U.S. DEPARTMENT OF ENERGY

Projected Biofuels Supply under the U.S. Renewable Fuel Standard

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Office of Policy and International Affairs

March 17, 2009
Biomass 2009: Regulation and Policy

Outline

- 2007 Energy Independence & Security Act
  - New Renewable Fuel Standard
- 2008 Farm Bill
- World Biofuels Study
  - MARKAL model
  - Assumptions
  - Results

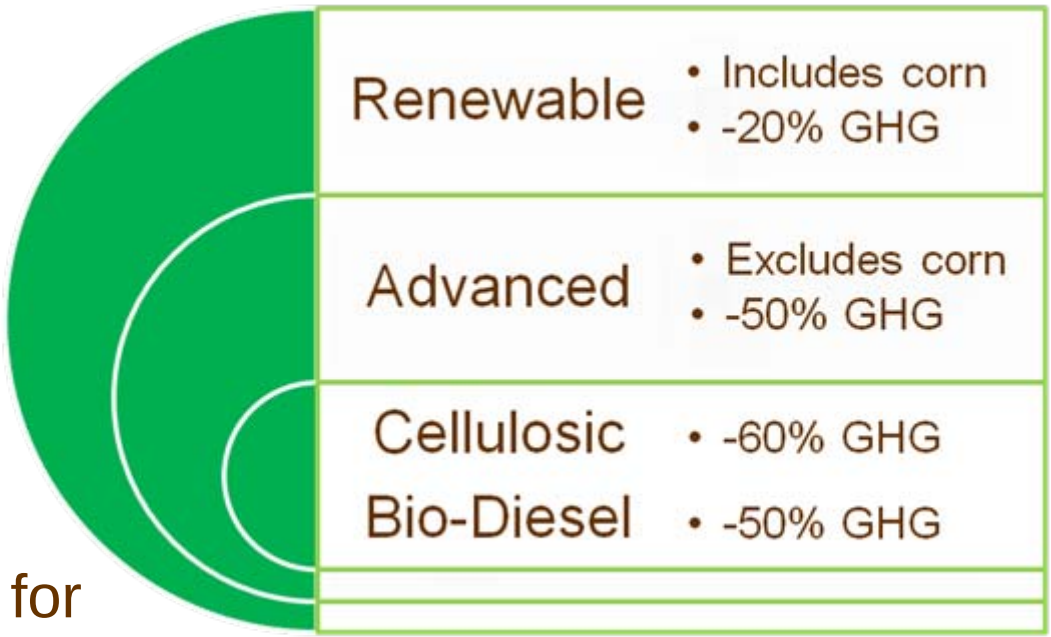
EISA Title II: New Renewable Fuel Standard

- Feedstocks included:
  - Crops from previously cleared, non-forested land
  - Biomass from private forest lands*
  - Algae
  - Separated yard, food wastes

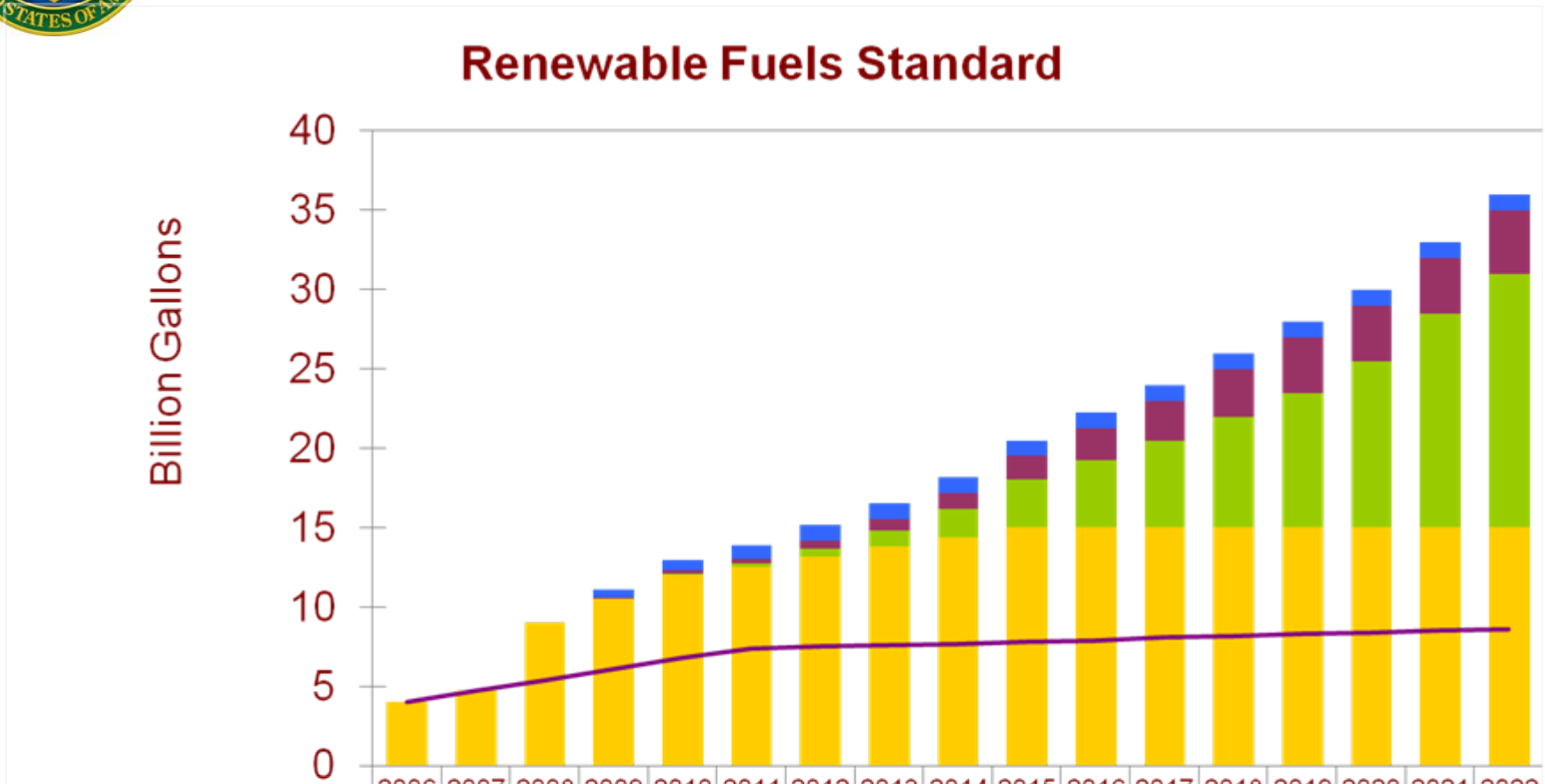
*Includes native-American lands, privately held forests and tree plantations

- Feedstocks excluded:
  - Biomass from ecologically sensitive, protected lands
  - Biomass from federal forest lands

- Current corn plants grandfathered
- Waivers available
- Cellulosic safety valve
- Adjustments up to 10% for GHG



New Renewable Fuel Standard

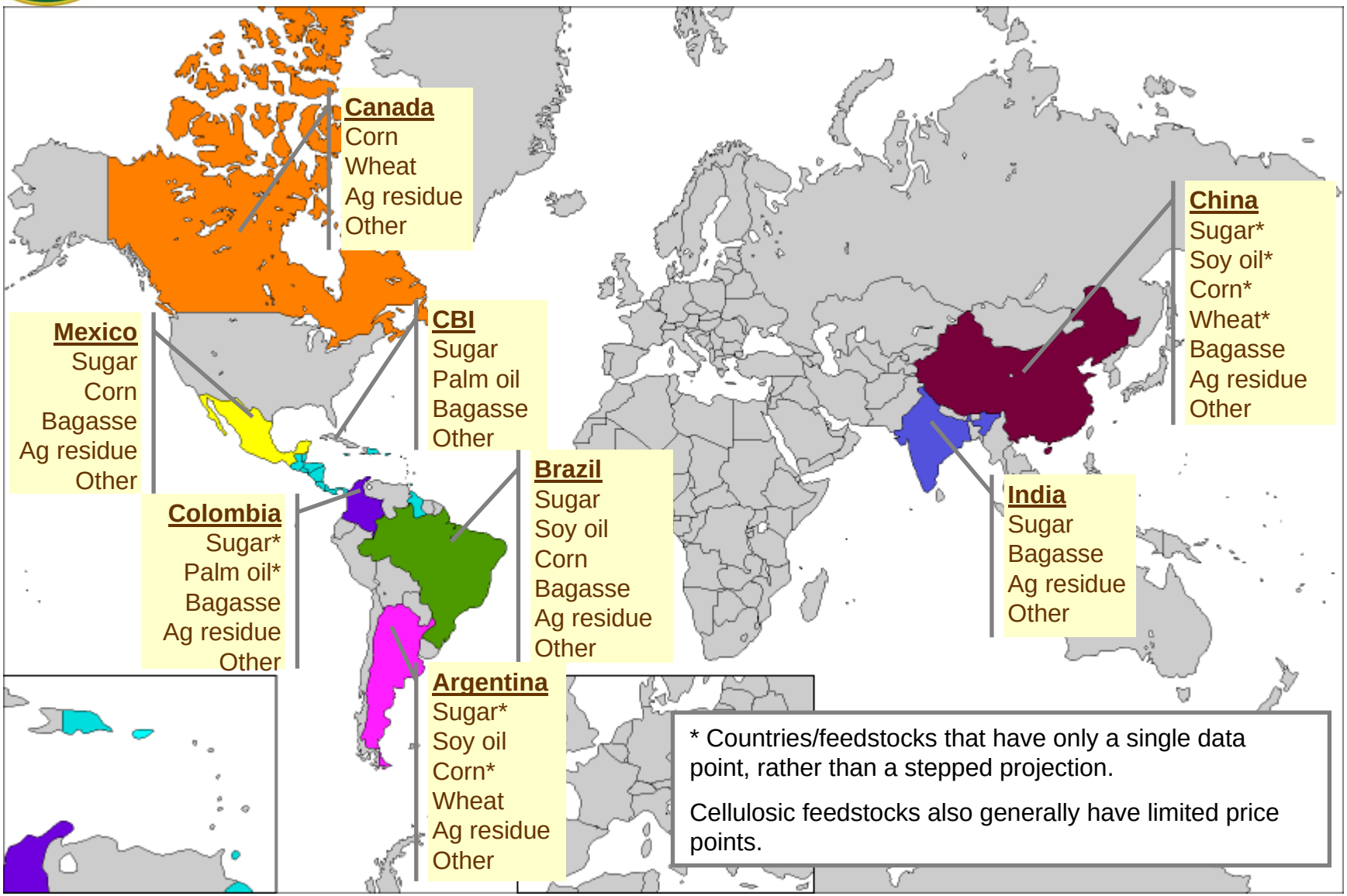


	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Biodiesel	0	0	0	0.5	0.65	0.8	1	1	1	1	1	1	1	1	1	1	1
Any Advanced	0	0	0	0.1	0.2	0.3	0.5	0.75	1	1.5	2	2.5	3	3.5	3.5	3.5	4
Cellulosic Advanced					0.1	0.25	0.5	1	1.75	3	4.25	5.5	7	8.5	10.5	13.5	16
Any Renewable Fuels	4	4.7	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

2008 Farm Bill

1. Cellulosic Biofuel Production Tax Credit
   - $1.01 per gallon, expires at end of 2012
2. Biodiesel Tax Credit, expires end of 2008 (no change)
3. Volumetric Ethanol Excise Tax Credit (VEETC)
   - Amended to $0.45 per gallon after 7.5 billion gallons of ethanol are produced and/or imported in the U.S. (2008), expires end of 2010

World Biofuels Study



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

MARKAL Model Structure

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

Energy Resources
- Cost and Availability

Energy Service Demands
- By Sector/Region

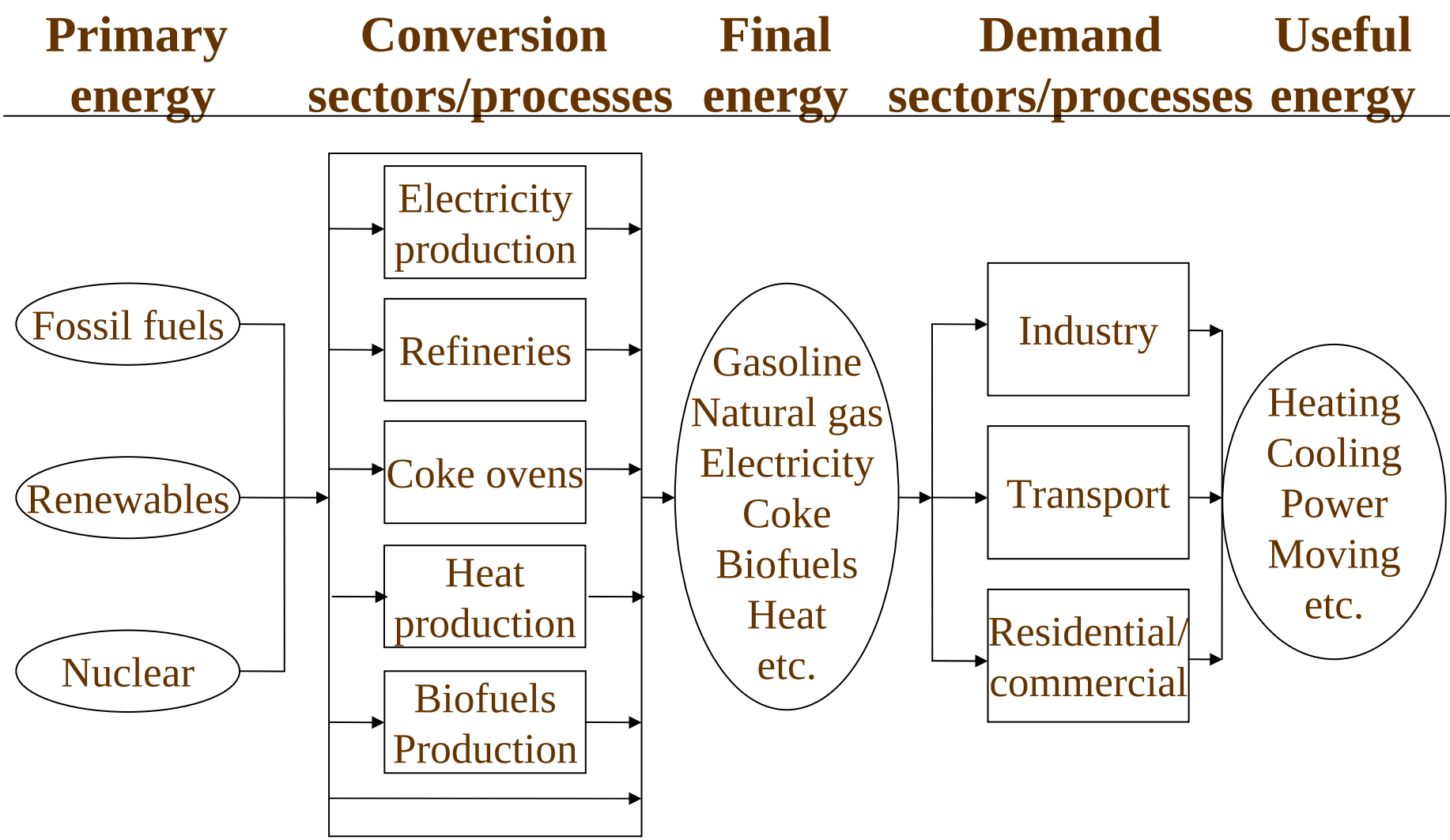
Other Assumptions
- Long-Term Discount Rate
- System Reserve Requirements

