



Effect of Additional Incentives for Aviation Biofuel:

Results from the Biomass Scenario Model

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Analysis Basis and Disclaimer

- **The data, results, and interpretations are subject to additional review and may be modified before final publication.**
- This analysis was conducted using the Biomass Scenario Model [http://www.nrel.gov/analysis/bsm/]. The Biomass Scenario Model is a dynamic model of the domestic biofuels supply chain. The Biomass Scenario Model explicitly focuses on policy issues, their feasibility, and potential side effects. It integrates resource availability, physical/technological/economic constraints, behavior, and policy. The analysis includes information and selects scenarios based on discussions with the California Air Resources Board staff, Airlines for America, and Graham Noyes on behalf of alternative jet fuel producers.
- This document has not been reviewed by technical experts beyond the National Renewable Energy Laboratory, Airlines for America, Department of Energy-Biomass Energy Technologies Office, the California Air Resources Board, and Graham Noyes on behalf of alternative jet fuel producers.
- This report was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof.

Introduction

- NREL: A national lab supporting U.S. Department of Energy, Biomass Energy Technologies Office (BETO)
- BETO engagement on aviation biofuels led to analysis for U.S. Department of Transportation, Federal Aviation Administration (FAA)
- Airlines for America (A4A) requested additional exploratory scenarios within FAA analytic framework
- A4A requested additional scenarios in support of California Air Resources Board (CARB) rulemaking through a Technical Services Agreement with NREL
- NREL does not advocate for or against the policies analyzed in this study

Acknowledgements

We gratefully acknowledge:

- Alex Menotti, for identifying the opportunity for this analysis, and for the financial support of Airlines for America;
- Anthy Alexiades, Katrina Castellano, James Duffy, Jiqing Fan, Jeff Kessler, and all of the CARB analysts who contributed to the data and methodology for this analysis;
- Graham Noyes, for consultation on behalf of alternative jet fuel producers;
- Alicia Lindauer and Zia Haq, DOE project managers who have contributed to the development of the Biomass Scenario Model;
- The Biomass Scenario Model project team;
- Nate Blair, Kevin Carroll, Heather Lammers, David Mooney, Robin Newmark, Gian Porro, Amy Schwab, Neil Snyder, the NREL reviewers;
- Steve Peterson, the Biomass Scenario Modeling team reviewer.

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Analysis Scope Selected in Consultation with CARB, A4A, and Representative of Alternative Jet Fuel Producers

- What would be the impact of extending to aviation biofuel a Low Carbon Fuel Standard (LCFS) credit worth $90/metric ton, starting in 2019?
- Impacts of interest include:
  - Biofuels production by conversion pathway
  - Biofuels production by product type
  - Feedstock use
- How would these impacts change under different scenarios for
  - Oil price?
  - Renewable Identification Number credit value?
  - Offtake agreements?

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Preview of Conclusions

This presentation provides context and caveats for the following conclusions:

- Under many of the conditions that we modeled, extending the LCFS to include alternative jet fuel increases production of hydrocarbons from cellulose and oil crops.
- Within the range of incentives and economic conditions that we examined, increased production appears more likely to increase production of hydrocarbons when other incentives and economic conditions for biofuels are moderately favorable, rather than when they are extremely favorable or extremely unfavorable.
- Under some conditions, extending the LCFS to jet fuel decreases production of hydrocarbons in some years, due to the dynamic market response to higher demand for cellulosic feedstocks from both hydrocarbon and ethanol pathways.
- The increases in annual biofuels production that occurred with the extension of the LCFS to jet were orders of magnitude greater, and occurred during more of the analysis conditions, than the decreases.

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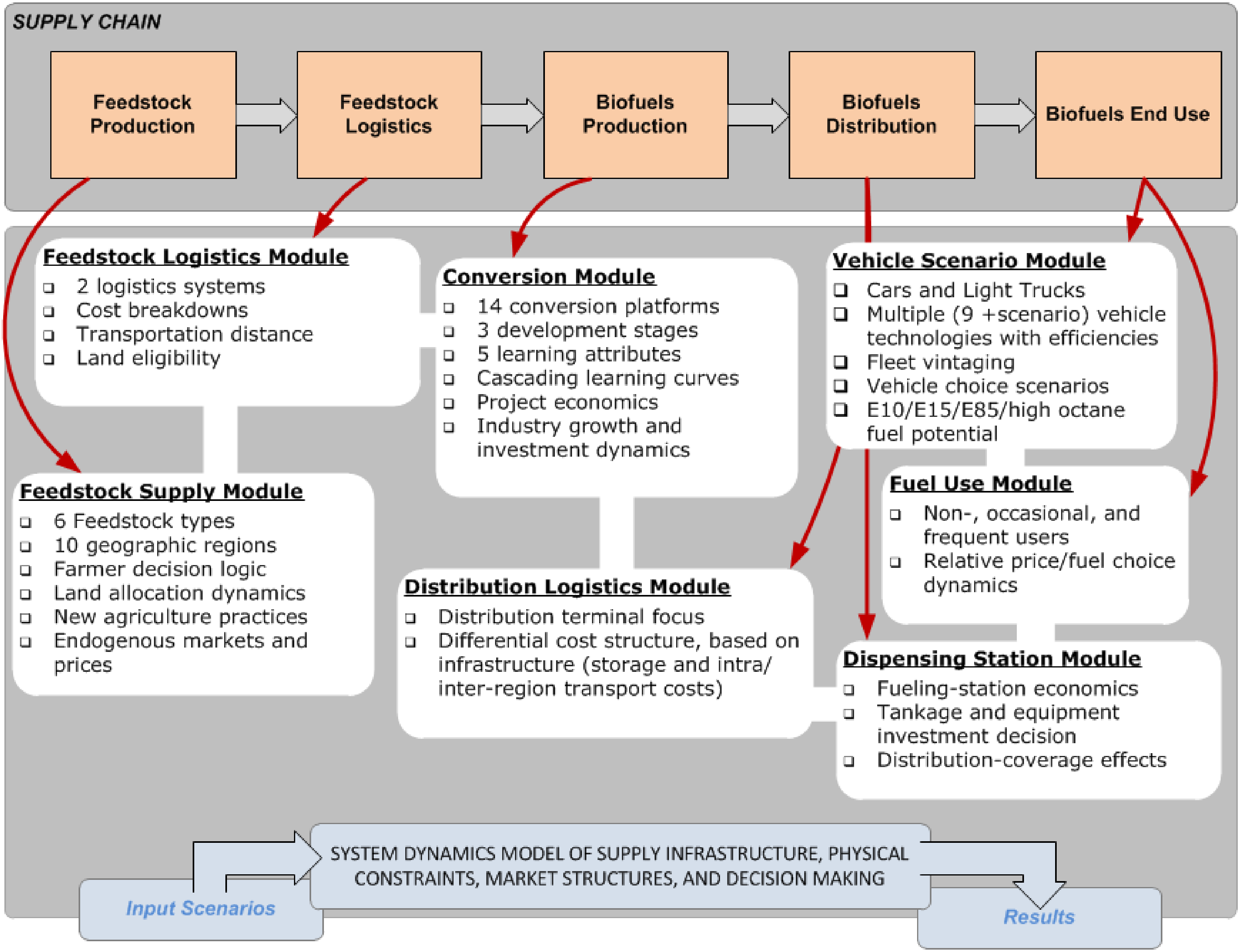
Methods

