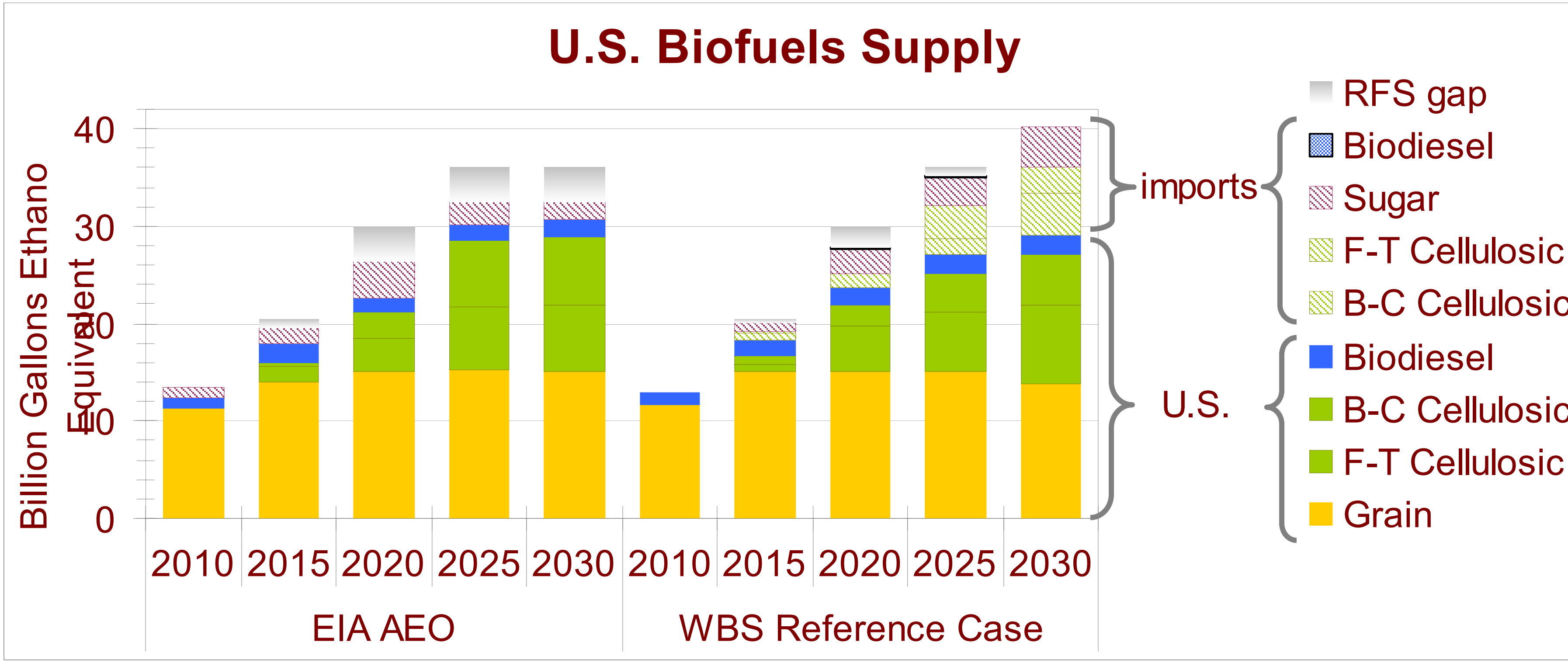
Oil prices are OECD import basket prices (typically much lower than NYMEX oil prices).

Worldwide Biofuels Production



- **Grain production levels off after 2015**
- **Large growth in cellulosic biofuels**
- **Subsidy for early cellulosic plants is crucial to this growth**

Reference Scenario vs. AEO



- We project more imports than EIA's Annual Energy Outlook.
- Both domestic & imported cellulosic biofuels will contribute to meeting the mandate.
- Main challenge is building cellulosic plants fast enough.