Other Constraints
- Max. CO_2 Emissions by Time Period

→ **Dynamic LP Optimization**

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

MARKAL Energy System



Energy Technology Perspectives

- Global MARKAL Model
- 15 Regions
- Developed at the International Energy Agency
- Calibrated to the World Energy Outlook

- *Energy Technology Perspectives 2006*
- *Energy Technology Perspectives 2008*

Updates to ETP Model-Technologies

Feed stock	Source	Conversion Technology	Product	Distribution/ Consumption
Sugar	Sugarcane	Sugar-ethanol mill	Ethanol	
Starch	Corn Wheat	Dry 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
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

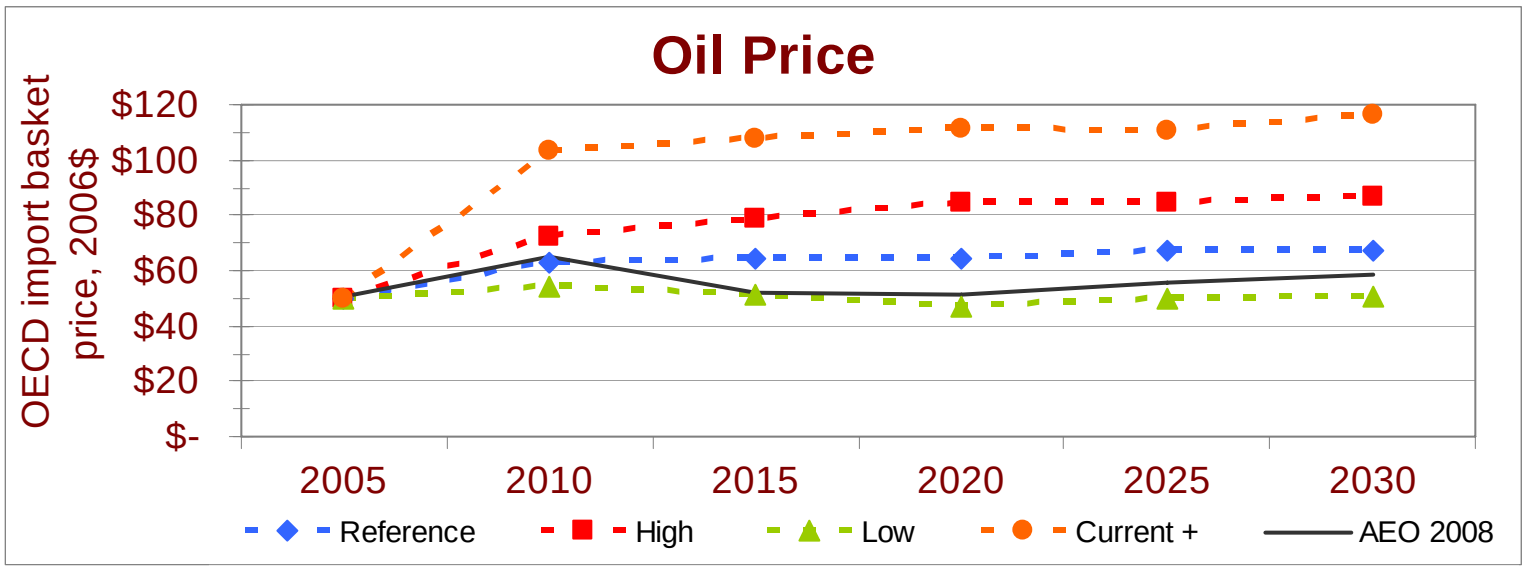
International Biofuel Policies

Country/ region	Gasoline tax	Biofuel tax exemption (2010)	Ethanol tariffs	Other Biofuels Policies
Australia	$1.40/gal	100%	90¢/gal	
Canada	$0.25/gal	100%	20¢/gal	
China	$0.15/gal	100%	0	
Central & S. America	$0.70/gal	50%	27¢/gal	Subsidy for hydrous ethanol & FFV; Brazil ethanol blending mandate of 20-25%
Europe	$2.80/gal	90%	90¢/gal	5.75% market share 2010 10% market share 2020
India	$1.90/gal	0%	200%	
Japan	$1.85/gal	90%	17%	500 million liters gasoline equivalent by 2010
S. Korea	$3.02/gal	90%	0	
USA	$0.42/gal	45¢/gal (ethanol)	54¢/gal	36 billion gallons ‘renewable fuels’ (2022); $1.01/gal cellulosic tax credit

* In the model, tax exemptions are gradually phased out over time; U.S. biodiesel receives a $1.00/gallon diesel equivalent tax credit.

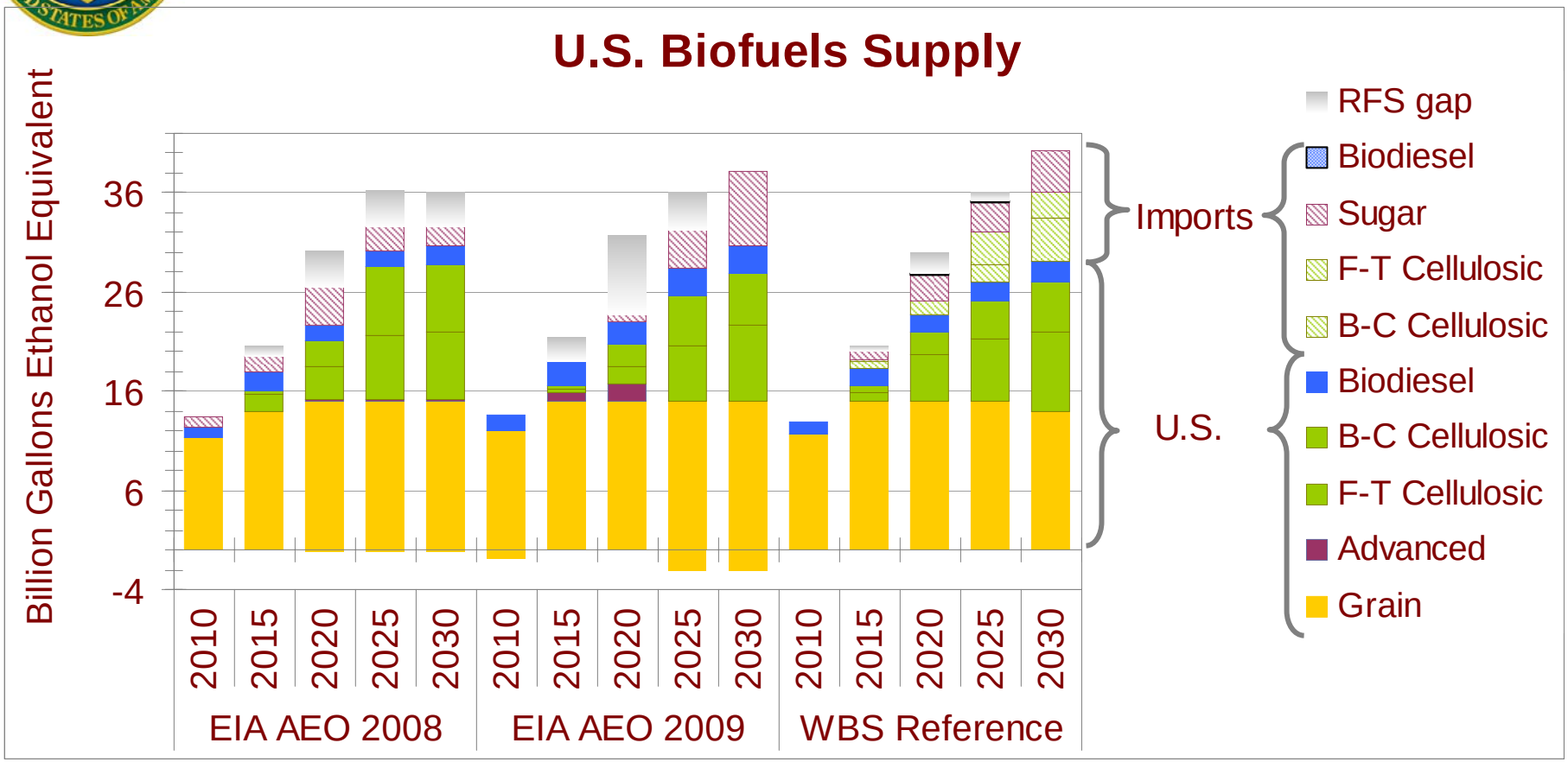
Reference Case Assumptions

- EISA Renewable Fuel Standard
- $1.01/gallon cellulosic biofuel subsidy extended until cost competitive (2008 Farm Bill)
- $1.00/gallon biodiesel subsidy
- Blenders' ethanol credit and Tariff expire in 2010
- Includes existing national biofuels policies worldwide



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

Reference Scenario vs. AEO 2009



- **We project more imports than EIA's AEO 2009**
- **Both domestic & imported cellulosic biofuels will contribute to meeting the mandate.**
- **Main challenge is building cellulosic plants fast enough.**

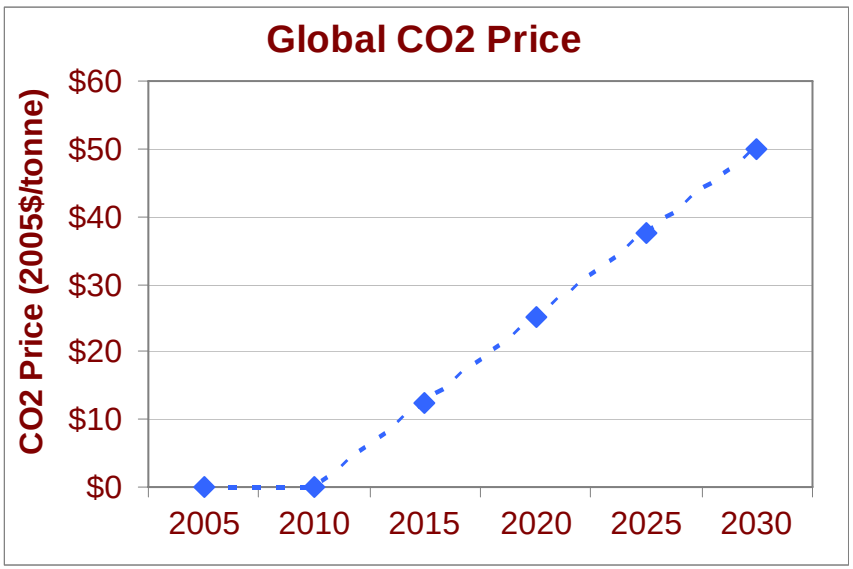
Scenarios Modeled

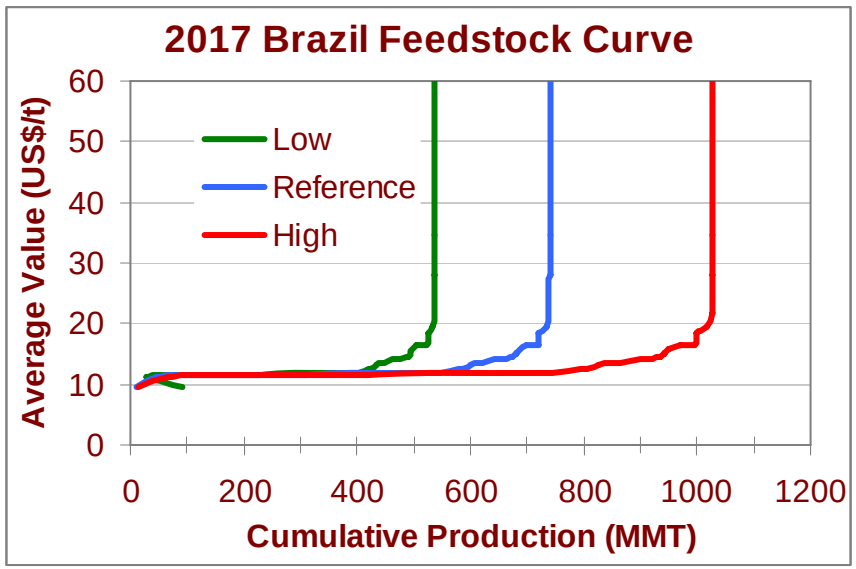
Policy Scenarios

Tariff/Credit Extension
Credit Extension
$50/tCO$_2$ (global)
E20 Certification
Grower's payment