NREL Used the Biomass Scenario Model for the Analysis



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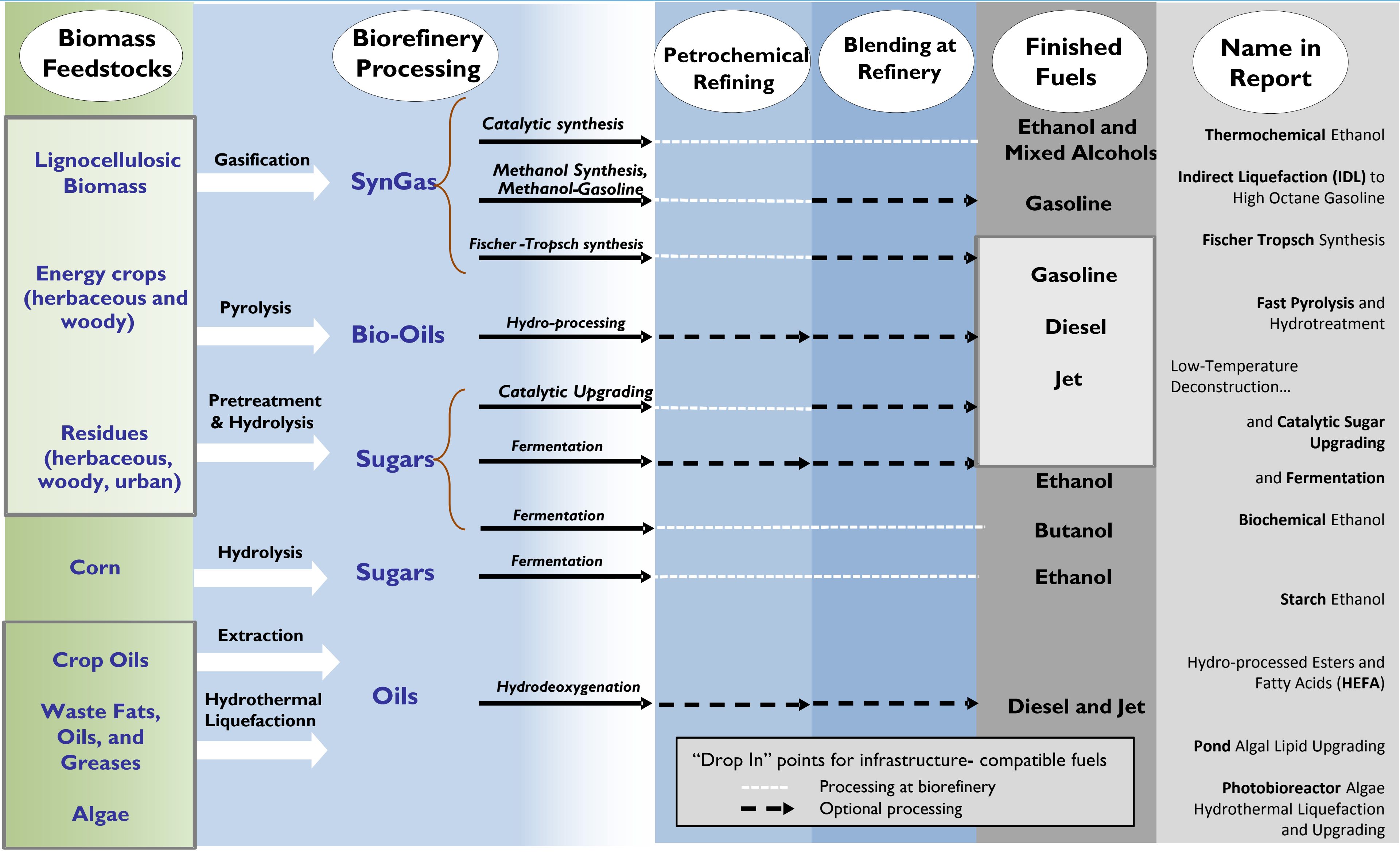
Biofuel Pathways in the Biomass Scenario Model



Modeled biofuel pathways are abstract approximations that are not representative of every facility.

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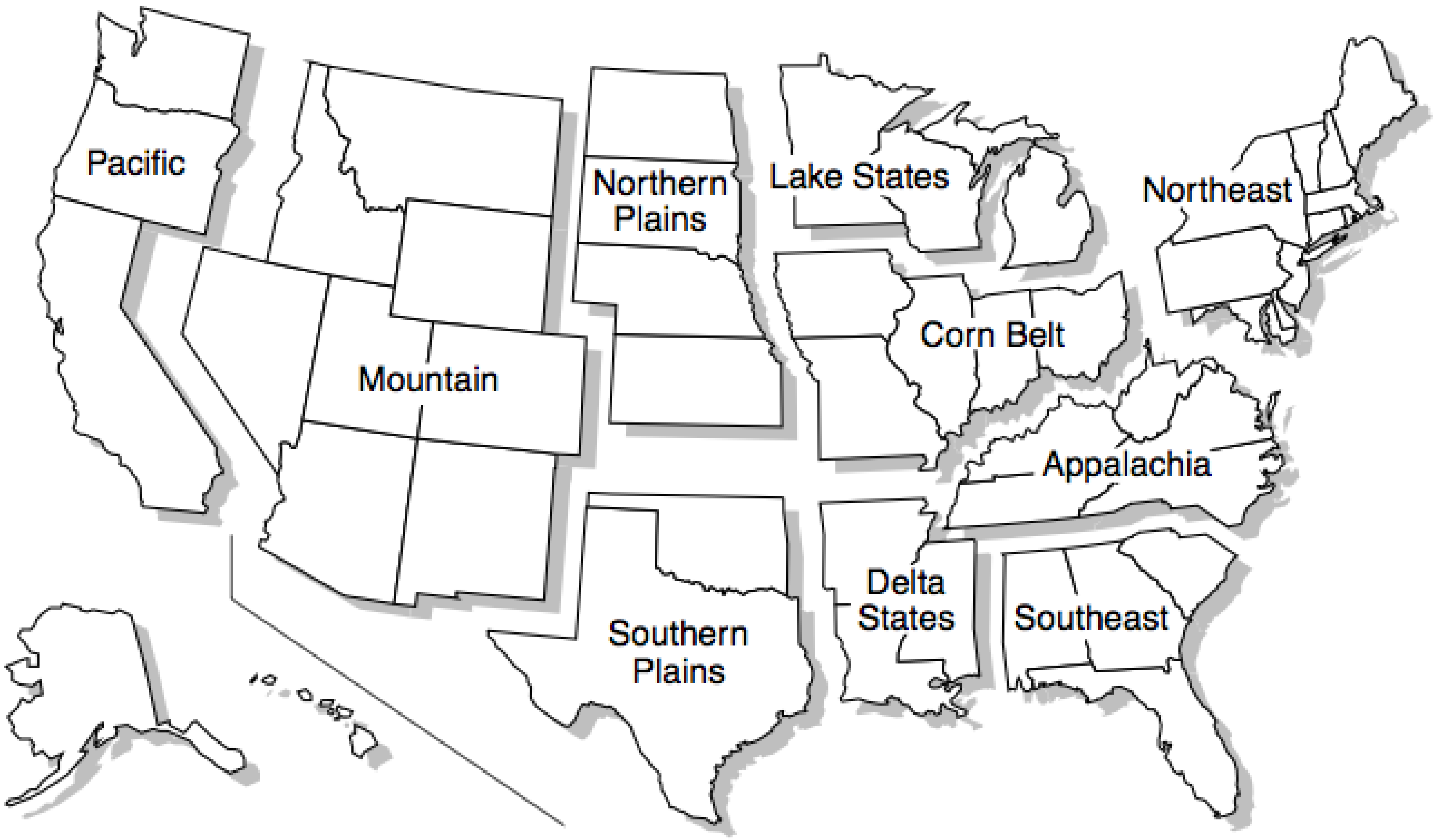
The Biomass Scenario Model Accounts for Use of Land in Contiguous U.S. by Region

Low Carbon Fuel Standard applies in Pacific region



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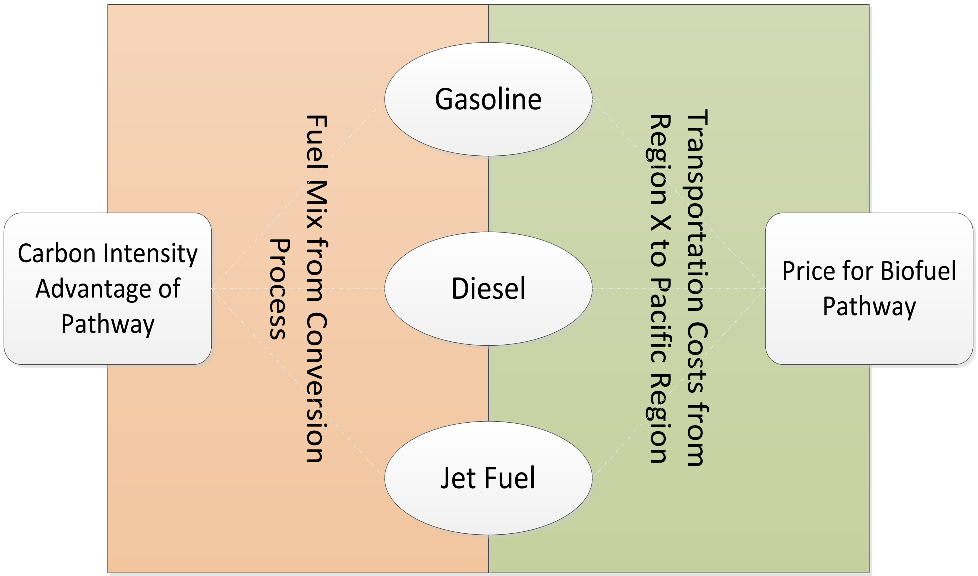
Low Carbon Fuel Standard in Pacific Region of the Biomass Scenario Model