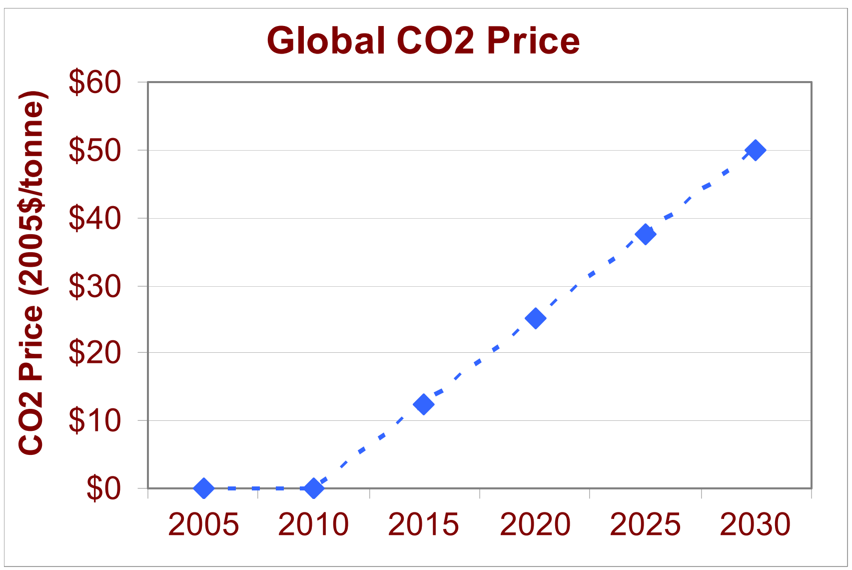
Scenarios Modeled

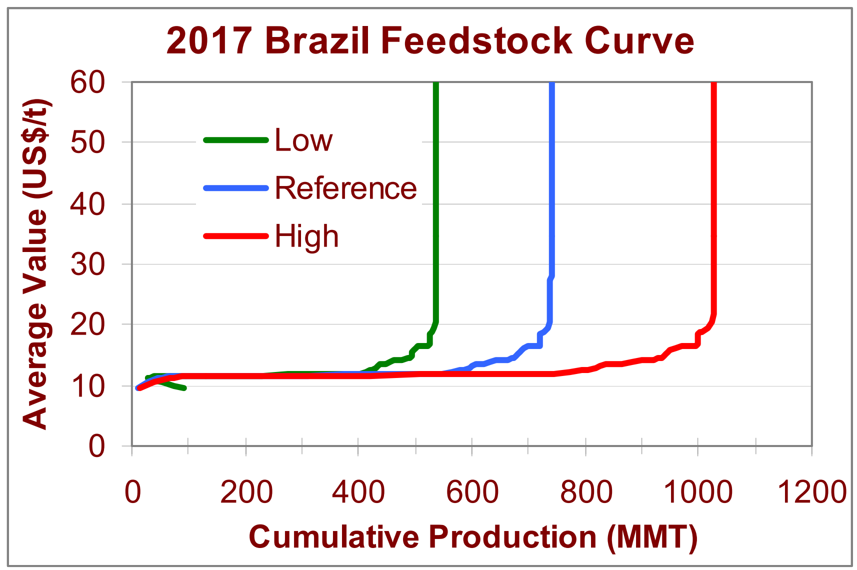
Policy Scenarios

Tariff/Credit Extension
Credit Extension
$50/t$CO_2$ (global)
E20 Certification
Grower's payment