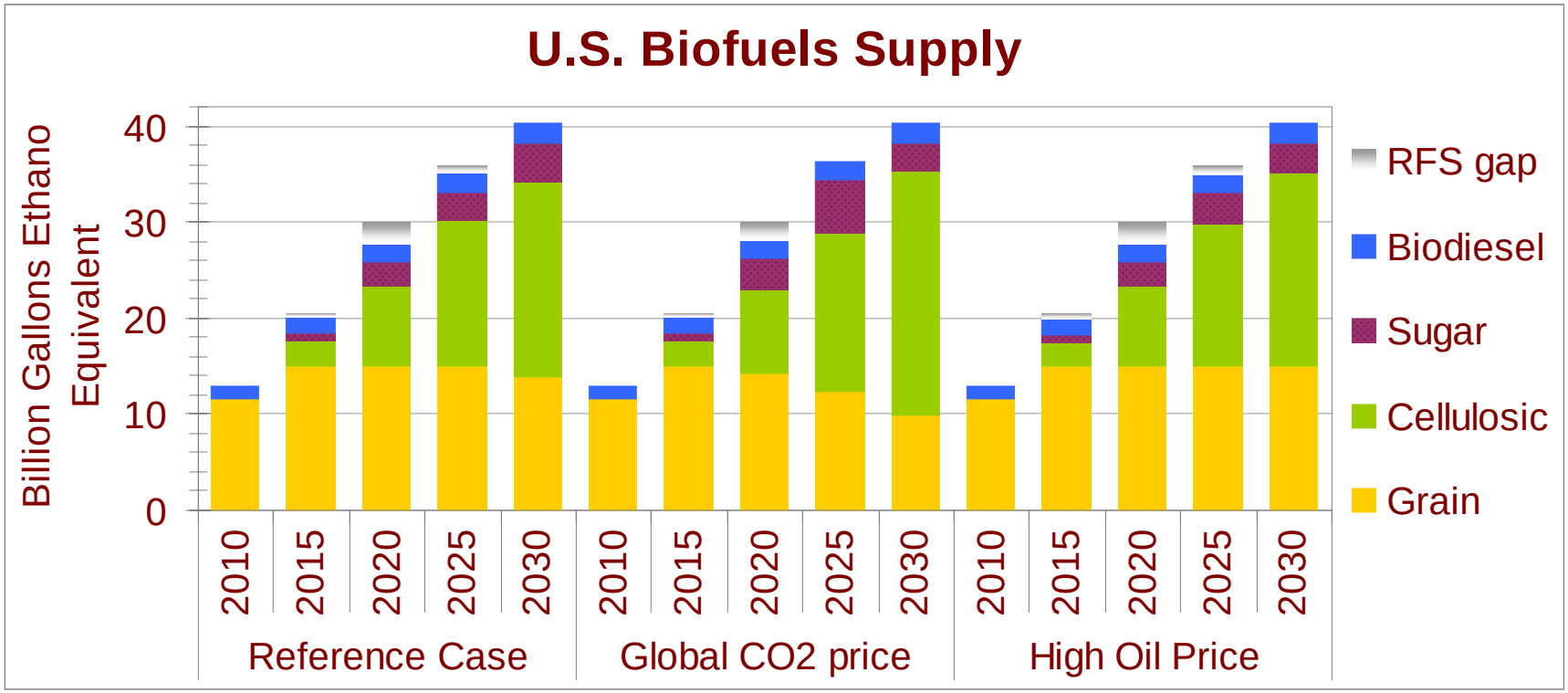
Market Scenarios

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



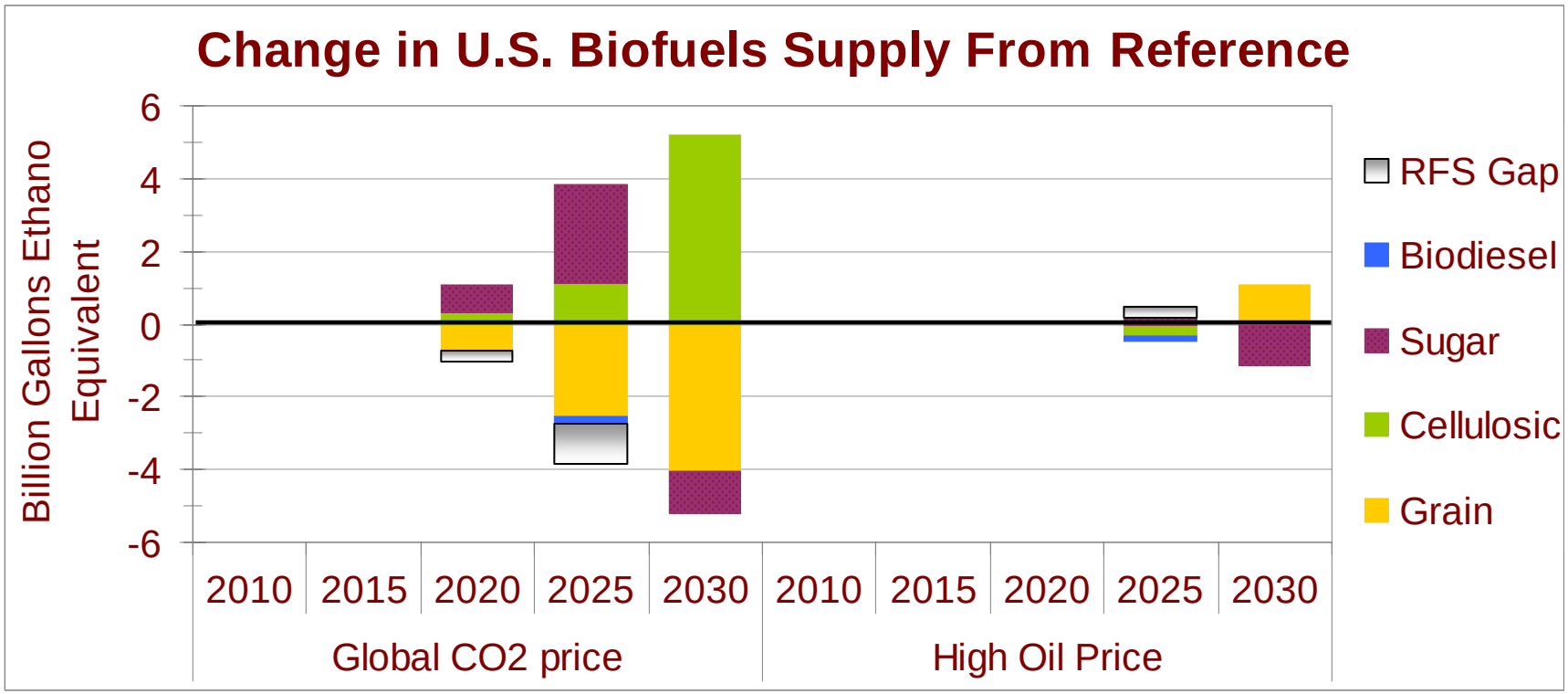


CO_2, Oil Price Scenarios (U.S.)



- **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**

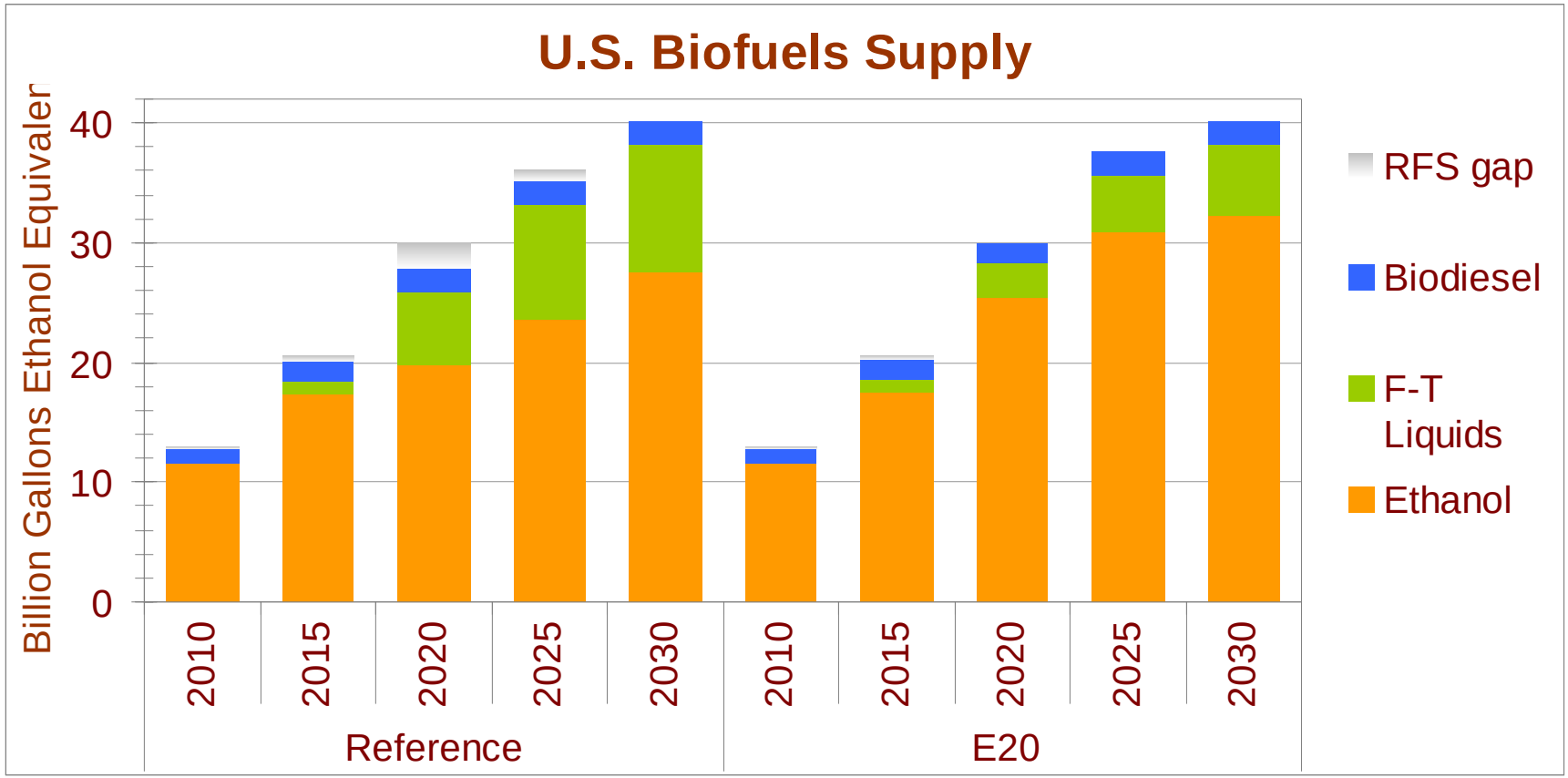
The barrier to meeting RFS?

Biofuels 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

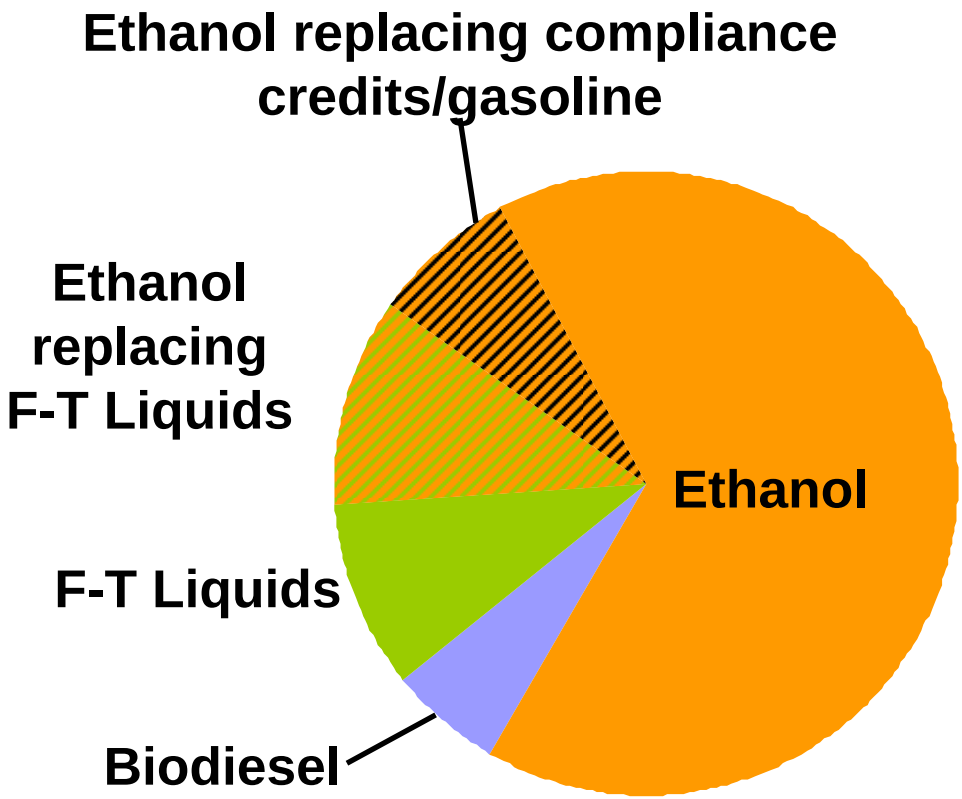


- **Only case to meet RFS**
- **Illustrates E85 infrastructure constraints**
  - **Pipelines, fueling stations, flexible fuel vehicles**

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

Conclusions

The Good:

- Imports (sugar, cellulosic)
- Cellulosic biofuels
  - Learning investment
- Flexibility between BTL and cellulosic ethanol
- CO_2 price, decline in grain ethanol

The Bad:

- High oil price, lower exports to U.S.
- At large volumes, production at inelastic portion of feedstock supply curve
  - Additional subsidies have little impact

The Ugly:

- E85 infrastructure constraints

Thank you for your attention

Please feel free to contact me
if you have additional questions and comments.

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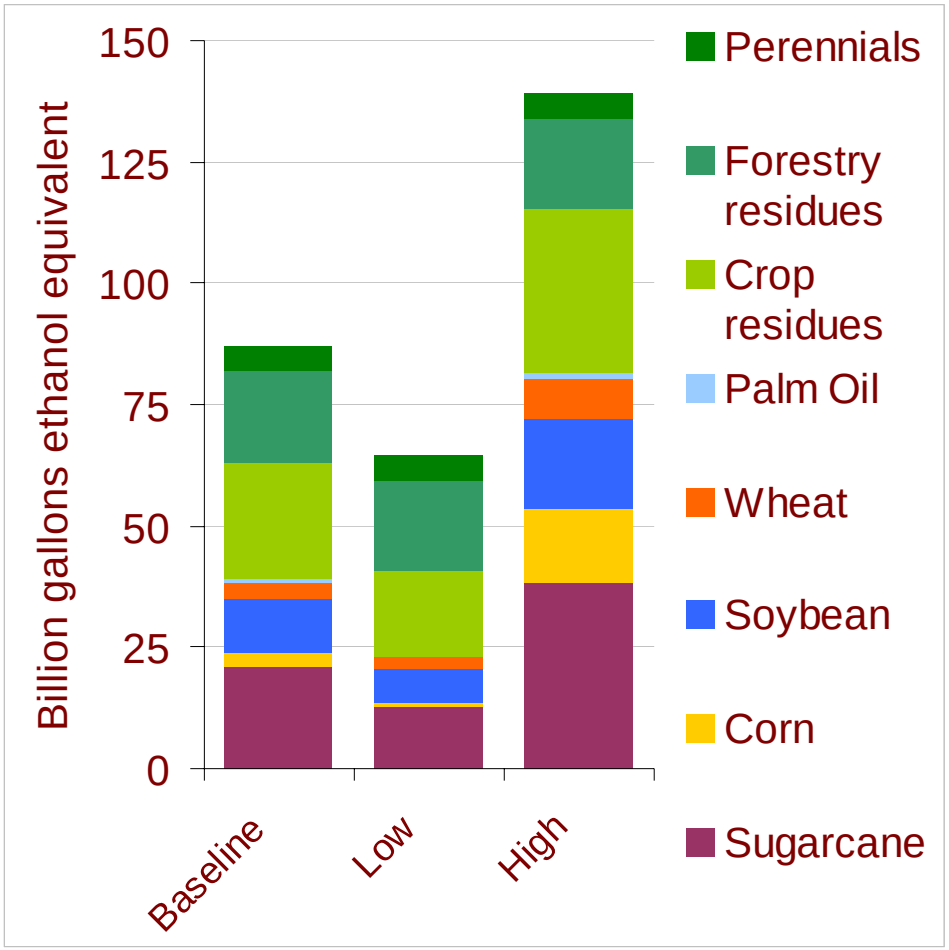
1-202-586-0101