- Calculate average carbon intensity by pathway from approved physical pathways.
- Subtract from target fossil (oil) carbon intensity.
- Apply to finished fuel covered by LCFS under given credit price.
- Estimate and apply transportation costs from biorefinery site to Pacific region.
- Apply the resulting price premium to pathway.
- This method does not include representation of price feedback in credit markets

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Assumptions

Biomass Scenario Model: Assumptions

The Biomass Scenario Model: A simulation model for scenario analysis of biomass-to-biofuels market development with detailed representation of policy, technology, resource, and investment. Two of the many key assumptions:

- Existing starch ethanol industry continues to contribute to E10 fuel supply
- Biorefinery construction is limited to 25 plants/yr, due to labor and materials constraints

This analysis used technology and resource assumptions specific to the CARB analysis:

- Product mix between gasoline, diesel, and jet fuel is constant for each production pathway
- Techno-economics are a key assumption (see subsequent slides)
- Available supply of fats, oils, and greases (FOG) is consistent with supply curves used in the study with the Federal Aviation Administration

Scenario results are contingent on the following and other design assumptions:

- How many and what type of biorefineries are operating or go into operation?
  - Existing and under construction facilities are from Warner et al. (2017)
  - Offtake agreements are modeled assuming that the contracted capacity comes online and delivers regardless of fuel price
  - Offtake capacity not under construction in Warner et al. (2017) is assumed to start construction in 2018 in core scenario
- What incentives are in place for biofuels?
  - Biomass Crop Assistance Program
  - Not in place in core scenario: Tax Credits, Loan Guarantees
  - RIN prices input as scenarios for D6 and D4 prices, with D3 price a function of oil price

Representation of Low Carbon Fuel Standard (LCFS), Renewable Identification Number (RIN), and Offtake Agreements does not include market feedbacks

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Selected Conditions for This Study

Input Assumption	Conditions
LCFS Value	$60, $90, $150, or $200/metric ton
LCFS Start Date for Jet	2019
RIN Values D6 Renewable Fuel D4 Biomass Based Diesel D3 Cellulosic Biofuels	D6: $0, $0.70, $1.70 D4: $0.32, $0.84, $1.70 {D4 Price} = 0.32 + 0.74*{D6 Price} D3: Calculated for each year as {D3 Price} = -1.1 + 1.11*{D4 Price} + 1.49*{Waiver.Credit}
Integrated Biorefinery Facilities	Existing and Under Construction (Warner et al. [2017])
Carbon Tax	None
Oil Price	1. AEO 2017 Reference Price 2. AEO 2017 High Oil Price
Offtake Agreements	1. Without Offtakes 2. With Offtakes starting in 2018 or 2021
Other Incentives	1. BCAP Only 2. Tax Credits + 65% or 80% Loan Guarantee
Dollar Year	2011

LCFS = Low Carbon Fuel Standard
RIN = Renewable Identification Number
AEO = Annual Energy Outlook
BCAP = Biomass Crop Assistance Program

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Alternative Jet Fuel Techno-economic Assumptions

Selected techno-economic analysis (TEA) assumptions for nth plant performance for new plants. The current state of technology varies in progress towards nth plant. Note that several current projects are retrofits, whose costs are not reflected here.

TEA Component	Units	Hydro-processed Esters and Fatty Acids (Pearlson 2012)	Alcohol to Jet Nominal (Staples 2014)	Fischer Tropsch (Tan 2016)
Minimum Fuel Selling Price	$/gal	3.69	7.77	3.35
Process Yield	gal/ton	245.0	42.2	69.3
Fixed Capital Investment	$	145,500,000	739,478,895	580,200,000
Fixed Operating Cost	$/yr	9,816,400	91,386,820	26,510,000
Other Variable Operating Cost	$/yr	19,400,000	77,654,946	5,324,000
Coproducts Sales Revenue	$/yr	0	0	0
Power Sales Revenue	$/yr	0	0	4,470,000
Feedstock Throughput Capacity	tons/day	788	3,991	2,205
Product Yield Breakdown (max distillate case)				
Gasoline Blendstock	gal/ton	6.1	4.0	14.6
Jet Fuel Blendstock	gal/ton	38.4	35.5	49.1
Diesel Blendstock	gal/ton	199.0	2.7	5.6

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Other Hydrocarbons Techno-economic Assumptions

		Fast Pyrolysis	Methanol to Gasoline	Catalytic Upgrading of Sugars	Fermentation	Algae
TEA Component	**Units**	w/ Upgrading (Jones et al. 2013)	Methanol to high octane gasoline (Tan et al, 2015)	Catalytic Upgrading (Davis 2015)	Biological to Hydrocarbons (Davis 2013)	[Pond] Algae (Davis et al. 2014)
Minimum Fuel Selling Price	**$/gal**	3.39	3.25	4.05	5.35	4.35
Process Yield	**gal/ton**	83.6	64.9	77.7	43.3	141.1
Fixed Capital Investment	**$**	665,200,000	415,200,000	626,500,000	553,200,000	436,100,000
Fixed Operating Cost	**$/yr**	33,600,000	20,600,000	16,100,000	14,080,000	13,700,000
Other Variable Operating Cost	**$/yr**	32,600,000	13,200,000	70,100,000	21,800,000	216,875,209
Coproducts Sales Revenue	**$/yr**	-	-	0	0	18,600,000
Power Sales Revenue	**$/yr**	0	-	5,370,000	5,115,500	3,100,000
Feedstock Throughput Capacity	**tons/day**	2,205	2,205	2,205	2,205	1,339
Product Yield Breakdown						
Gasoline Blendstock	**Gal / Ton**	39.9	64.9	15.85		36.40
Jet Fuel Blendstock	**Gal / Ton**					
Diesel Blendstock	**Gal / Ton**	43.7		61.84	43.3	104.7

TEA = Techno-Economic Analysis

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Cellulose to Ethanol Techno-economic Assumptions

		Cellulose to Ethanol	
TEA Component	**Units**	Biochem* (Humbird et al. 2011)	Thermochem* (Dutta et al. 2011)
Minimum Fuel Selling Price	**$/gal**	2.75	2.6
Process Yield	**gal/ton**		
Fixed Capital Investment	**$**	447,000,000	545,115,008
Fixed Operating Cost	**$/yr**	11,800,000	25,703,000
Other Variable Operating Cost	**$/yr**	30,700,000	8,956,000
Coproducts Sales Revenue	**$/yr**	0	14,417,000
Power Sales Revenue	**$/yr**	6,200,000	-
Feedstock Throughput Capacity	**tons/day**	2,205	2,205
Product Yield Breakdown			
Gasoline Blendstock	**Gal / Ton**	79.00	83.80
Jet Fuel Blendstock	**Gal / Ton**		
Diesel Blendstock	**Gal / Ton**		

*Techno-economic assumptions were aligned with more recent unpublished design cases.

TEA = Techno-Economic Analysis

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Carbon Intensity Assumptions by Pathway

Pathway	Technology	CARB-specified Carbon Intensity ($g\ CO_2e/MJ$)		
		Jet	Diesel	Gasoline
Algae to Hydrocarbons		76.4	63.3	
Cellulose to Ethanol	Biochemical			14.4
Cellulose to Ethanol	Thermochemical			15.6
Cellulose to Hydrocarbons	Catalytic Upgrading of Sugars	25.5		
Cellulose to Hydrocarbons	Cellulosic Ethanol-based Alcohol to Jet	32.4		
Cellulose to Hydrocarbons	Fermentation	37		
Cellulose to Hydrocarbons	Fast Pyrolysis	16.6	15.4	15.4
Cellulose to Hydrocarbons	Fischer Tropsch	13.7	14.4	14.4
Cellulose to Hydrocarbons	Methanol to Gasoline			15.6
Oil Crop to Hydrocarbons	HEFA	59.2	49.2	
Petroleum		93.3	102	99.8
Starch Ethanol				75
Starch Ethanol-based Alcohol to Jet		85.9		

These assumptions, along with the techno-economic analysis assumptions, are used to calculate the value of the Low Carbon Fuel Standard to each pathway.