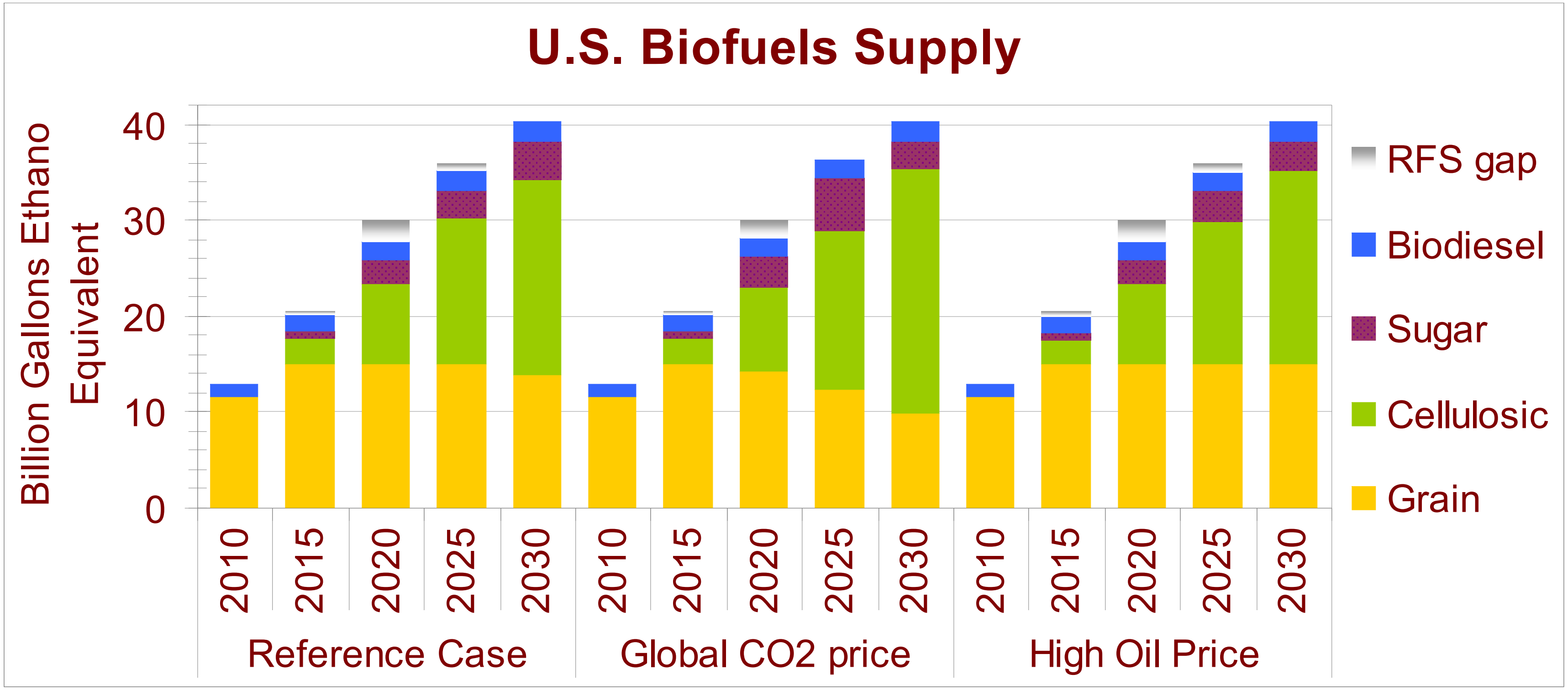
Market Scenarios

High/Low Feedstock Supply
Low/High/Higher Oil Price
Higher share of Brazilian sugar to ETOH
High Oil Price + High Feed
Low Oil Price + Low Feed