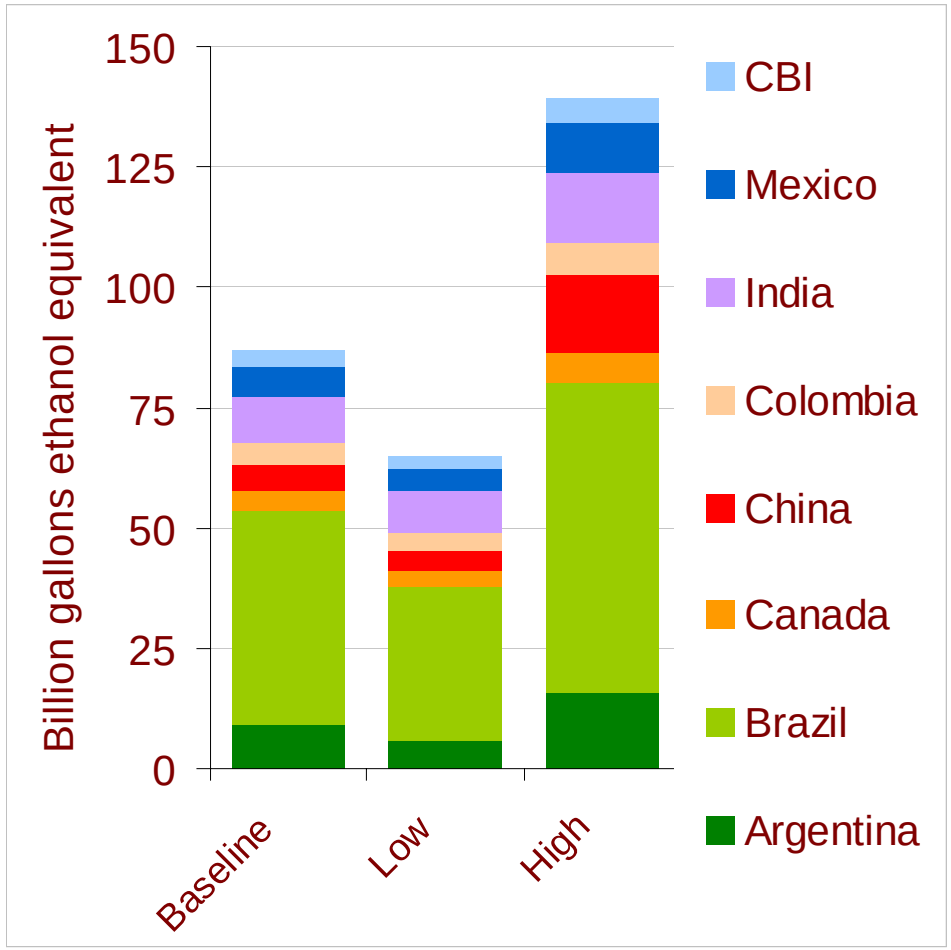
Final report available at
www.pi.energy.gov

ORNL/NREL/BNL reports at http://www.osti.gov/bridge/
search 924080, 921804, 939942

Back-up Slides

ORNL Feedstock Assessment

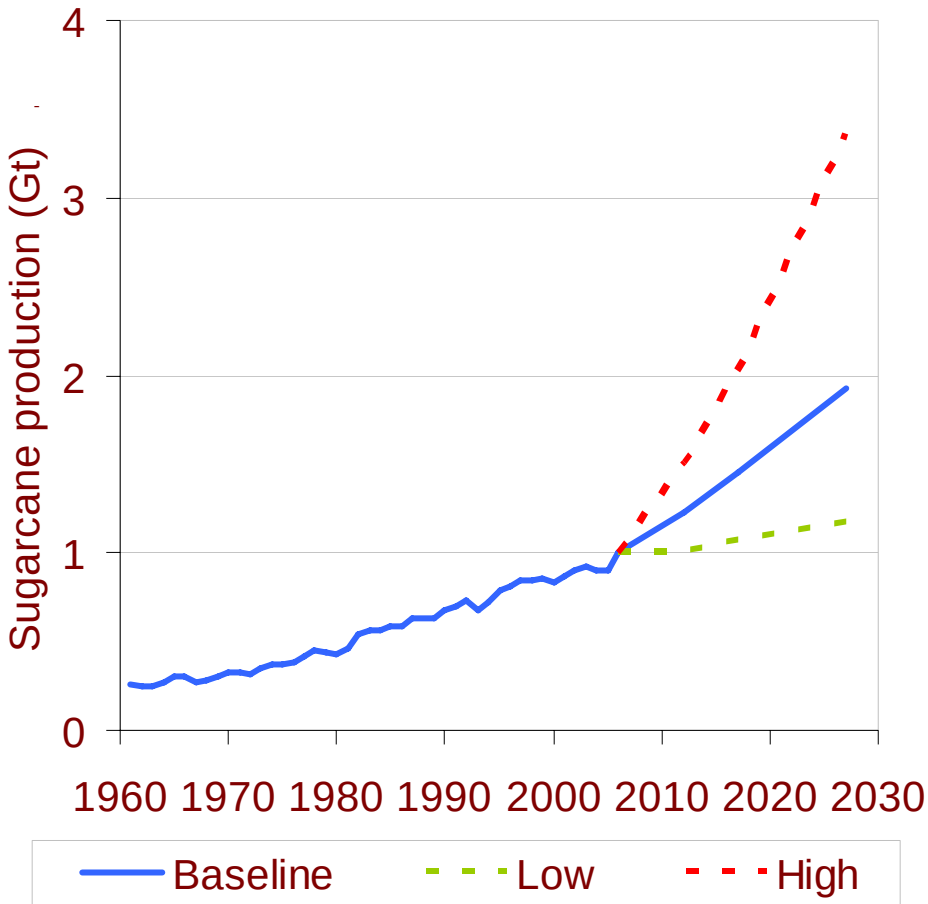


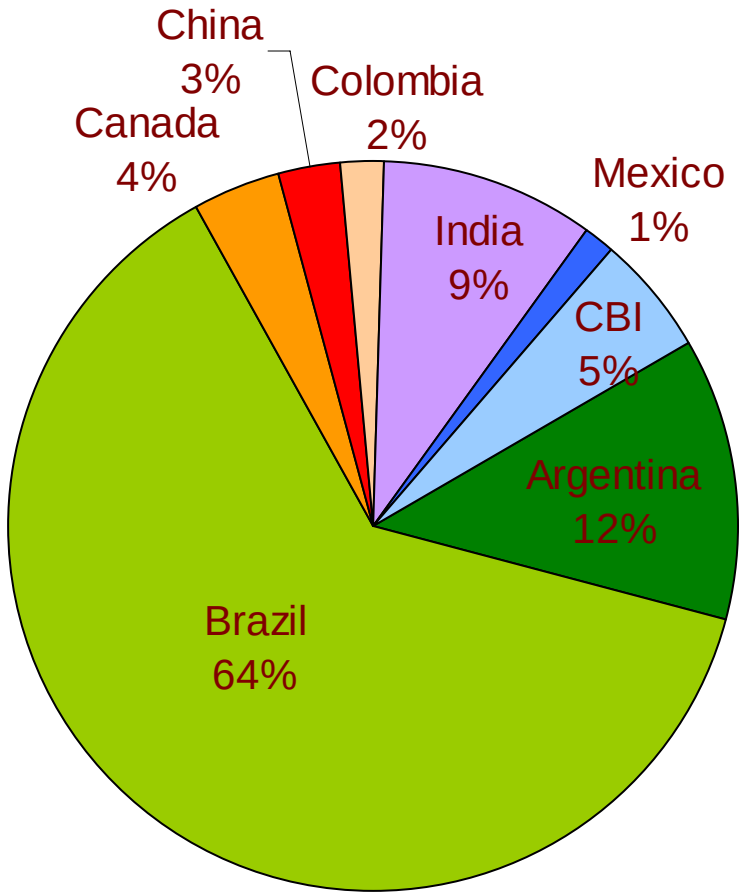


Feedstock Potential Available for Export in 2017

ORNL Feedstock Assessment

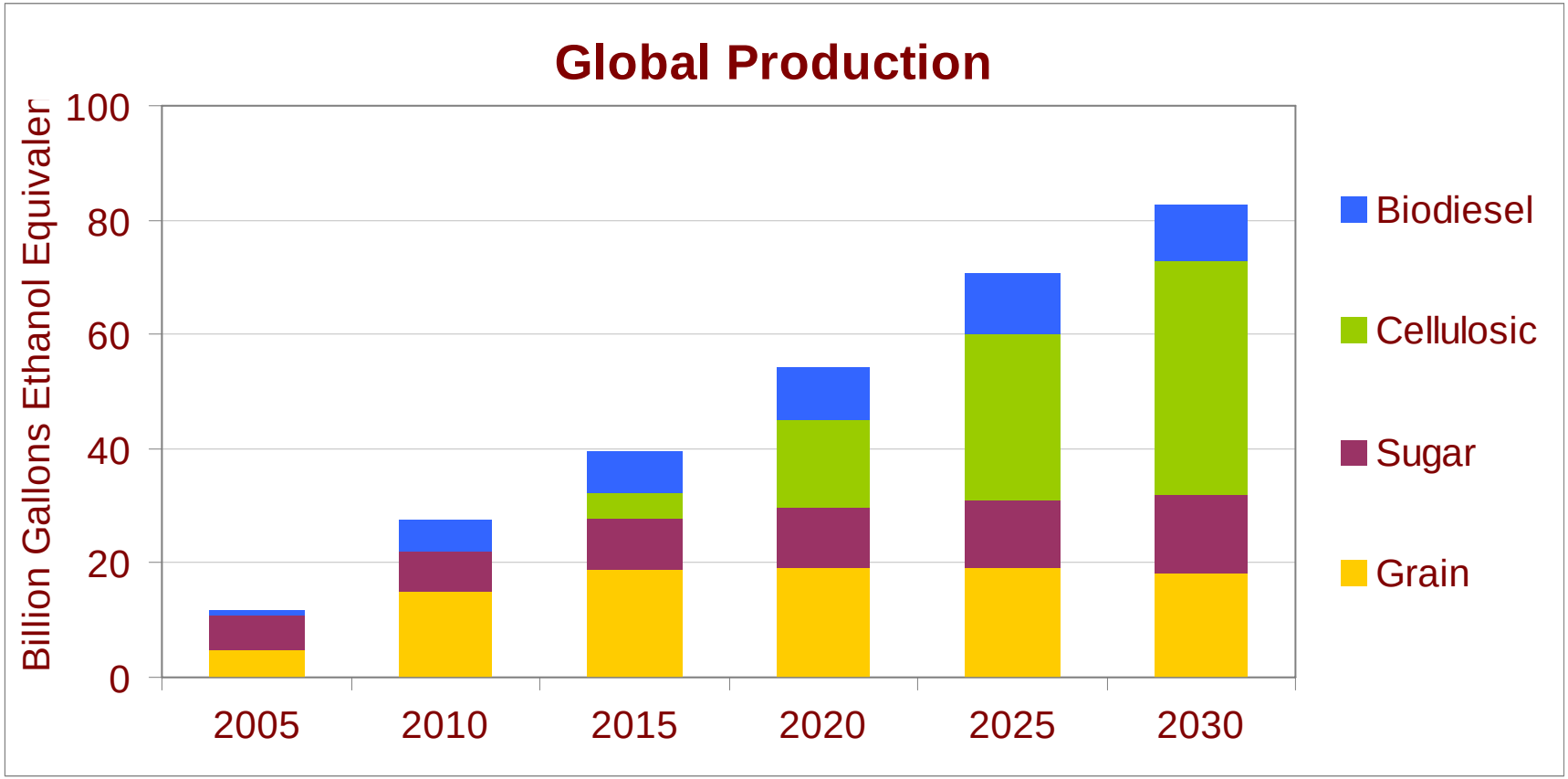
Sugarcane
Historic Trend and Projection
total aggregate supply





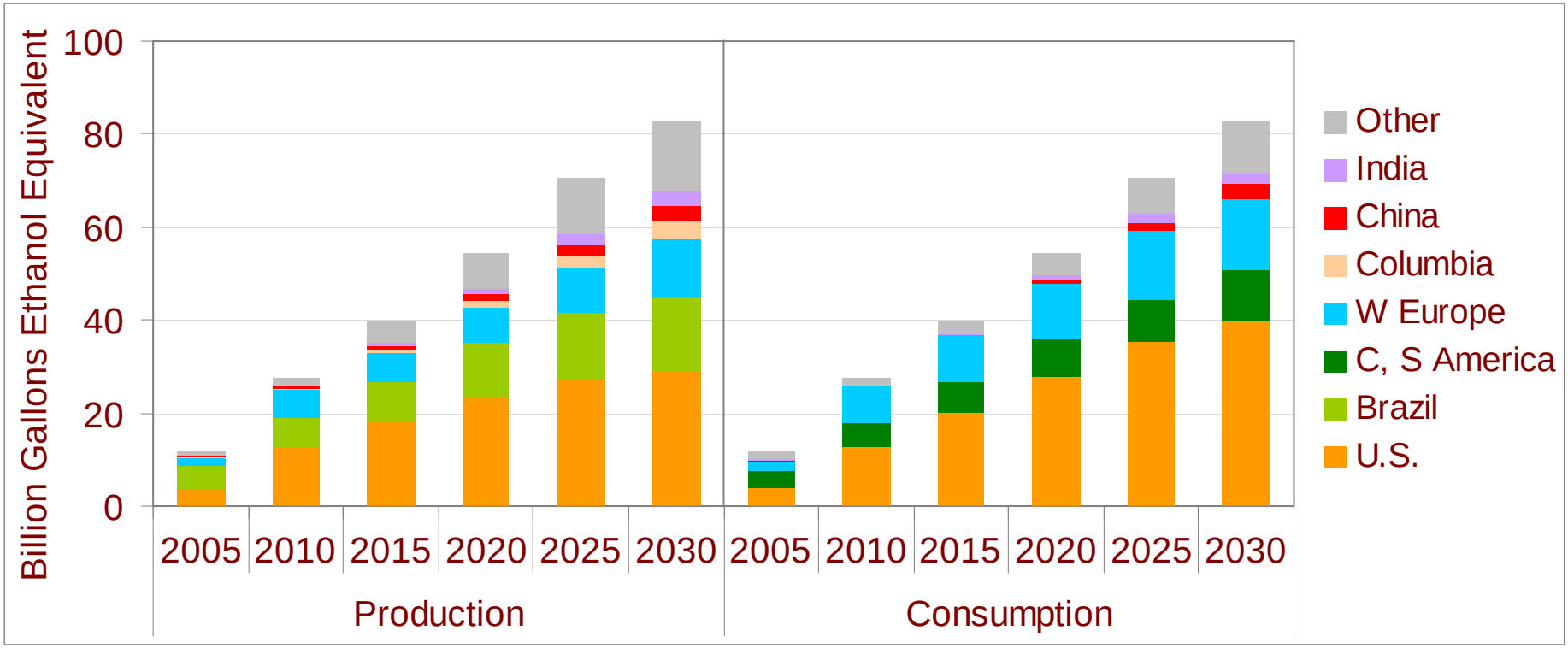
Feedstock Potential Available for Export in 2017
(gasoline eq. basis)