CARB = California Air Resources Board
CO_2e = carbon dioxide equivalent
MJ = megajoule
HEFA = Hydro-processed Esters and Fatty Acids

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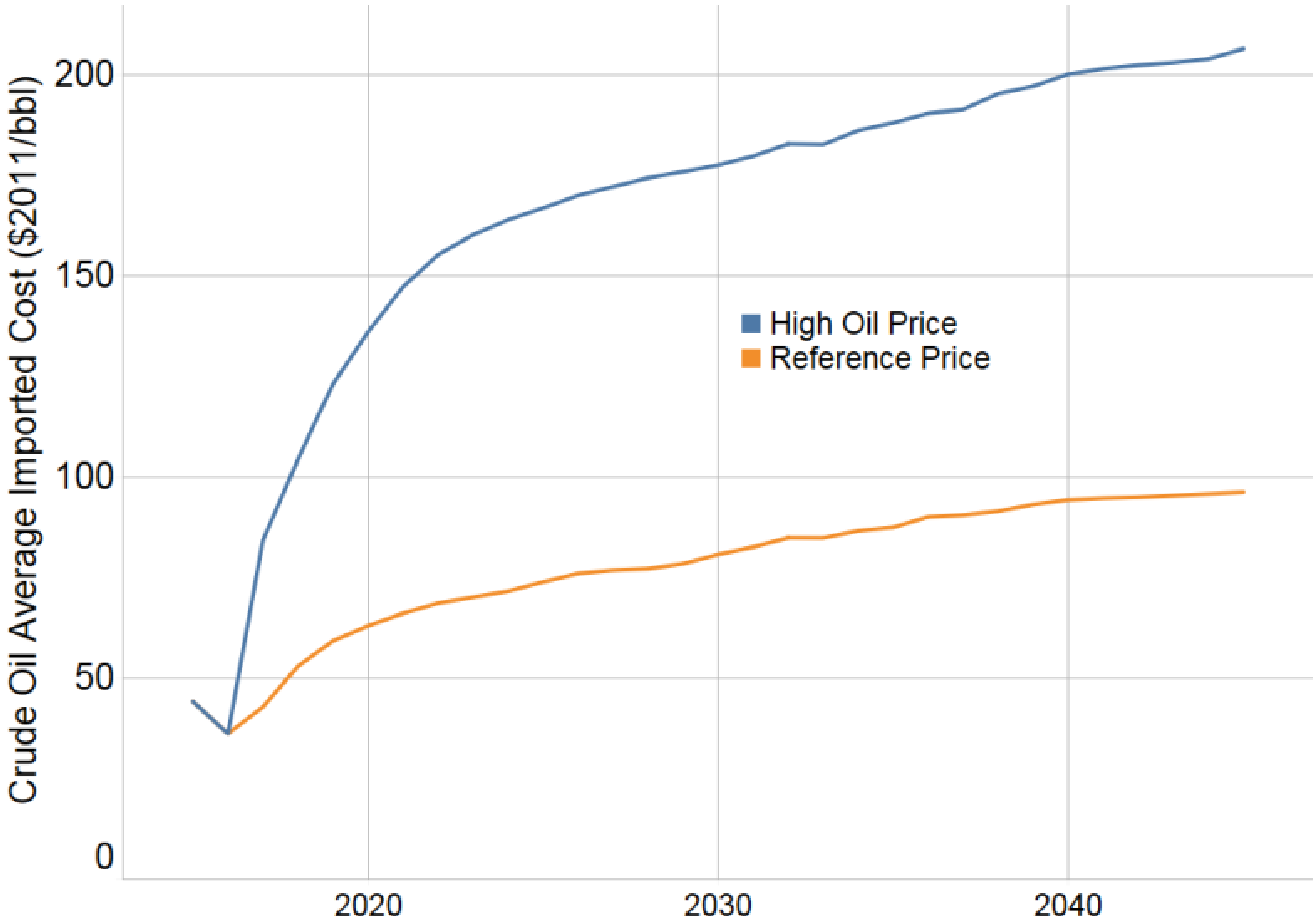
Annual Energy Outlook (AEO 2017) Petroleum Cost



bbl = barrel

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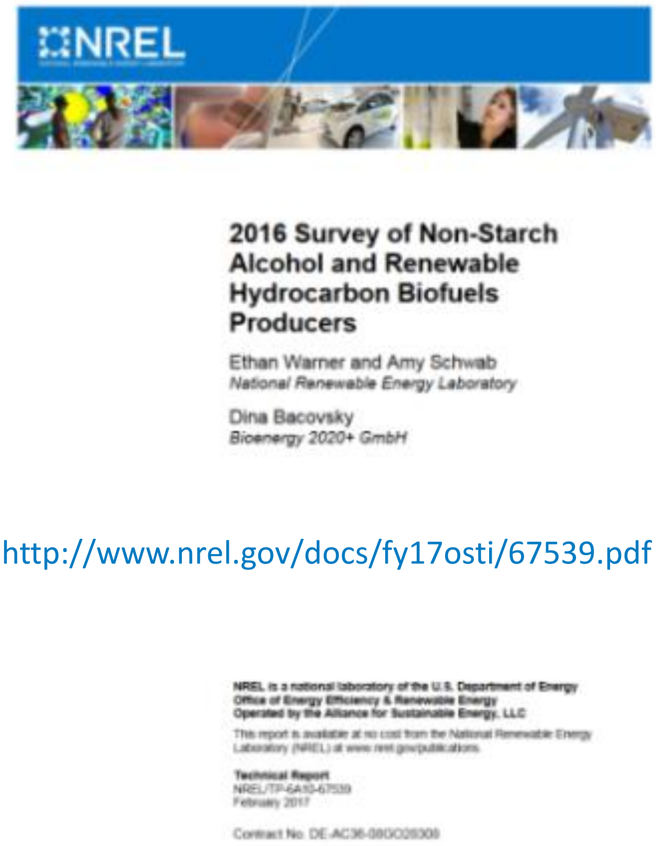
Certain Biorefineries Are Entered in the Biomass Scenario Model (from NREL Survey)

- Biorefineries that are entered in the Biomass Scenario Model advance industrial learning in the model
- Biorefineries that are…
  - Under Construction and Operating
  - In the United States

  ….are entered in the model
- Quantities are based on 2016 NREL Survey
- Consistent with Environmental Protection Agency (U.S. EPA) data
- Includes cellulosic and oil feedstocks
- Does not include biorefineries in planning, idle, or that use Corn Kernel Cellulose
- Next two slides show selected biorefineries



http://www.nrel.gov/docs/fy17osti/67539.pdf

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Cellulose to Ethanol Facilities in the U.S., Not Corn Kernel, and Operating or Under Construction are in the Biomass Scenario Model (see overview of biorefineries entered in the model on slide 20)