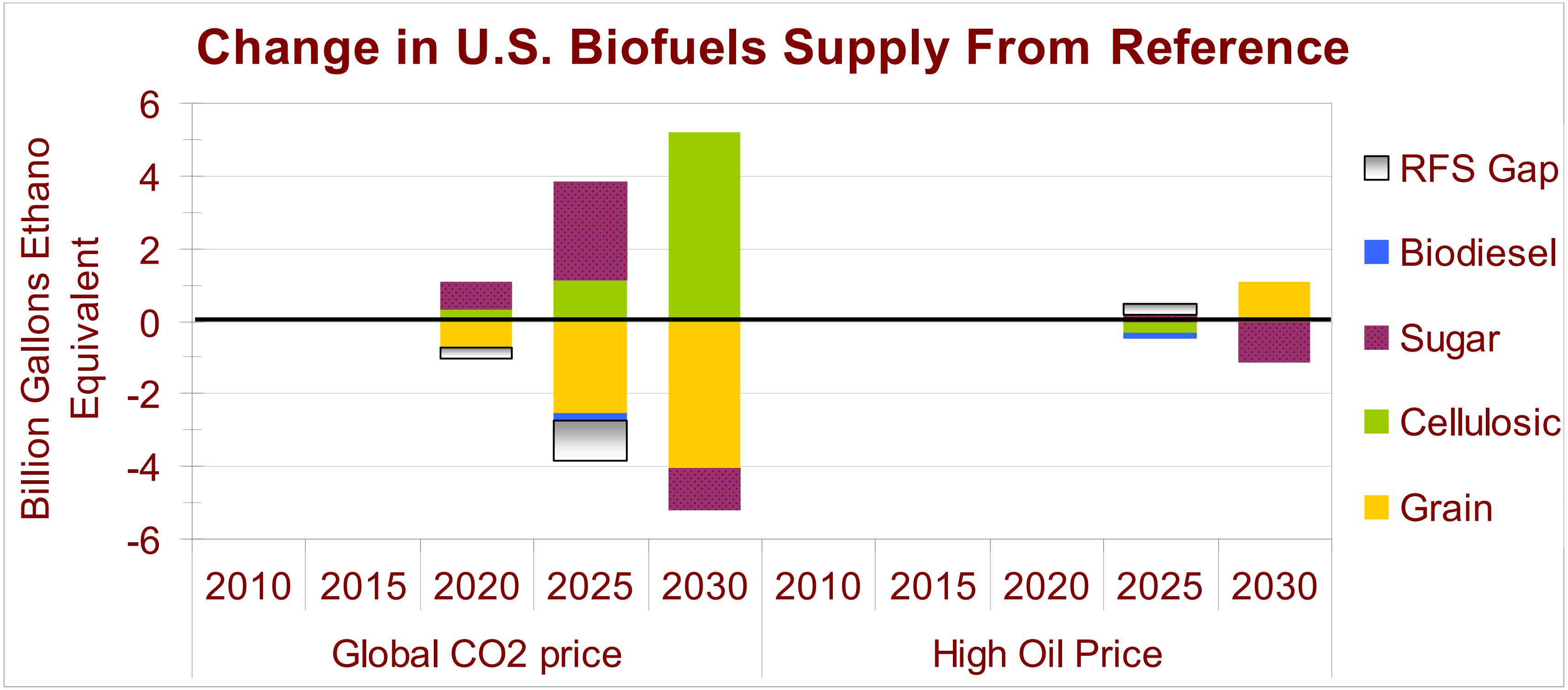


CO_2, Oil Price Scenarios (U.S.)



- **Global CO_2 price:**
  - **RFS is met after 2025**
  - **High oil price: little change from reference because buy-out for cellulosic varies with oil price**

CO_2, Oil Price Scenarios (U.S.)