Worldwide Biofuels Production



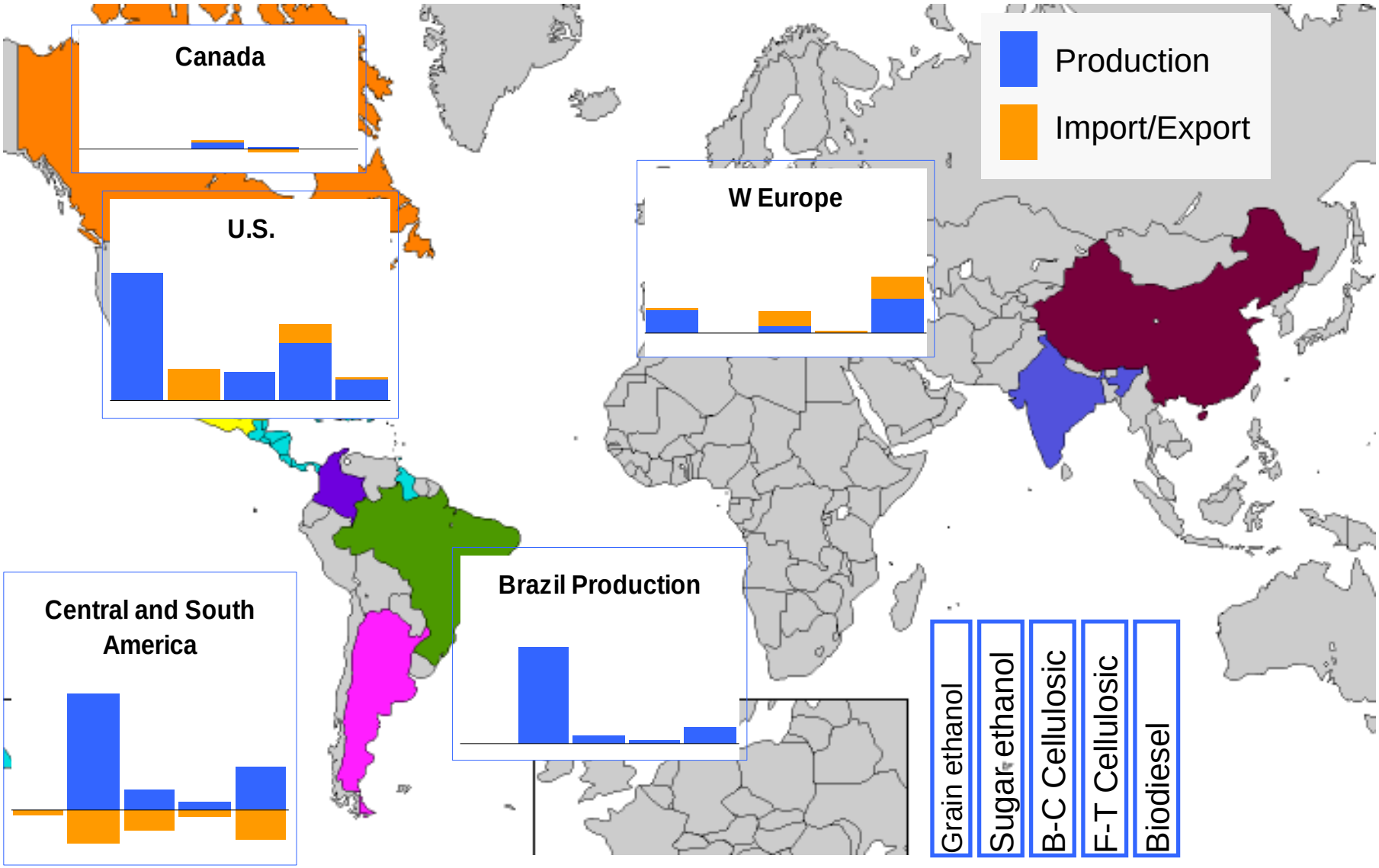
- **Grain production levels off after 2015**
- **Large growth in cellulosic biofuels**
- **Subsidy for early cellulosic plants is crucial to this growth**

Production vs. Consumption

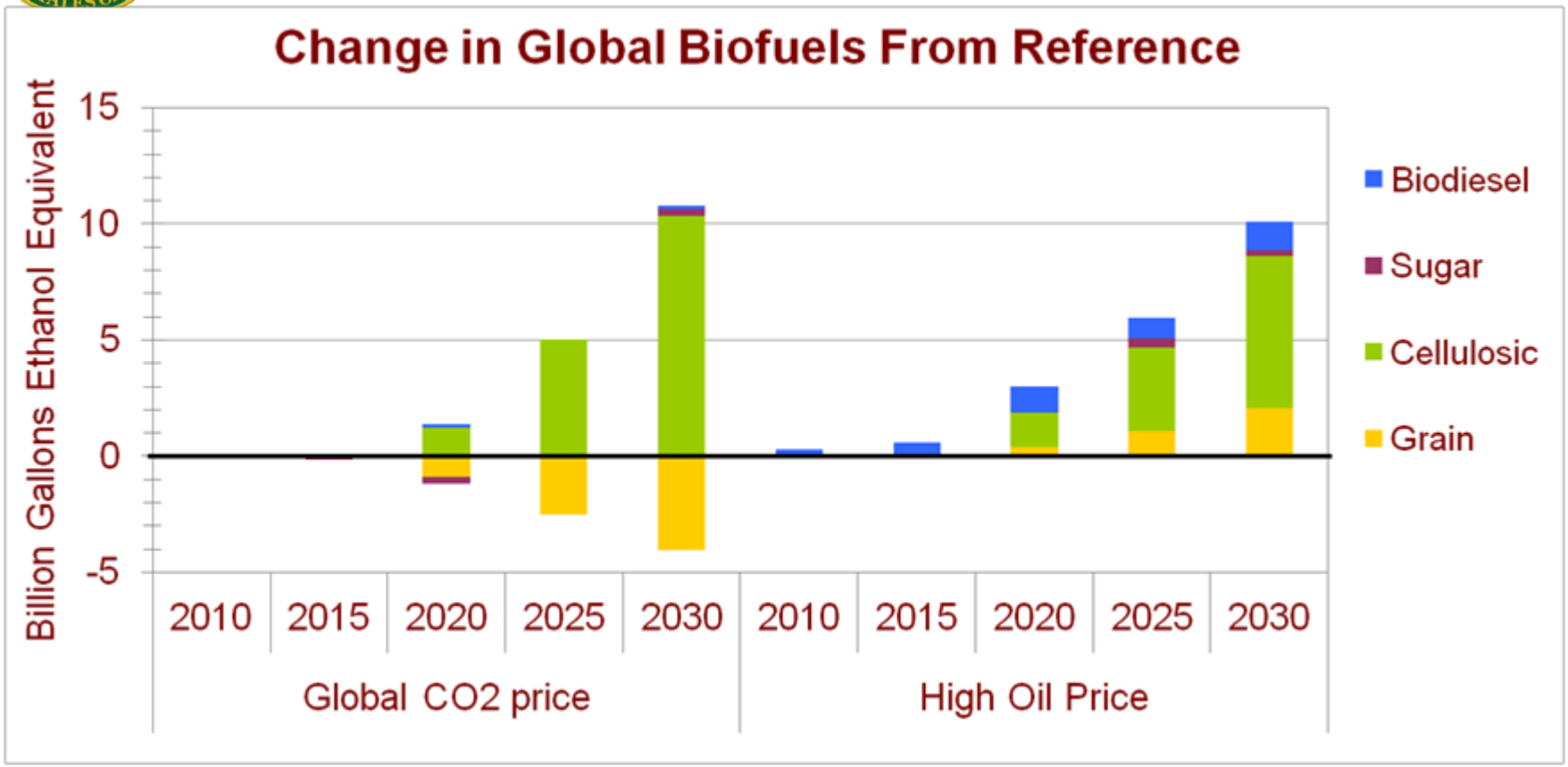


- **U.S. and Western Europe are net importers**
- **U.S. consumes roughly half of supply**
- **Brazil is net exporter**
- **Not all mandates are expected to be met (including U.S.)**

2020 Supply (million gal eth eq)



CO_2, Oil Price Scenarios (global)

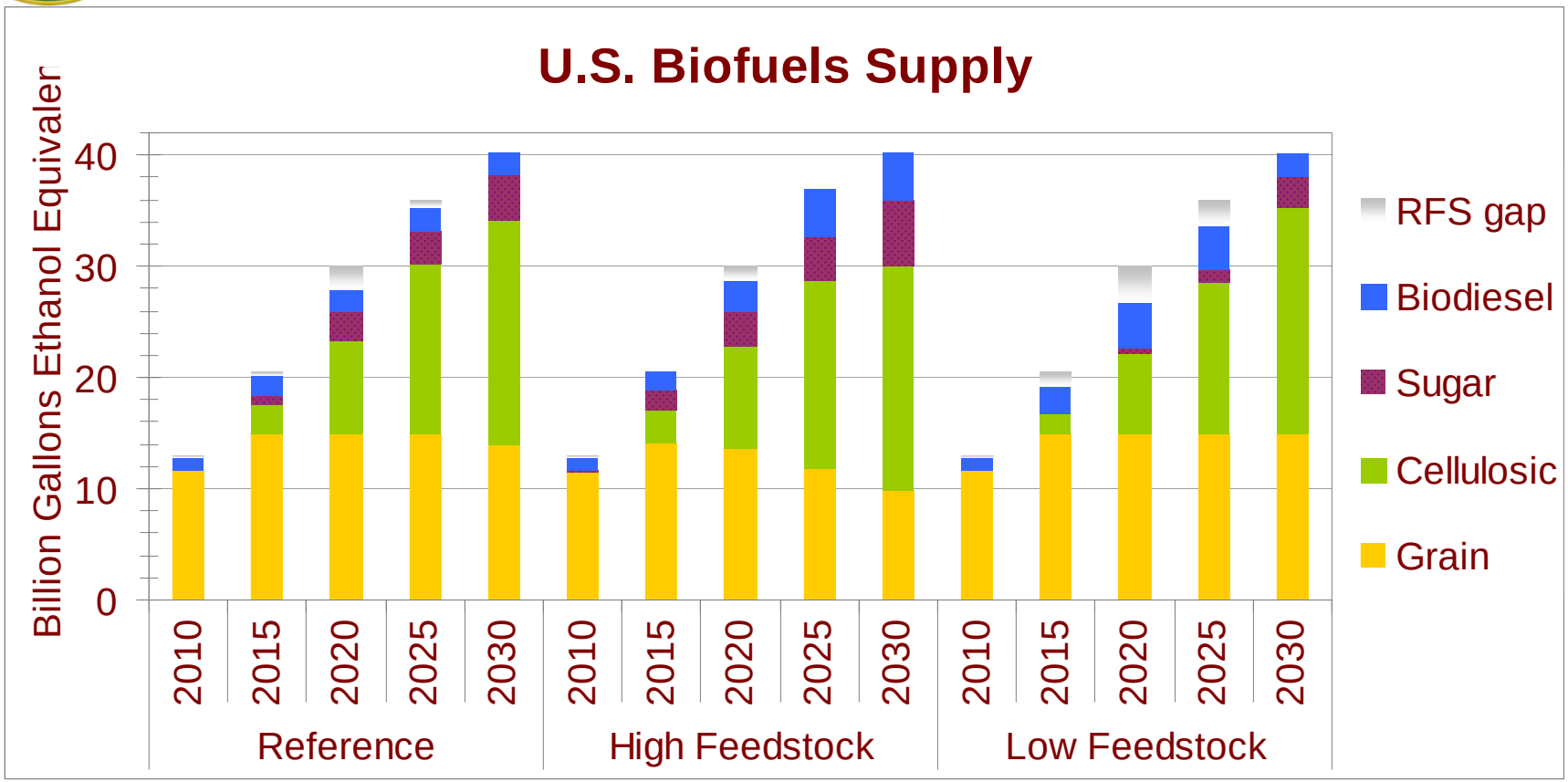


- Global CO_2 price:
  - Large increase in cellulosic production
  - Grain ethanol production is replaced
- High oil price: Increase in total production

Conclusions

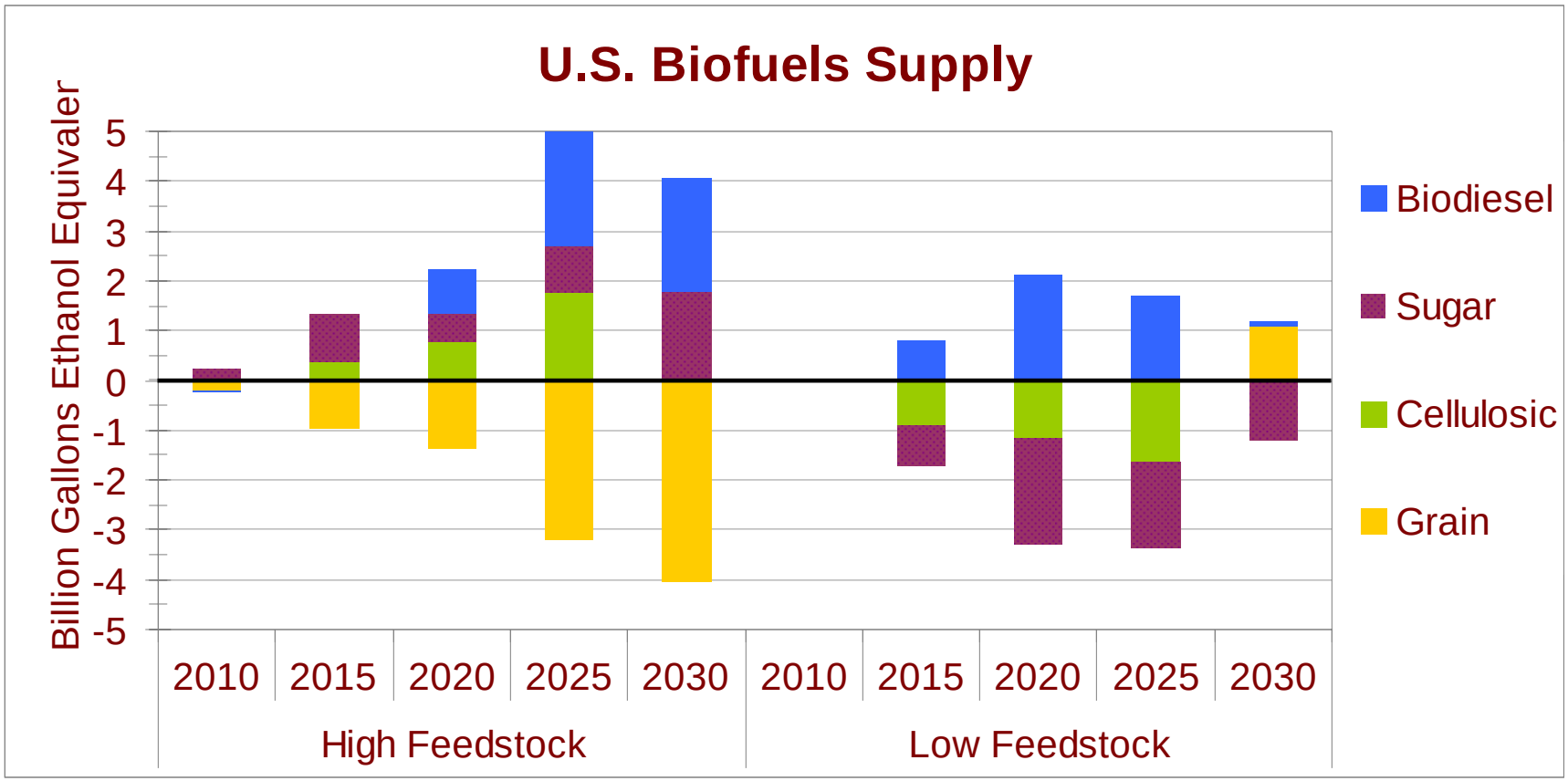
- Potential to double or triple feedstock production by 2017 for some countries/feedstocks
  - increase cultivated area (esp. sugarcane)
  - improving yields and farming practices
- Brazil is major source of available supply
- Grain production levels off after 2015
- Large growth in cellulosic biofuels (subsidy is crucial)
- U.S. consumes roughly half of supply
- Not all mandates are expected to be met (incl U.S.)
- Global CO_2 price replaces grain with cellulosic
- High oil price increases in total production (incl. grain)