	Deconstruction Technology	Upgrading Technology	Project Name	Location Detail	Anticipate Product/ Market	Commercial Capacity (MMGY)	Operating	Under Construction	~~Planning~~	~~Idle~~
U.S. Commercial	A/E Pretreatment	-	Sweetwater Energy	Mountain Iron, MN, USA	TBS/bioproducts	3.5			▽	
				Rochester, NY, USA	TBS/bioproducts	3.5			▽	
		Fermentation	DuPont	Nevada, IA, USA	TBS	30	✱ Yes			
			Pacific Ethanol (EdeniQ)	Stockton, CA, USA	TBS	1.5	◁ X			
			POET-DSM	Emmetsburg, IA, USA	TBS	20	✱ Yes			
			Quad County Corn	Galva, IA, USA	TBS	2.1	◁ X			
			Redfield Energy (ICM)	Redfield, SD, USA	TBS	3.42	◁ X			
			Flint Hills (EdeniQ)	Shell Rock, IA, USA	TBS	3	◁ X			
				Fairbank, IA, USA	TBS	3		◁ X		
				Iowa Falls, IA, USA	TBS	2.5		◁ X		
				Menlo, IA, USA	TBS	3		◁ X		
			E Energy Adams (ICM)	Adams, NE, USA	TBS	3		◁ X		
			Fiberight	Hampden, ME, USA	TBS	6		◇ Yes		
			Kansas Ethanol (ICM)	Lyons, KS, USA	-	3.6		◁ X		
			MAAPW (EdeniQ)	Madrid, NE, USA	TBS	1.1		◁ X		
			Siouxland Energy (EdeniQ)	Sioux Center, IA, USA	TBS	1.5		◁ X		
			Beta Renewables	Clinton, NC, USA	TBS	20			▷	
			ZeaChem	Boardman, OR, USA	TBS/bioproducts	22			▽	
			Abengoa	Hugoton, KS, USA	TBS	25				✱
	Gasification	Syngas Catalytic	Enerkem	Pontotoc, MS, USA	TBS/bioproducts	10			◇	
		Fermentation	INEOS New Planet Bioenergy	Vero Beach, FL, USA	TBS	8				◇
International Commercial	A/E Pretreatment	Fermentation	GranBio	Sao Miguel, Brazil	TBS	22	✱			
			Raizen Energia	Piracicaba, Brazil	TBS	11	✱			
			ShanDong Longlive	Yucheng, China	TBS	16	✱			
			Henan Tianguan Group	Nanyang, China	TBS	14	✱			
						72			✱	
				Zhenping, China	TBS	4.8	✱			
			IGPC Ethanol	Alymer, Canada	-	3.18		◁		
			Beta Renewables	Crescentino, Italy	TBS	20	✱			
				Fujian, China	TBS	20			✱	
				Strazske, Slovakia	TBS	20			✱	
			COFCO Zhaodong Co.	Zhaodong, China	TBS	24			▷	
	Gasification	Syngas Catalytic	Enerkem	Edmonton, Canada	TBS/bioproducts	10	◇			
				Varennes, Canada	TBS/bioproducts	10			◇	

Intermediate Product
- Sugars
- Syngas

Feedstock Category
- ◁ ~~Corn Kernel Cellulose~~
- ✱ Crop Residues
- ▷ Dedicated Energy Crops
- ◇ MSW
- ▽ Woody Biomass

Items circled and not marked X or struck out are entered in the model.

Hydrocarbon-producing Facilities in the U.S. and Operating or Under Construction are in the Biomass Scenario Model (see overview of biorefineries entered in the model on slide 20)

	Deconstruction Technology	Upgrading Technology	Project Name	Location Detail	Anticipate Product/Market	Commercial Capacity (MMGY)	Operating	Under Construction	Planning	Idle
U.S. Commercial	-	Oil Catalytic	AltAir Fuels	Los Angeles, CA, USA	TBS	42	△			
			Cetane Energy	Carlsbad, NM, USA	TBS	3	△			
			Renewable Energy Group	Geismar, LA, USA	TBS	75	△			
			Diamond Green Diesel	Norco, LA, USA	TBS	160	△			
						115		△		
			East Kansas Agri-Energy	Garnett, KS, USA	TBS	3		△		
			Emerald Biofuels	Plaquemine, LA, USA	TBS	88			△	
			SG Preston	South Point, OH, USA	TBS	120			△	
			Green Energy Products	Wichita, KS, USA	TBS	3				△
	Gasification	Syngas Catalytic	Fulcrum BioEnergy	Reno, NV, USA	TBS	10			◇	
			Red Rock Biofuels	Lakeview, OR, USA	TBS	15.5			▽	
			Sundrop Fuels	Boyce, LA, USA	TBS	200			▽	
	Pyrolysis	-	Ensyn	Vienna, Georgia, USA	refinery feedstock	20			▽	
		Oil Catalytic	KiOR	Columbus, MS, USA	TBS	13				▽
International Commercial	-	-	Solazyme	Moema, Brazil	TBS/bioproducts	2.7	○			
		Oil Catalytic	ENI	Port Marghera, Italy	TBS	24	△			
			Neste Oil	Porvoo, Finland	TBS	63	△			
				Rotterdam, Netherlands	TBS	275	△			
				Singapore, Singapore	TBS	275	△			
			UPM Biofuels	Lappeenranta, Finland	TBS	32	△			
			La Mède	Châteauneuf-les-Martig..	TBS	24		△		
	Gasification	Syngas Catalytic	Total	Dunkirk, France	TBS	72		▽		
	Pyrolysis	-	BTG	Hengelo, Netherlands	refinery feedstock	5.3	▽			
			Fortum	Joensuu, Finland	heating oil	24	▽			
			Ensyn	Renfrew, Canada	heating oil	3	▽			
				Cote Nord, Canada	refinery feedstock	10		▽		
				Aracruz, Brazil	refinery feedstock	20			▽	

Intermediate Product
- Oils
- Pyrolysis Oils
- Syngas

Feedstock Category
- ○ Algae
- △ FOG
- ◇ MSW
- ▽ Woody Biomass

Items circled and not struck out are entered in the model.

Assumptions about Integrated Biorefineries Producing Jet Fuel, Including Offtakes

Offtake start date variations include: 2018 and 2021, shown here for 2018.

Company Name	Location	Type	Jet Share (%)	Assumed Capacity [GPY]	Offtake Airline	Modeled Construction Start	Modeled Offtake Start	Modeled Offtake End	CARB category
AltAir Fuels	Los Angeles, CA	HEFA	15.7	42,000,000		2013			Merchant
Cetane Energy	Carlsbad, NM	HEFA	15.7	3,000,000		2011			Merchant
Diamond Green Diesel	Norco, LA	HEFA	15.7	160,000,000		2011			Merchant
Diamond Green Diesel	Norco, LA	HEFA	15.7	115,000,000		2015			Merchant
East Kansas Agri-Energy	Garnett, KS	HEFA	15.7	3,000,000		2012			Merchant
Renewable Energy Group	Geismar, LA	HEFA	15.7	75,000,000		2013			Merchant
AltAir Fuels	CA	HEFA	15.7	5,000,000	United		2016	2018	Offtake
Fulcrum Bioenergy	NV	FT	32.4	37,500,000	Cathay Pacific		2018	2027	Additional Offtake
Fulcrum Bioenergy	NV	FT	32.4	9,000,000	United		2018	2027	Additional Offtake
Red Rock Biofuels	OR	FT	32.4	3,000,000	Southwest		2018	2024	Additional Offtake
Red Rock Biofuels	OR	FT	32.4	3,000,000	FedEX		2018	2024	Additional Offtake
D'Arcinoff Group	TX	FT	32.4	500,000	GE		2018	2022	Additional Offtake
SG Preston	OH	HEFA	15.7	10,000,000	jetBlue		2018	2027	Additional Offtake
Gevo	MN	ATJ	84.1	8,000,000	Lufthansa		2018	2022	Additional Offtake

Integrated Biorefineries that have offtakes and are not yet operating or under construction (Warner et al. [2017]) are assumed to start offtakes in 2018. Capacities and durations from:

http://www.bizjournals.com/denver/blog/earth_to_power/2014/09/red-rock-biofuels-lands-contracts-with-southwest.html
http://dgenergy.darcinoff.com/projects/hudspeth-county-texas
http://www.biofuelsdigest.com/bdigest/2016/09/19/jetblue-makes-record-setting-330-million-gallon-renewable-jet-fuel-order/
http://www.biofuelsdigest.com/bdigest/2016/09/08/gevo-lufthansa-rock-markets-with-renewable-jet-fuel-deal/
http://fulcrum-bioenergy.com/wp-content/uploads/2015/03/2015-06-30-Fulcrum-United-Strategic-Partnership-FINAL.pdf

HEFA = Hydro-processed Esters and Fatty Acids: FT = Fischer Tropsch; ATJ = Alcohol to Jet