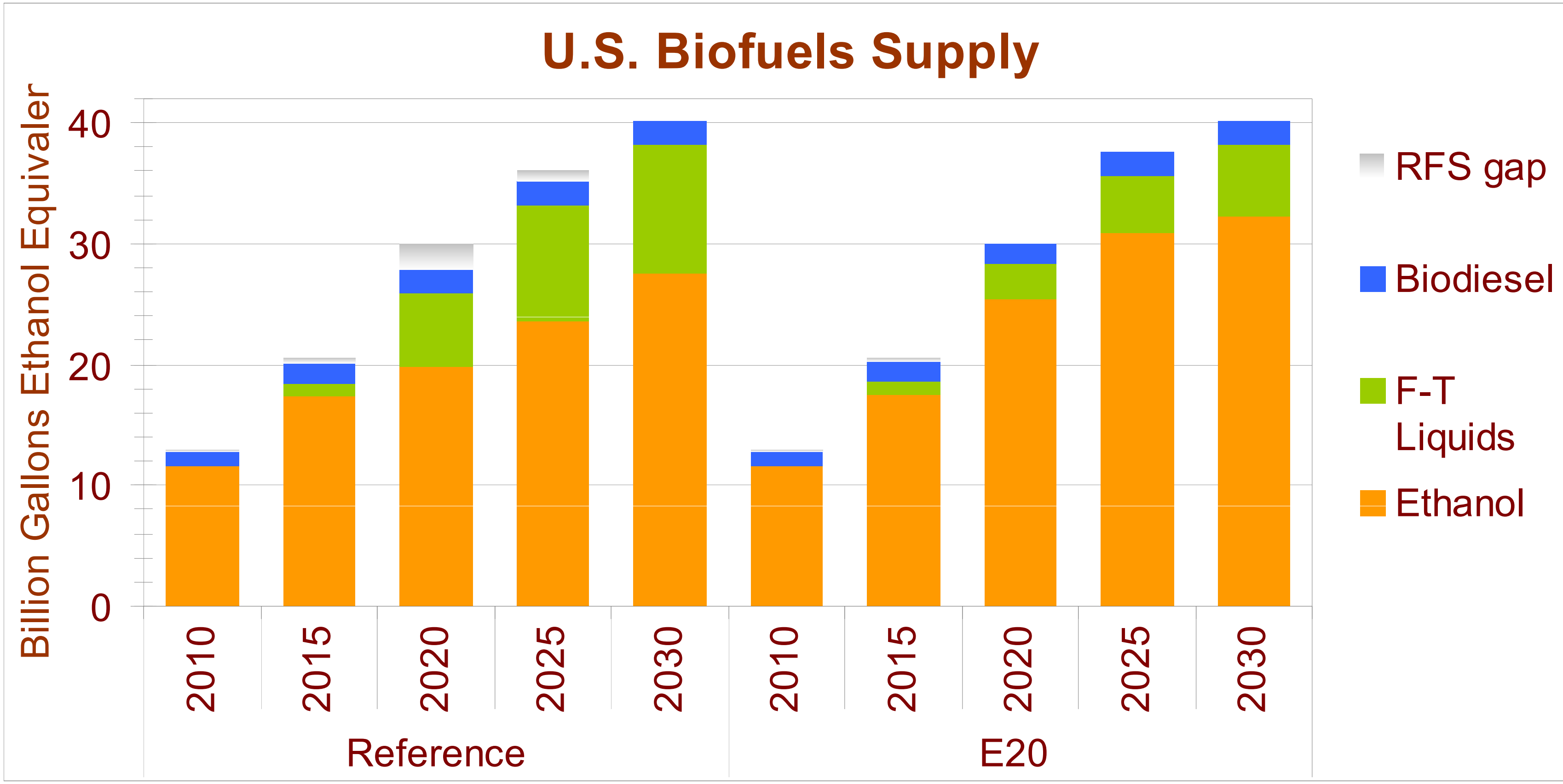
- **Global CO_2 price:**
  - **Closer to meeting RFS than Reference Case**
  - **Sugar replaces corn and fills in RFS gap in 2025**
  - **Cellulosic replaces sugar and corn in 2030**
- **High oil price: slightly more corn in place of sugar**

The barrier to meeting RFS?

Biefuels Supply or Infrastructure

- We used the E20 certification scenario to investigate whether ethanol infrastructure was the barrier to meeting the RFS.
- The E20 scenario is a hypothetical scenario that allows increased use of ethanol without new pipelines, fueling stations, and flex fuel vehicles.