High/Low Feedstock Scenario



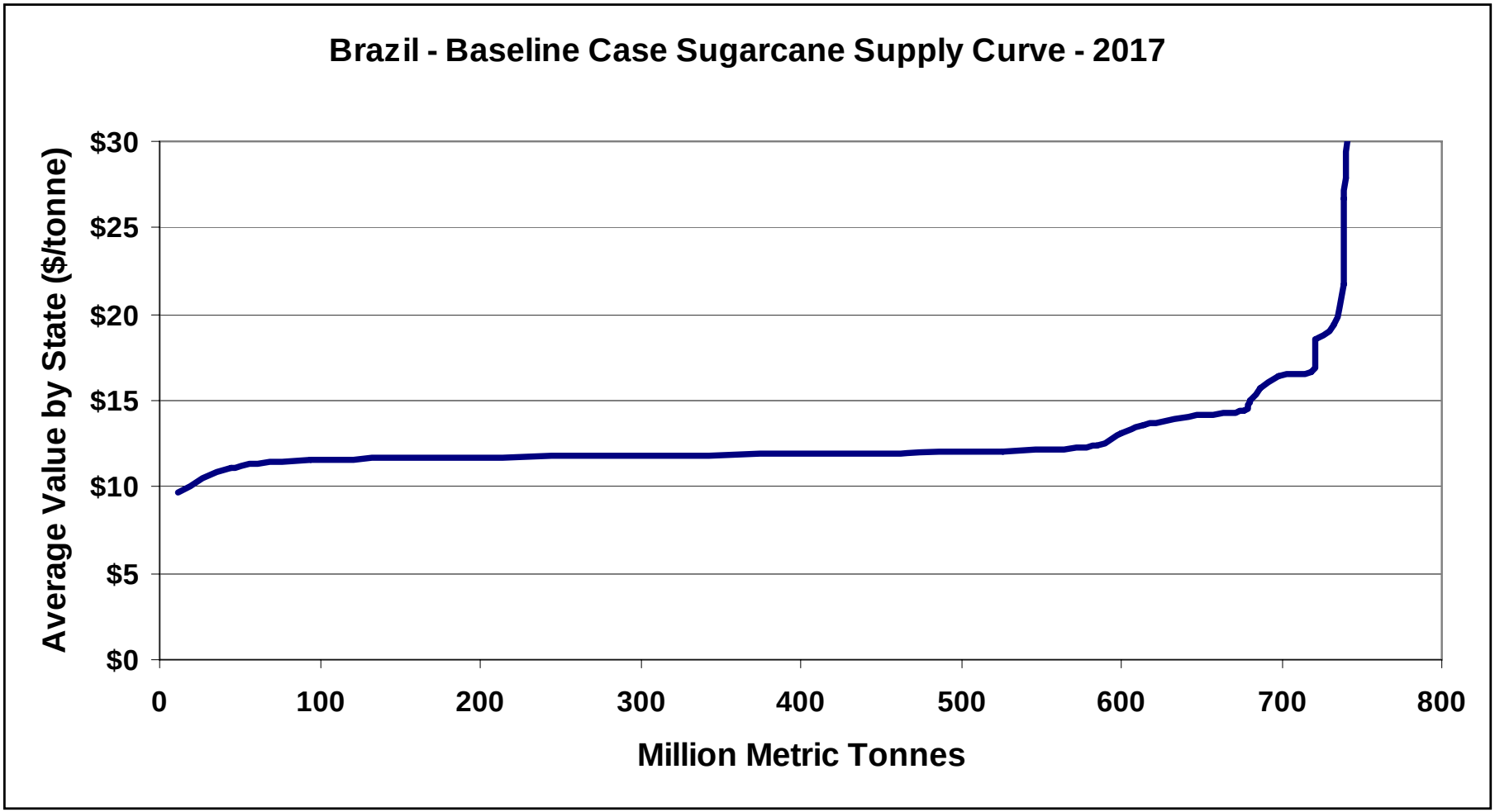
- High feedstock pertains to countries updates, not U.S.

High/Low Feedstock Scenario

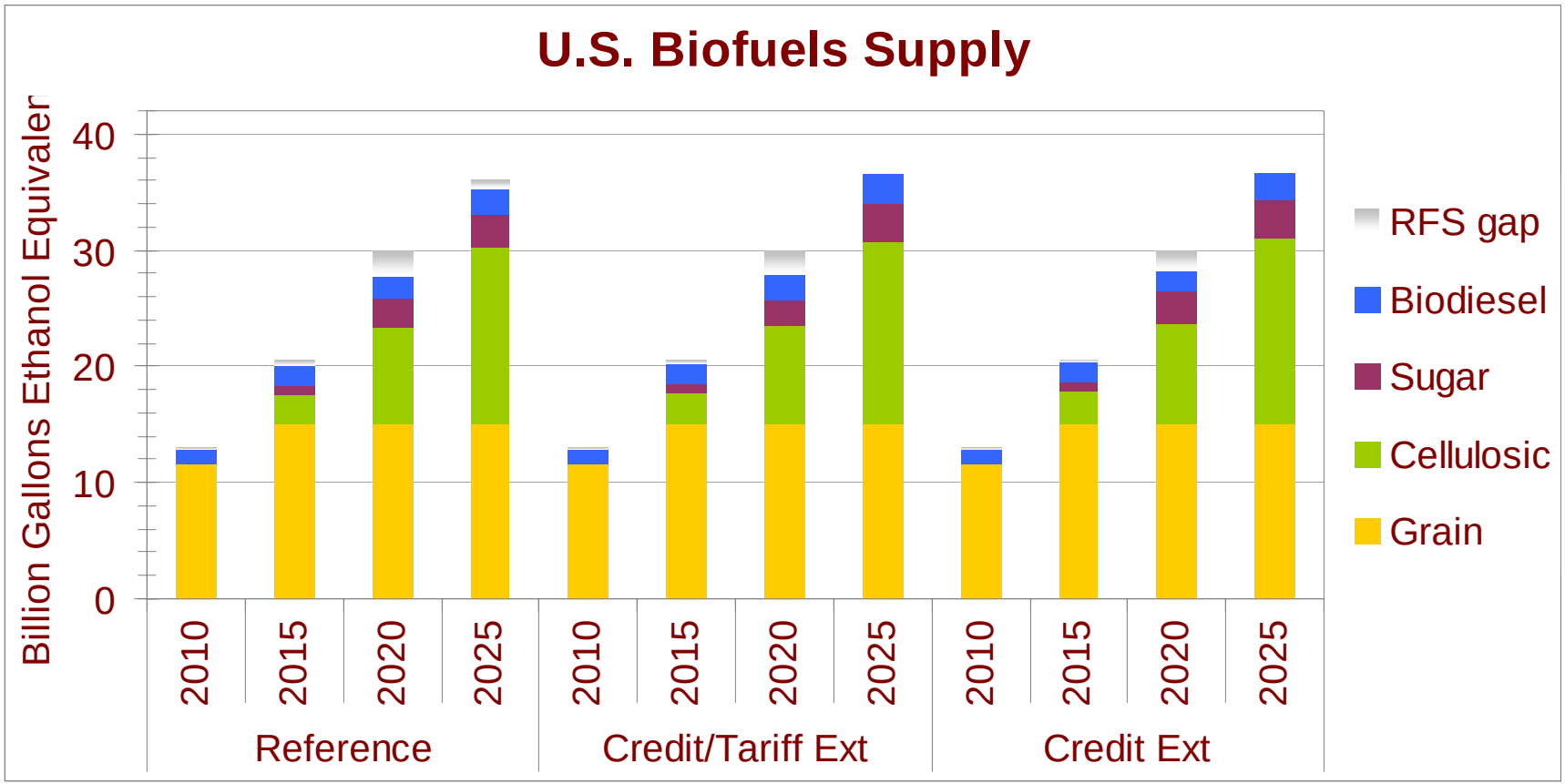


- High feedstock pertains to countries updates, not U.S.
- Sugar and cellulosic replace U.S. grain ethanol

Sugarcane Supply Curve (2017)- Brazil

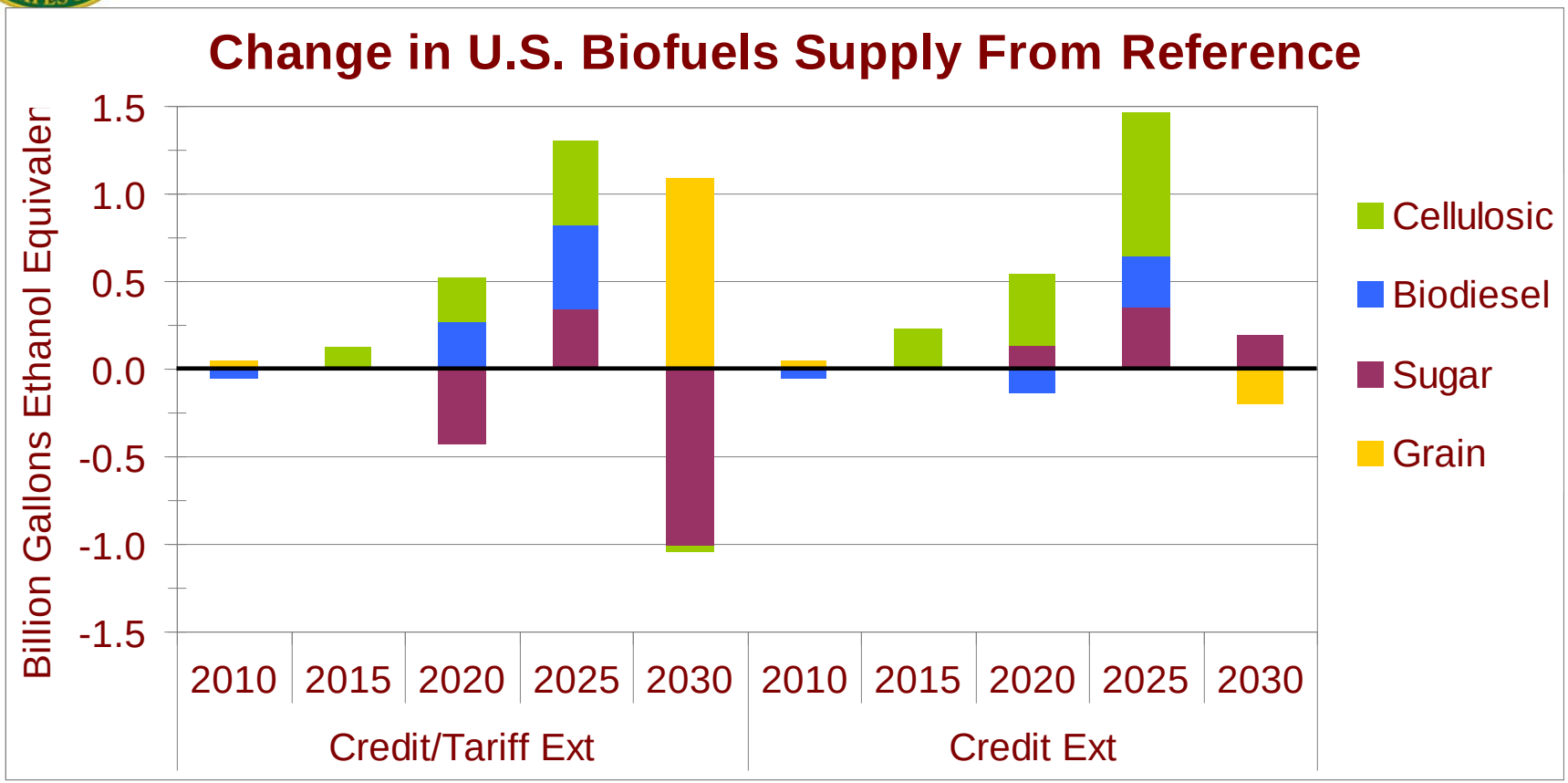


Credit/Tariff Extension Scenario



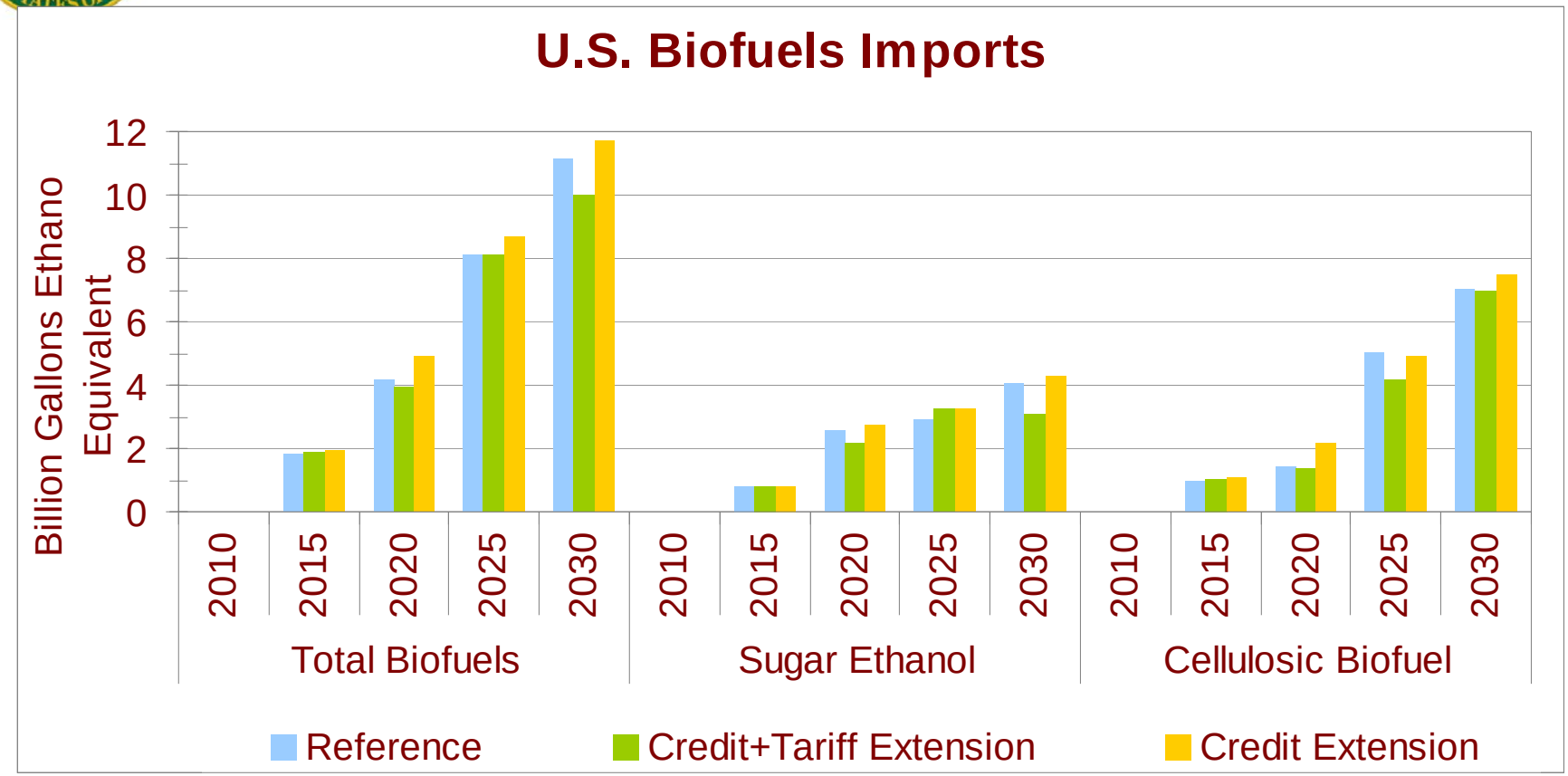
- Blenders' Credit and Tariff Extension
  - –already at inelastic portion of feedstock supply curve before 2020

Credit/Tariff Extension Scenario



- Not targeted to cellulosic biofuels
- Does not relieve cellulosic infrastructure constraint
- Directed towards biofuels that are already mandated
- Very small supply increase