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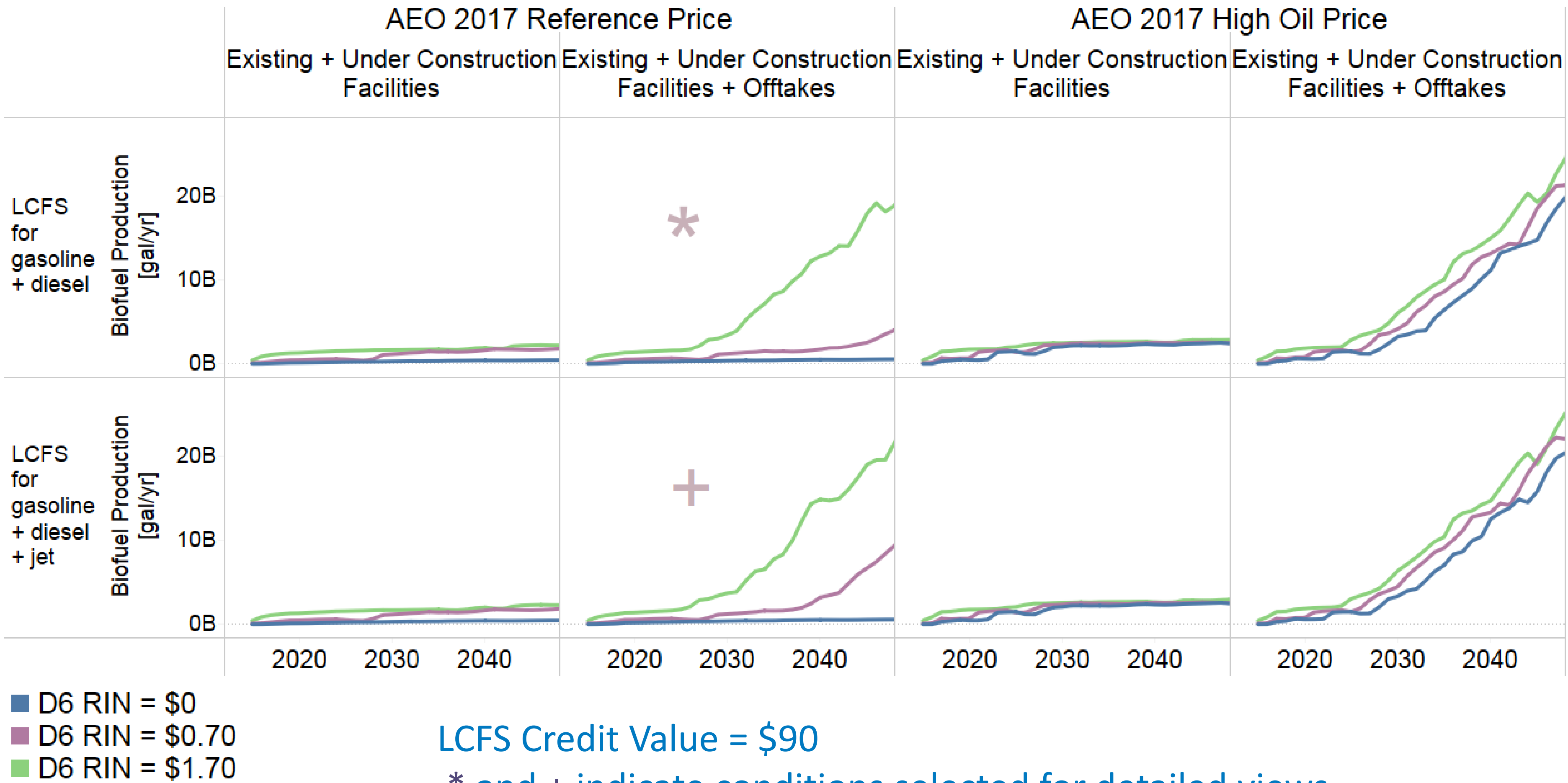
Results

Biofuel Production with Different Petroleum Prices, Offtake Agreements, LCFS coverage, and RIN Values



LCFS Credit Value = $90

* and + indicate conditions selected for detailed views

AEO = Annual Energy Outlook

LCFS = Low Carbon Fuel Standard

RIN = Renewable Identification Number

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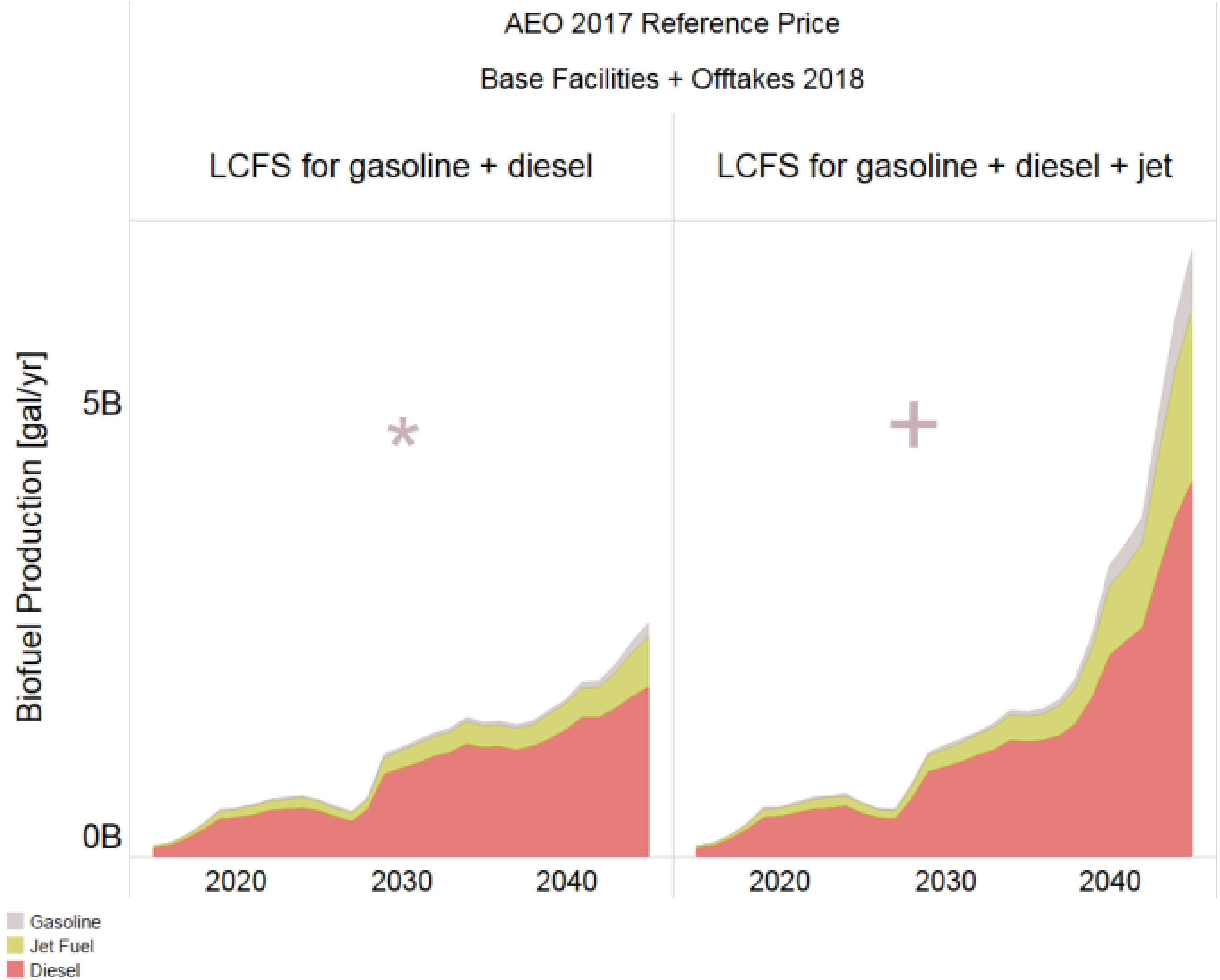
Product Mix: * and + from slide 25