E20 Scenario: U.S. Supply

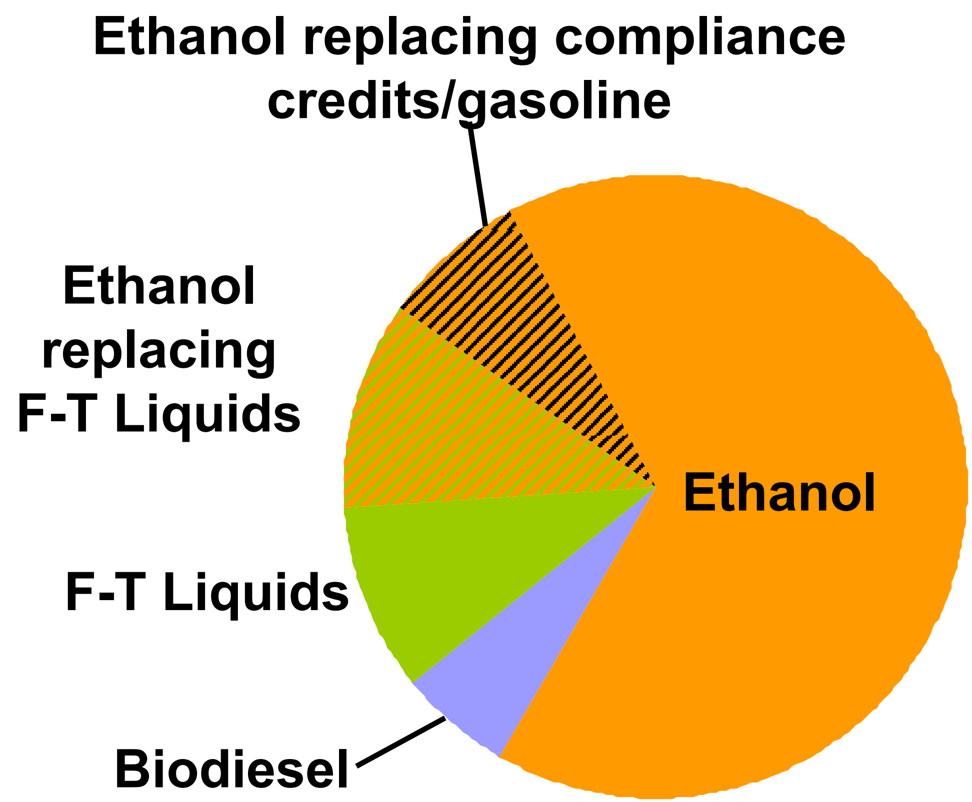


- **Only case to meet RFS**
- **Illustrates E85 infrastructure constraints**
  - **Pipelines, fueling stations, flexible fuel vehicles**

E20 Scenario: U.S. Supply Shares

- Significant increase in ethanol use.
- E20 allows lower cost ethanol to replace some F-T liquids and compliance credits (gasoline).
- E20 case shows benefits to reduce ETOH distribution constraints (e.g., expanded E85 retail outlets & more fuel-flexible vehicles).