Credit/Tariff Extension Scenario



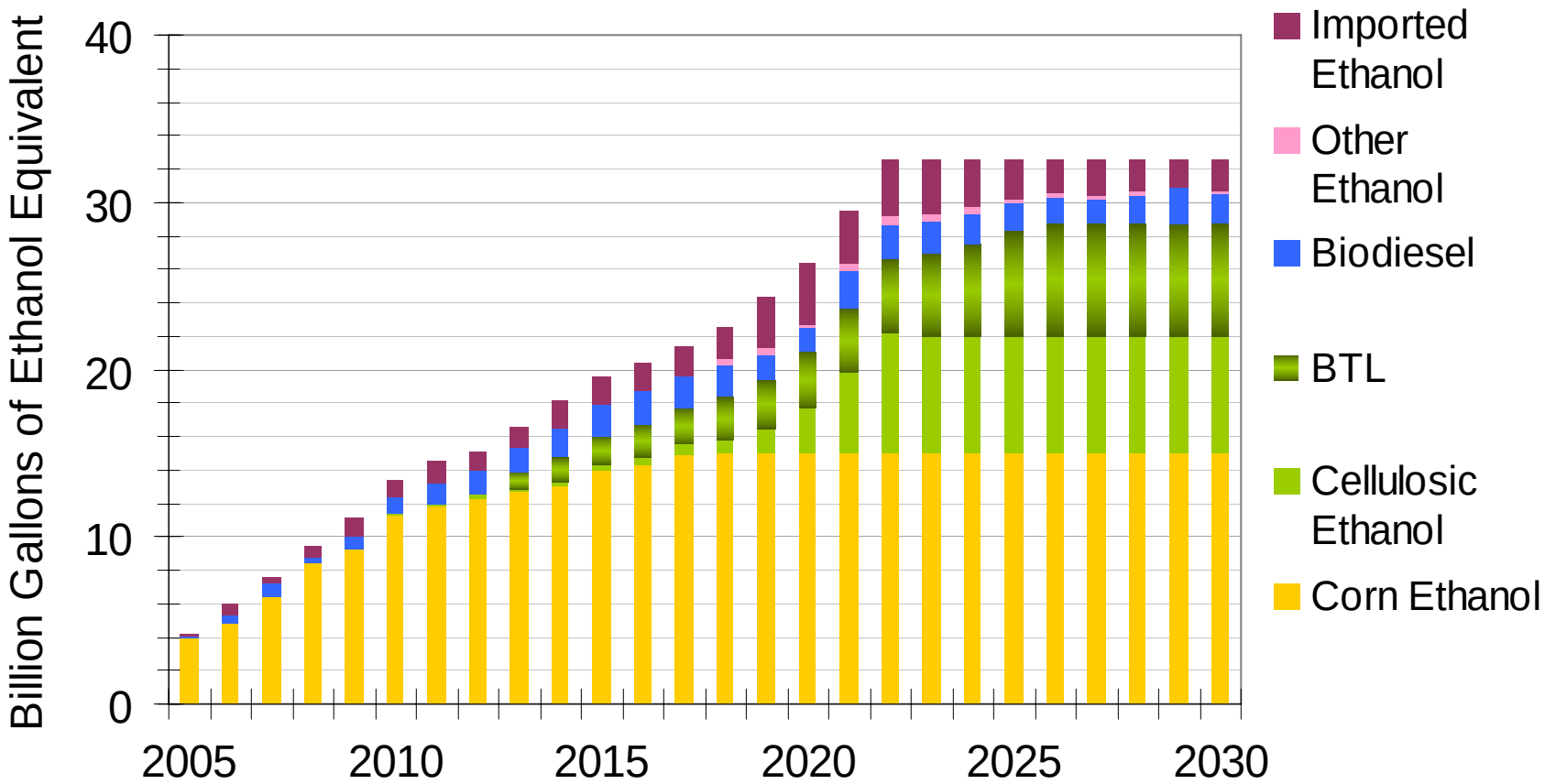
- Blenders' Credit and Tariff Extension
  - Small effect on imports until 2030
- Blenders' Credit Extension
  - Small increase in imports

Cellulosic Biofuel Costs

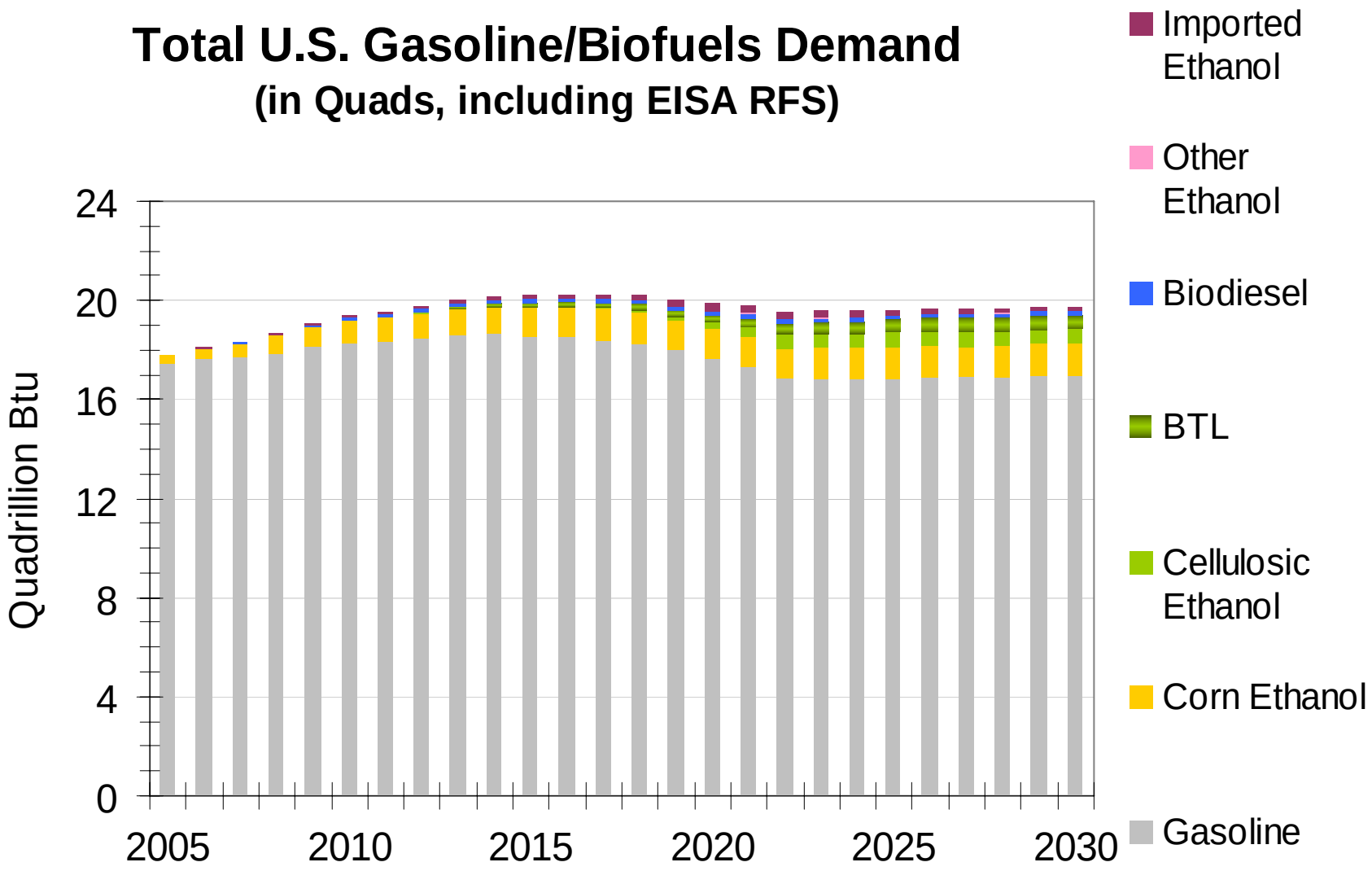
	Year	First Cost $/gal-eth	Annual Cost $/gal-eth	Net Operating $/gal-eth, incl elec cred	Denatured Eth Yield gal/ton	Anhydrous Eth Yield gal/ton	Feedstock Cost $/ton	Feedstock Cost $/gal-eth	Total Cost $/gal-eth
w/out	2015	$ 6.71	$ 1.01	$ 0.53	89.25	85.00	$ 51.24	$ 0.60	$ 2.15
Learni	2020	$ 5.69	$ 0.86	$ 0.37	89.25	85.00	$ 55.73	$ 0.66	$ 1.88
ng	2025	$ 5.23	$ 0.79	$ 0.31	89.25	85.00	$ 57.60	$ 0.68	$ 1.78
Invest	2030	$ 4.76	$ 0.72	$ 0.28	89.25	85.00	$ 58.90	$ 0.69	$ 1.69
w/	2015	$ 3.20	$ 0.483	$ 0.28	89.25	85.00	$ 51.24	$ 0.60	$ 1.37
Learni	2020	$ 3.20	$ 0.483	$ 0.28	89.25	85.00	$ 55.73	$ 0.66	$ 1.42
ng	2025	$ 3.20	$ 0.483	$ 0.28	89.25	85.00	$ 57.60	$ 0.68	$ 1.44
Invest	2030	$ 3.20	$ 0.483	$ 0.28	89.25	85.00	$ 58.90	$ 0.69	$ 1.46

AEO 2008: Biofuels

U.S. Biofuels Demand
(billion gallons ethanol equivalent)



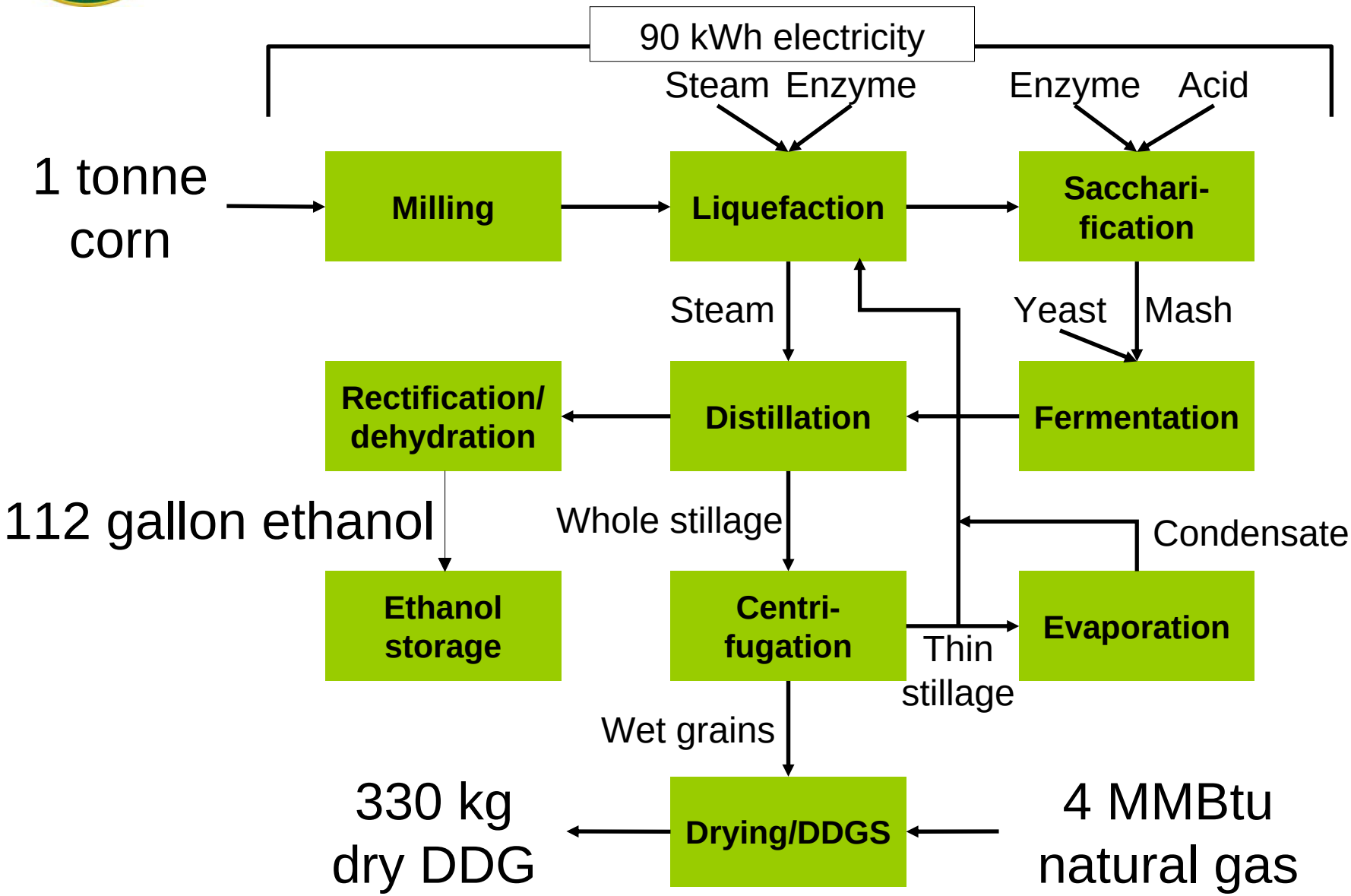
Annual Energy Outlook 2008



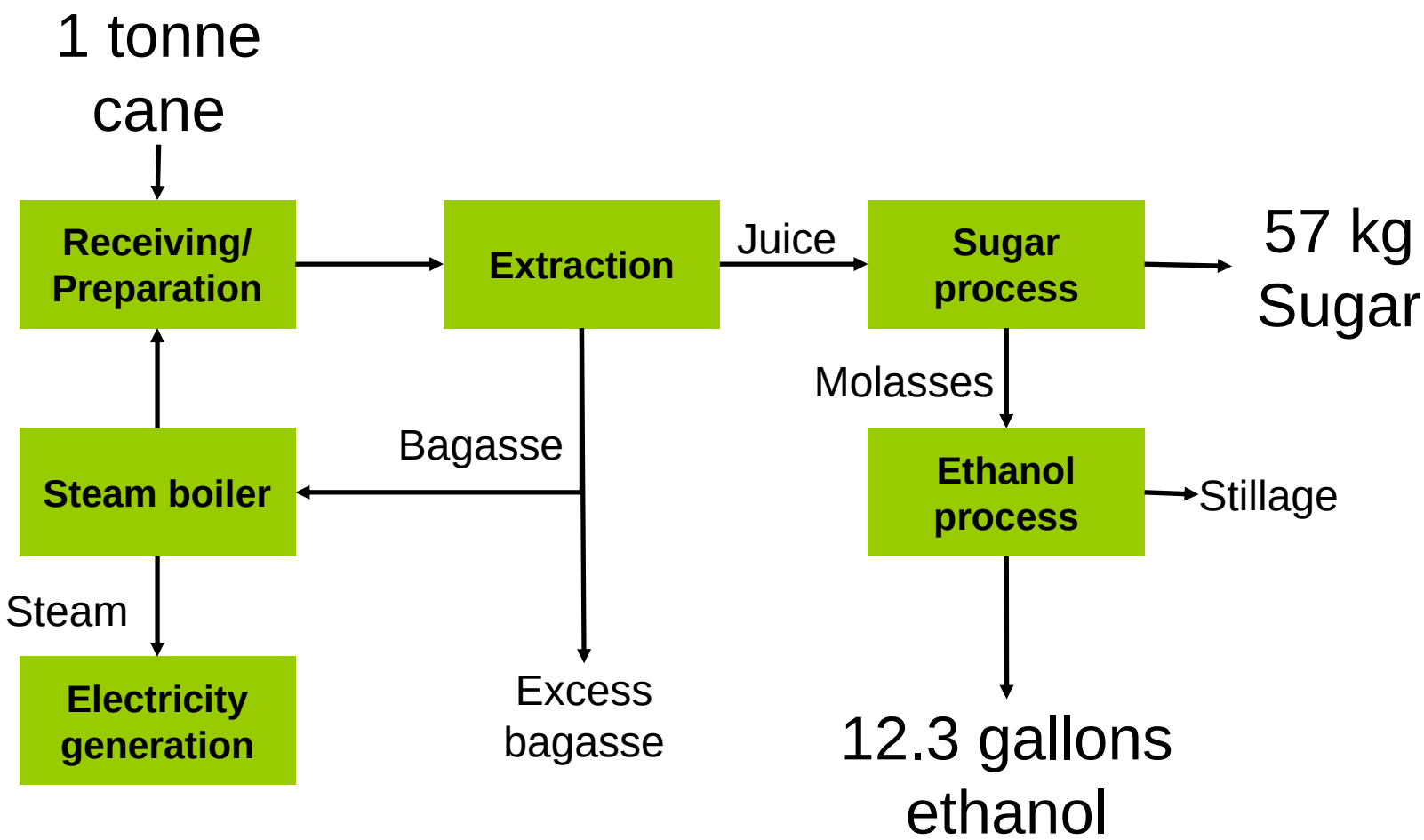
Conversion Technologies

- 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)