D6 RIN = $0.70
LCFS Credit Value = $ 90

AEO = Annual Energy Outlook
LCFS = Low Carbon Fuel Standard

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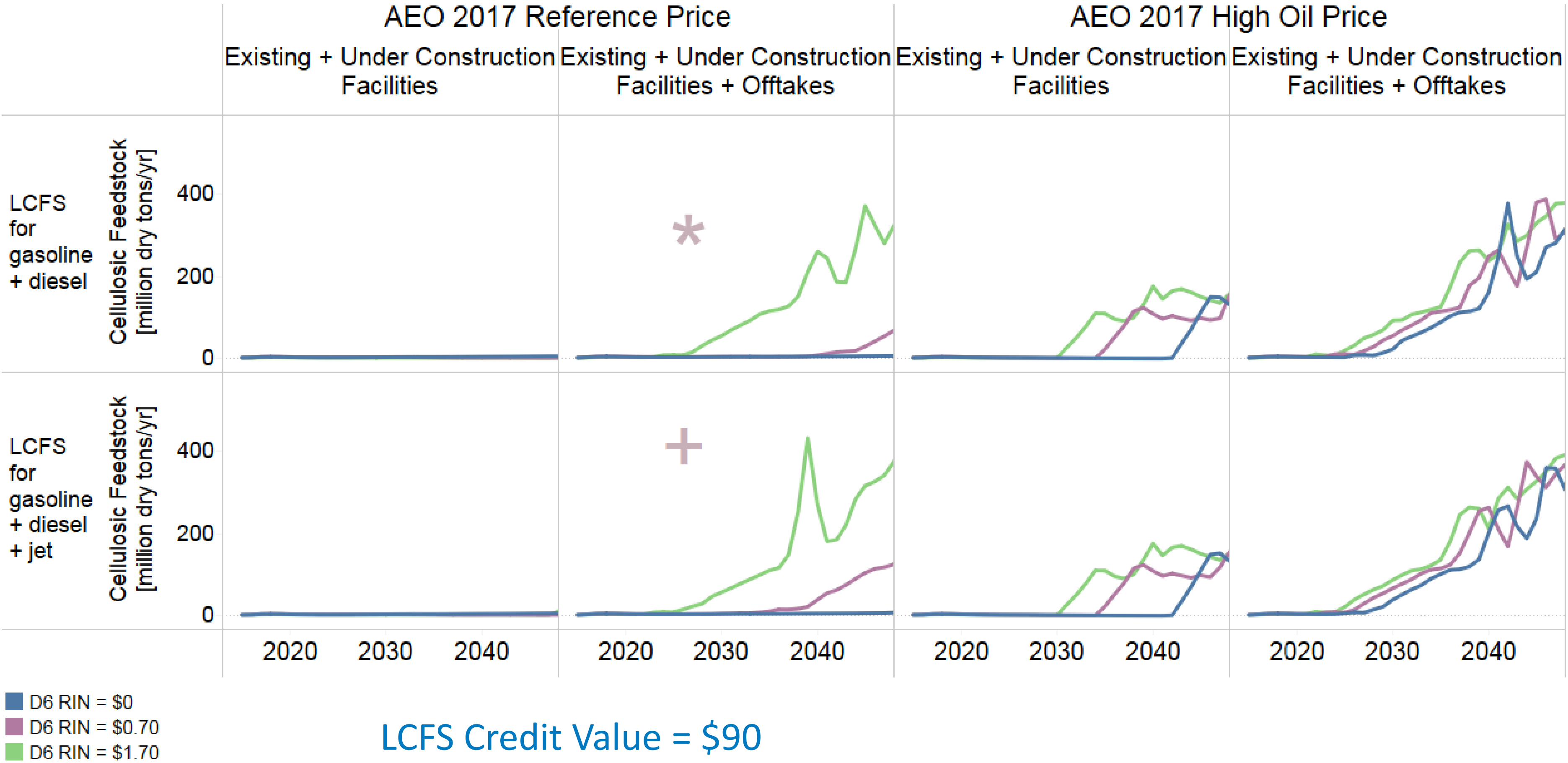
Cellulosic Feedstock Supply: * and + from slide 25



LCFS Credit Value = $90

* and + indicate conditions selected for detailed views

AEO = Annual Energy Outlook

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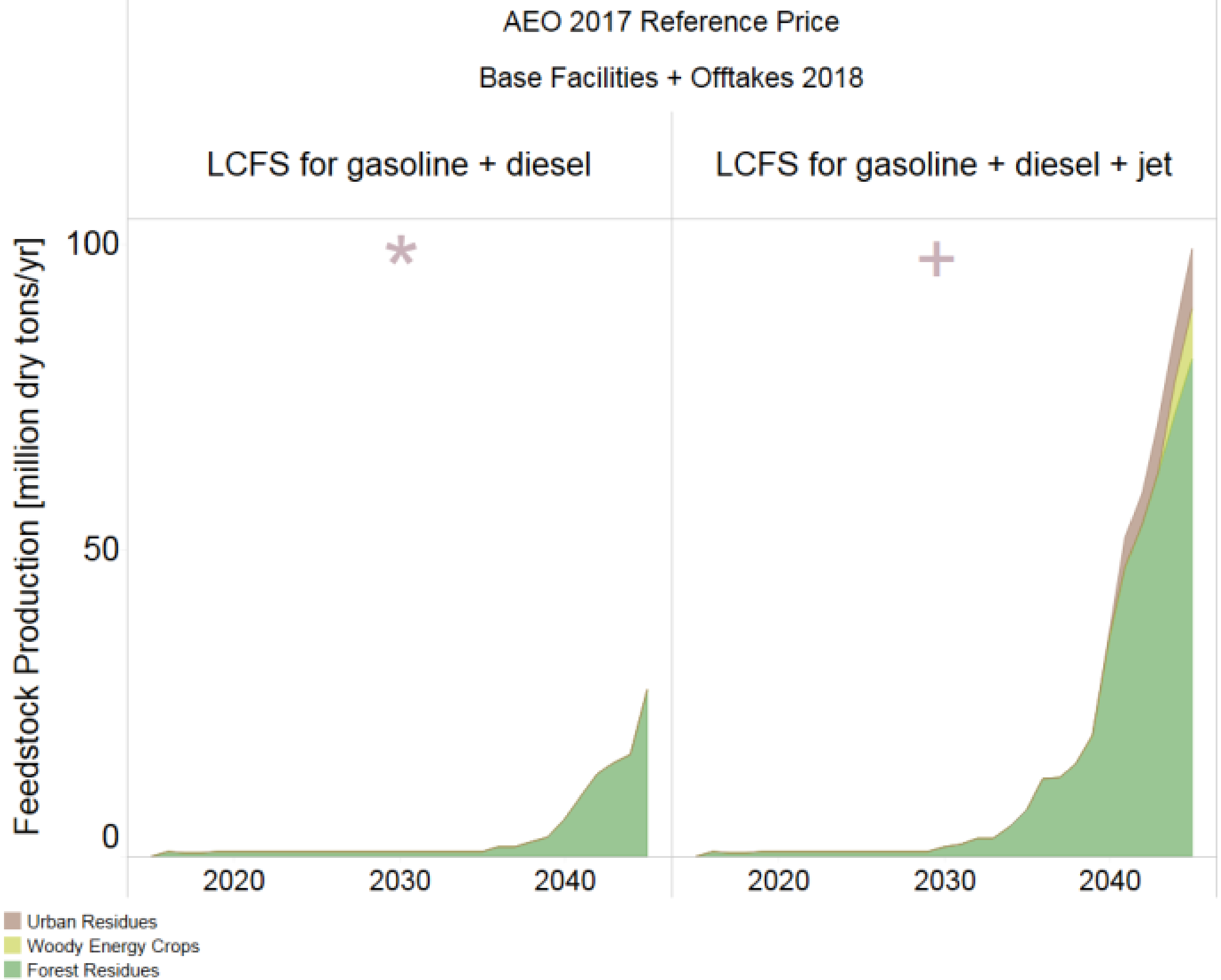
Woody Feedstock Supply: * and + from slide 25