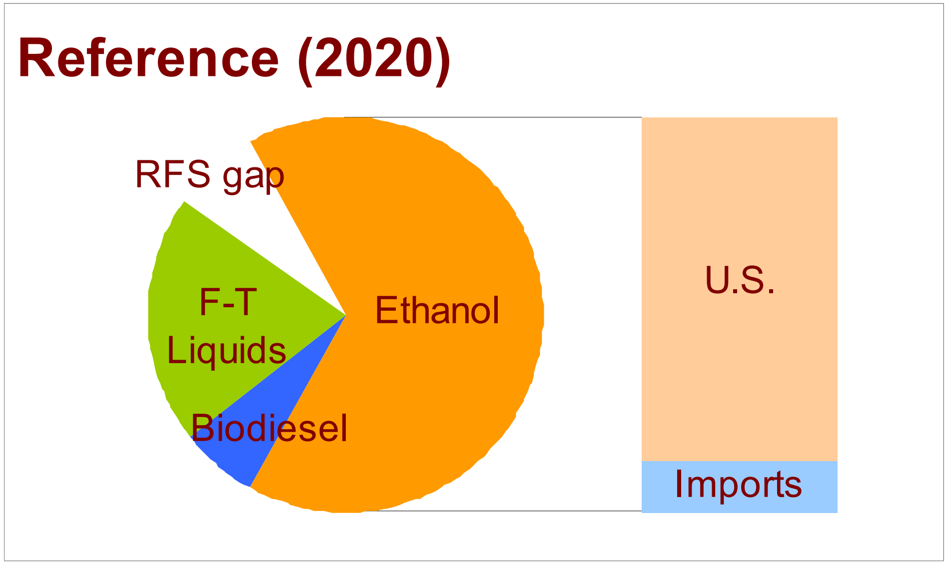
E20 (2020)

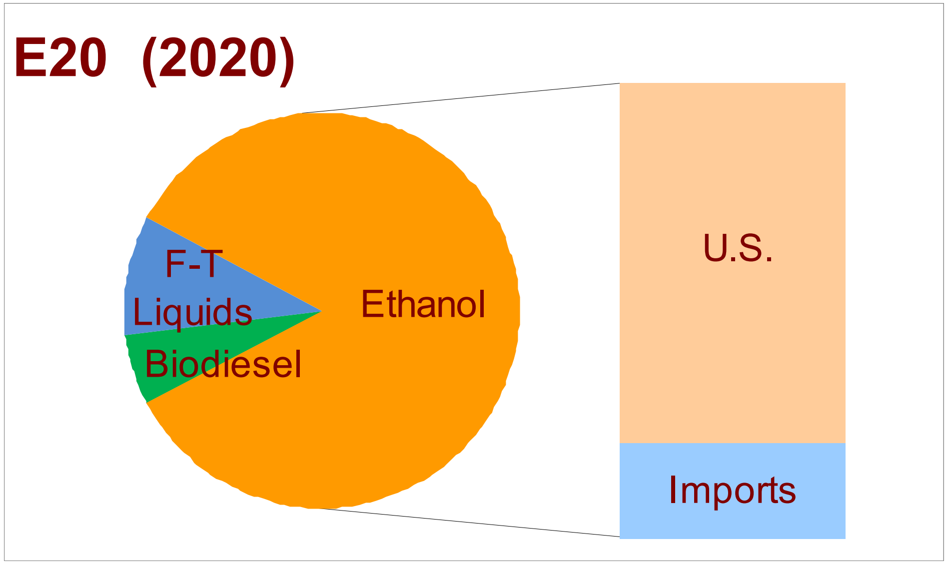


Total: 28 B gallons in Ref
30 B gallons in E20

E20 Scenario: U.S. Supply Shares

- Increase in ethanol is partly made possible by imports
- Imports increase by 60%





Conclusions

- Cellulosic biofuels are crucial share of RFS
  - Importance of learning investment and technology penetration
- E85 infrastructure constraints
  - Demonstrated by E20 scenario
  - Switch between biochemical and Fischer-Tropsch cellulosic
- Large volumes mandated, production is at inelastic portion of feedstock supply curve
  - Additional subsidies have little impact
- Sizeable role of imports (sugar and cellulosic)
- Implicit global price on CO_2, decline in grain ethanol
- High oil price, lower exports to U.S.

World Biofuels Study (WBS)

Collaboration

Project Management by **Office of Policy and International Affairs**

With Funding Support from **EERE / Office of Biomass Programs**

Feedstock Resource Potential	Conversion Process	Integrated Assessment
Oak Ridge National Laboratory	NREL	Brookhaven National Laboratory

ORNL & NREL reports at http://www.osti.gov/bridge/ search 924080, 921804