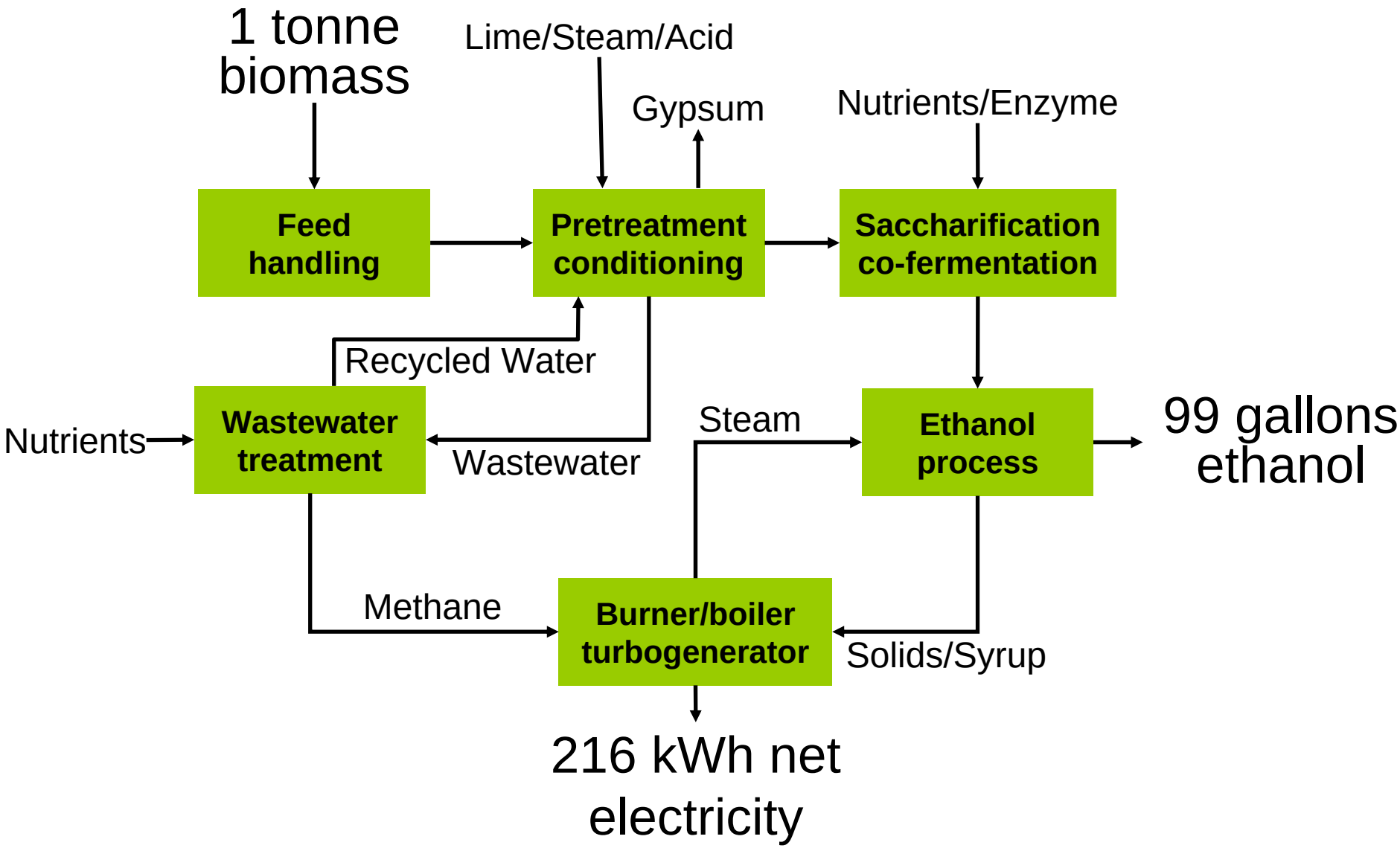
Dry Corn Mill



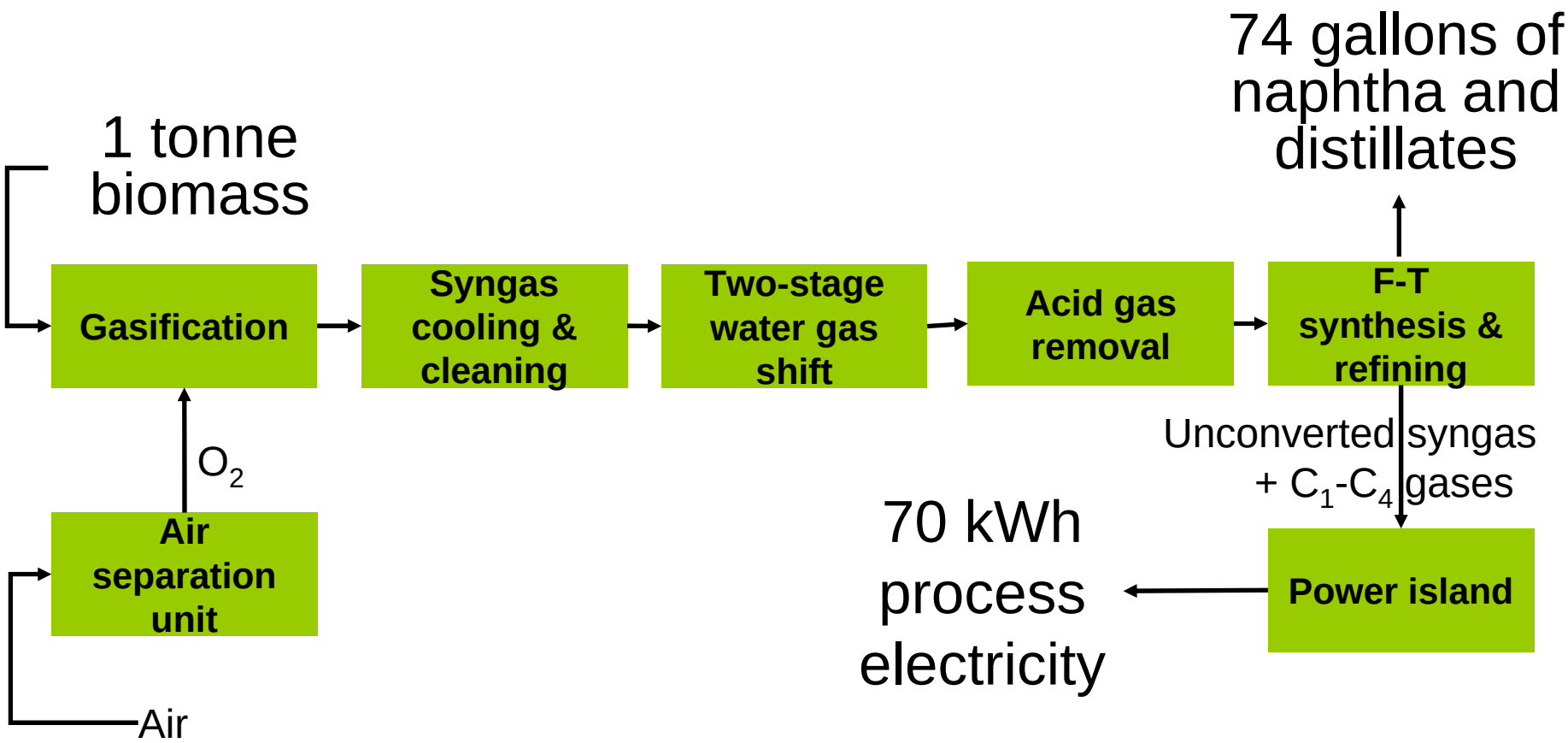
Sugarcane Mill



Bio-chemical Conversion



Thermo-chemical Conversion



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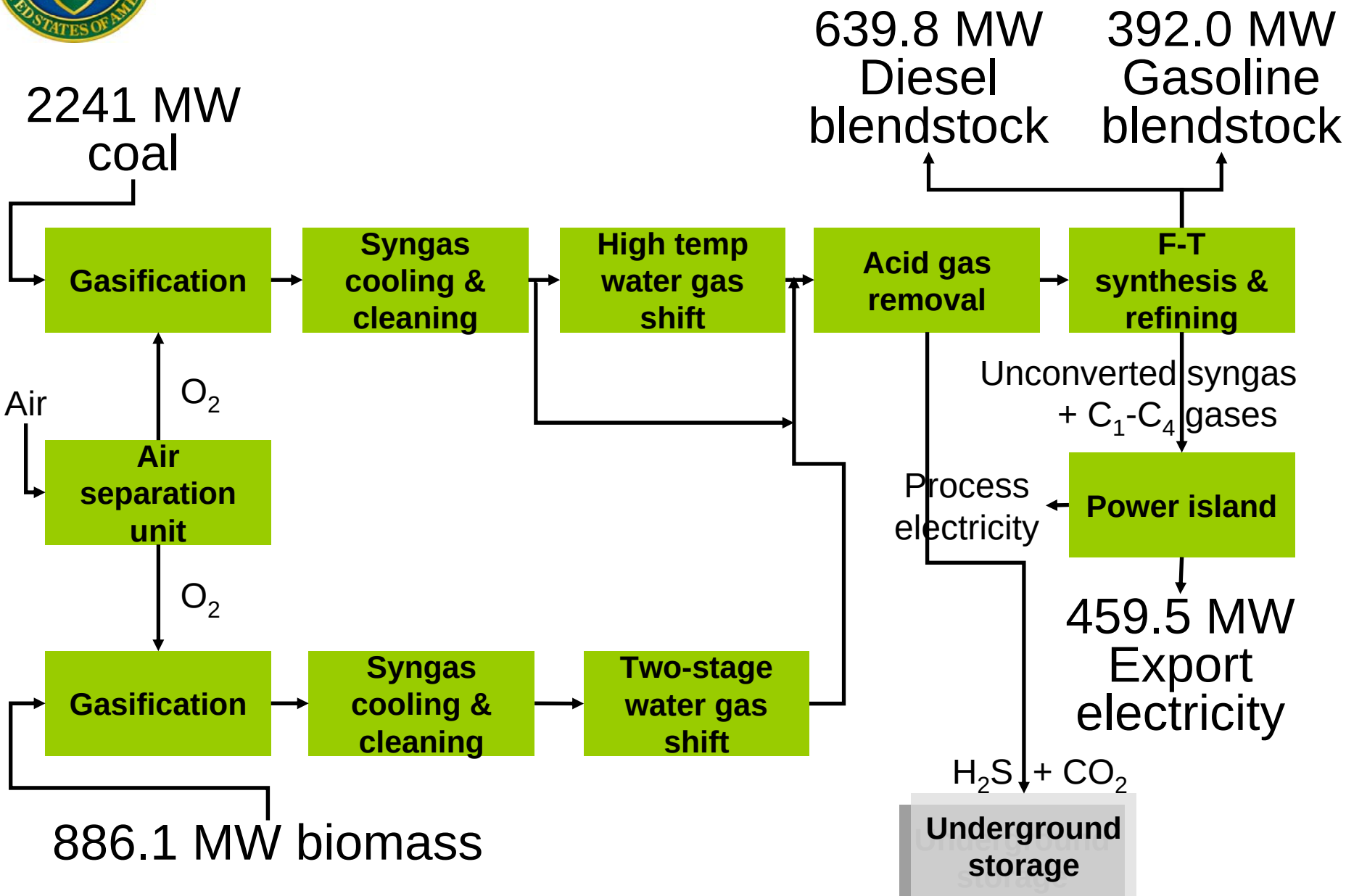

Definition: Renewable Biomass

- (I) RENEWABLE BIOMASS- The term `renewable biomass' means each of the following:
- (i) Planted crops and crop residue harvested from agricultural land cleared or cultivated at any time prior to the enactment of this sentence that is either actively managed or fallow, and nonforested.
- (ii) Planted trees and tree residue from actively managed tree plantations on non-federal land cleared at any time prior to enactment of this sentence, including land belonging to an Indian tribe or an Indian individual, that is held in trust by the United States or subject to a restriction against alienation imposed by the United States.
- (iii) Animal waste material and animal byproducts.
- (iv) Slash and pre-commercial thinnings that are from non-federal forestlands, including forestlands belonging to an Indian tribe or an Indian individual, that are held in trust by the United States or subject to a restriction against alienation imposed by the United States, but not forests or forestlands that are ecological communities with a global or State ranking of critically imperiled, imperiled, or rare pursuant to a State Natural Heritage Program, old growth forest, or late successional forest.
- (v) Biomass obtained from the immediate vicinity of buildings and other areas regularly occupied by people, or of public infrastructure, at risk from wildfire.
- (vi) Algae.
- (vii) Separated yard waste or food waste, including recycled cooking and trap grease.

GHG Emission Requirements

- (i) IN GENERAL- The term `advanced biofuel' means renewable fuel, other than ethanol derived from corn starch, that has lifecycle greenhouse gas emissions, as determined by the Administrator, after notice and opportunity for comment, that are at least 50 percent less than baseline lifecycle greenhouse gas emissions.
- (E) CELLULOSIC BIOFUEL- The term `cellulosic biofuel' means renewable fuel derived from any cellulose, hemicellulose, or lignin that is derived from renewable biomass and that has lifecycle greenhouse gas emissions, as determined by the Administrator, that are at least 60 percent less than the baseline lifecycle greenhouse gas emissions.

ETP - Regions

IEA-Regions

- US
- Canada
- Japan
- Australia and New Zealand
- IEA-Europe
- South Korea

Non-IEA Regions

- **Eastern Europe**
- **FSU**
- **China**
- **India**
- **Rest of Asia**
- **Latin America**
- **Mexico**
- **Africa**
- **Middle East**