D6 RIN = $0.70
LCFS Credit Value = $ 90

AEO = Annual Energy Outlook
LCFS = Low Carbon Fuel Standard

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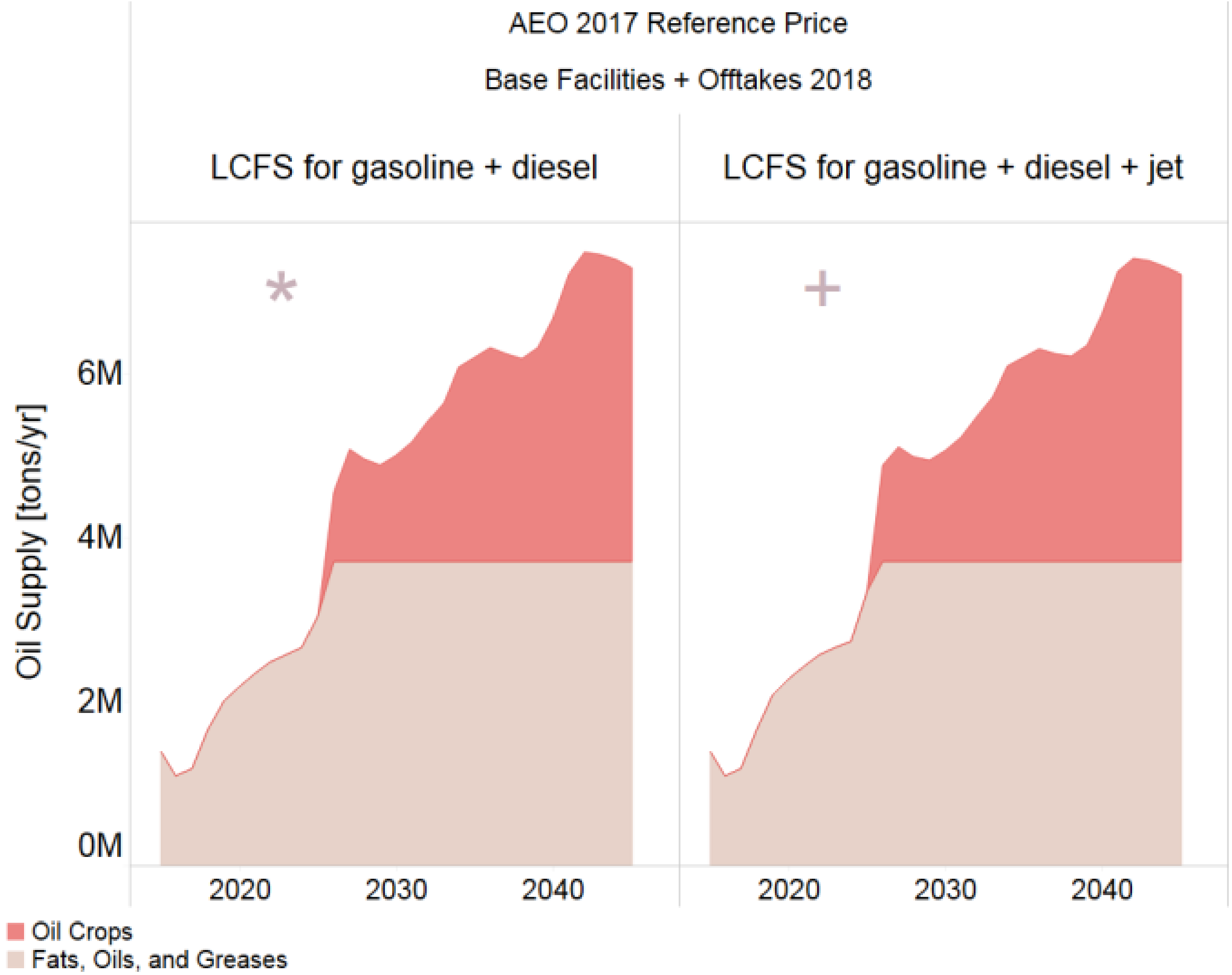
Oil Feedstock Supply: * and + from slide 25



D6 RIN = $0.70
LCFS Credit Value = $ 90

AEO = Annual Energy Outlook
LCFS = Low Carbon Fuel Standard

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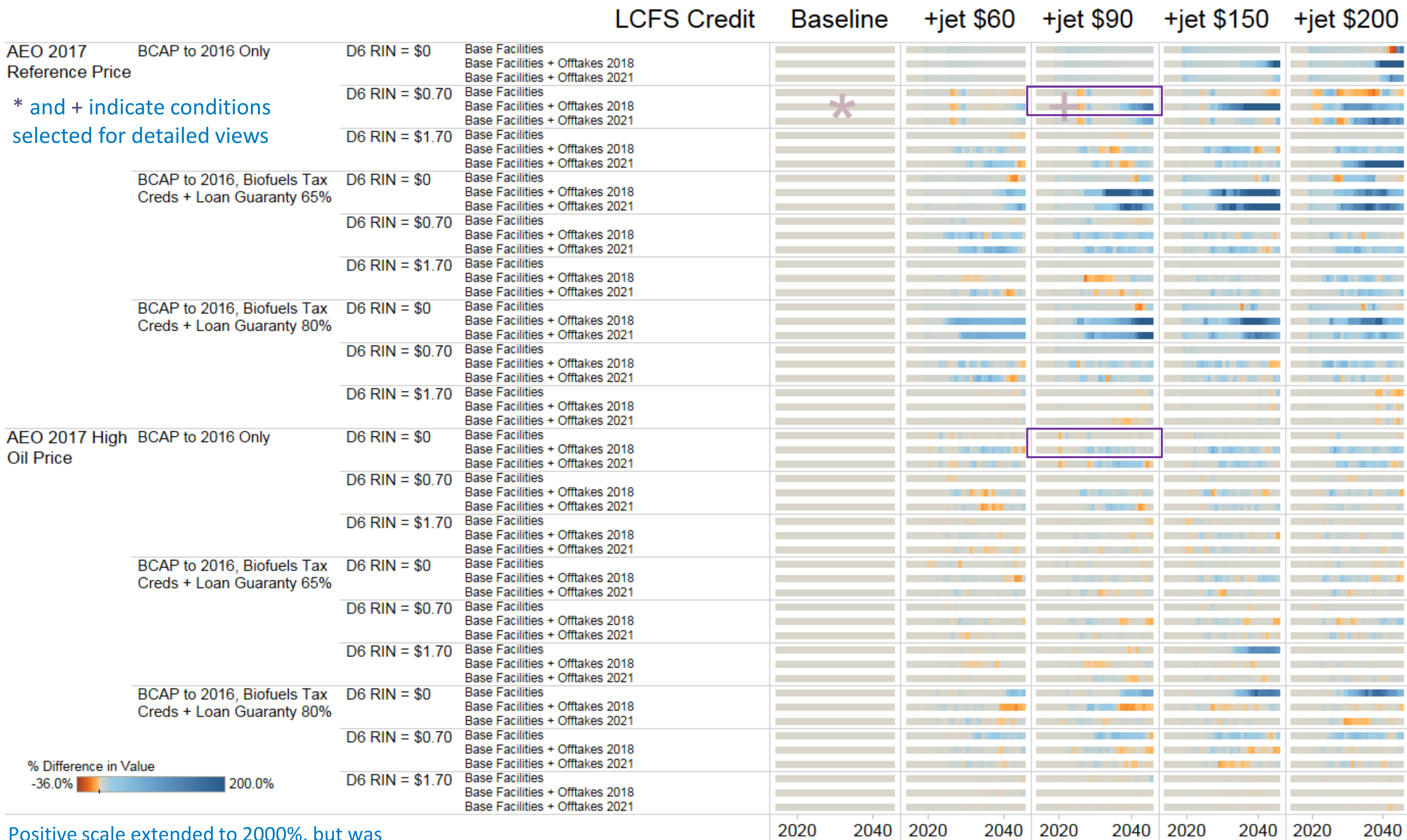
Jet LCFS Increases Biofuel Production Under Certain Conditions

Baseline = gas and diesel only (LCFS = $60, $90, $150, or $200)



Positive scale extended to 2000%, but was truncated for clarity.

* , + , and ▭ indicate selections for detailed views

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Conclusions and Limitations

Jet Low Carbon Fuel Standard Could Increase Production of Hydrocarbons from Biomass

- Under many of the conditions that we modeled, extending the LCFS to include alternative jet fuel increases production of hydrocarbons from cellulose and oil crops.
- Within the range of incentives and economic conditions that we examined, increased production appears more likely to increase production of hydrocarbons when other incentives and economic conditions for biofuels are moderately favorable, rather than when they are extremely favorable or extremely unfavorable.
- Under some conditions, extending the LCFS to jet fuel decreases production of hydrocarbons in some years, due to the dynamic market response to higher demand for cellulosic feedstocks from both hydrocarbon and ethanol pathways.
- The increases in annual biofuels production that occurred with the extension of the LCFS to jet were orders of magnitude greater, and occurred during more of the analysis conditions, than the decreases.

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Limitations

- Results depend upon many assumptions
  - Input assumptions may not reflect future conditions
  - Model algorithms are necessarily a simplified representation of reality
- Not all relevant alternative jet fuel or other pathways are represented
- The simplified representation of LCFS credit applies to the Pacific region, one of the 10 regions in the Biomass Scenario Model
- Price feedback is not included in LCFS credit markets, RIN markets, or representation of offtake agreements.
- Offtakes are modeled as fixed scenarios of **guaranteed** production, strongly driving industrial learning
- Results show system behaviors are more robust than specific quantitative results.

Discussion

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