Life Cycle of Palm Oil: Biofuels and Co-products

6 **Global Oils & Fats Forum**
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Outline

- LCA and Fuels
- Palm Oil Biodiesel Direct Emissions
- Indirect Land Use
- Observations

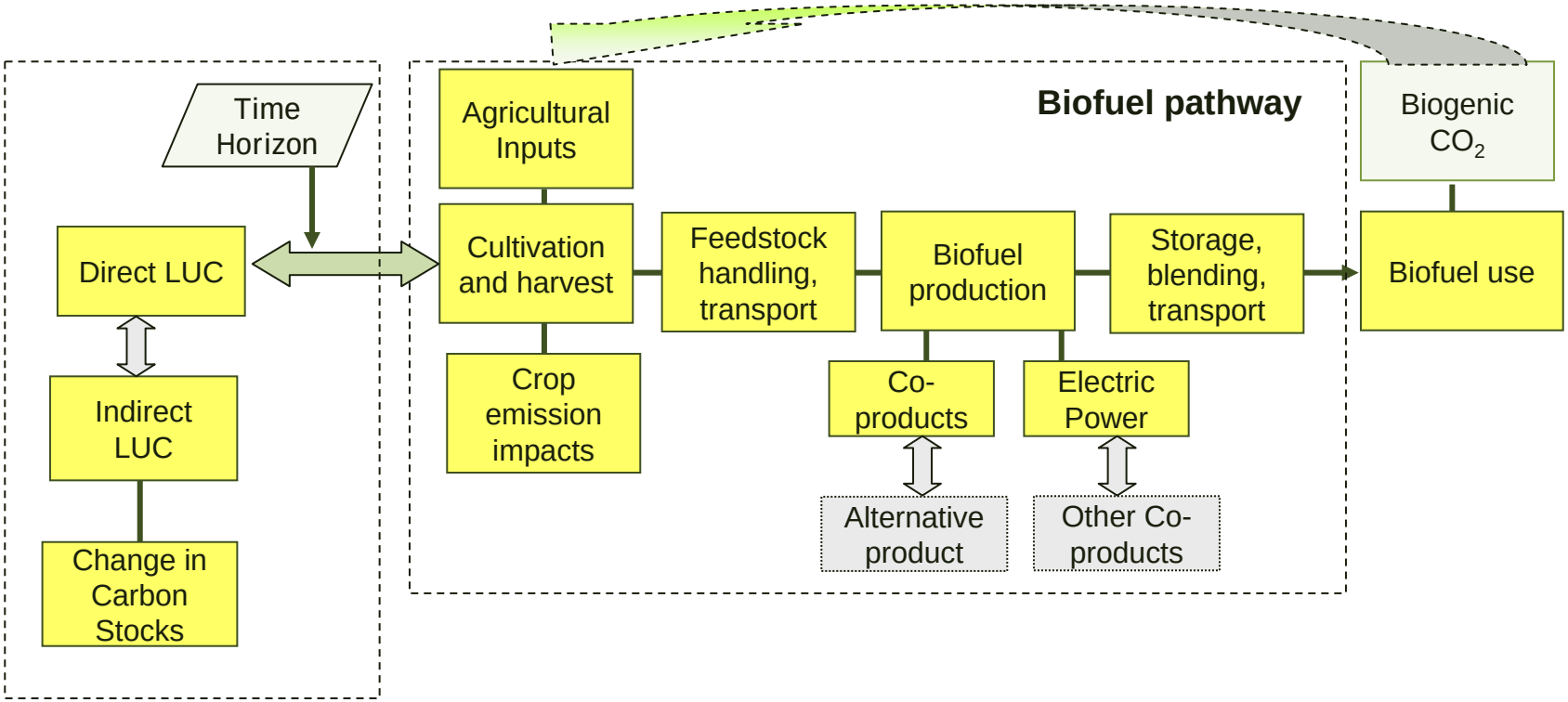
Biofuel Policies

- Expanding use of fuel LCA in global fuels policy
- California LCFS
  - 10% reduction in GHG emissions by 2020
  - Separate gasoline and diesel pools
  - Discreet fuel pathways and sub pathways
- EPA Renewable Fuel Standard RFS2
  - 36 billion gallons by 2022
  - 20%, 50%, 60% GHG reduction thresholds
- EU Biofuels Directive
  - 10% mandate by 2020

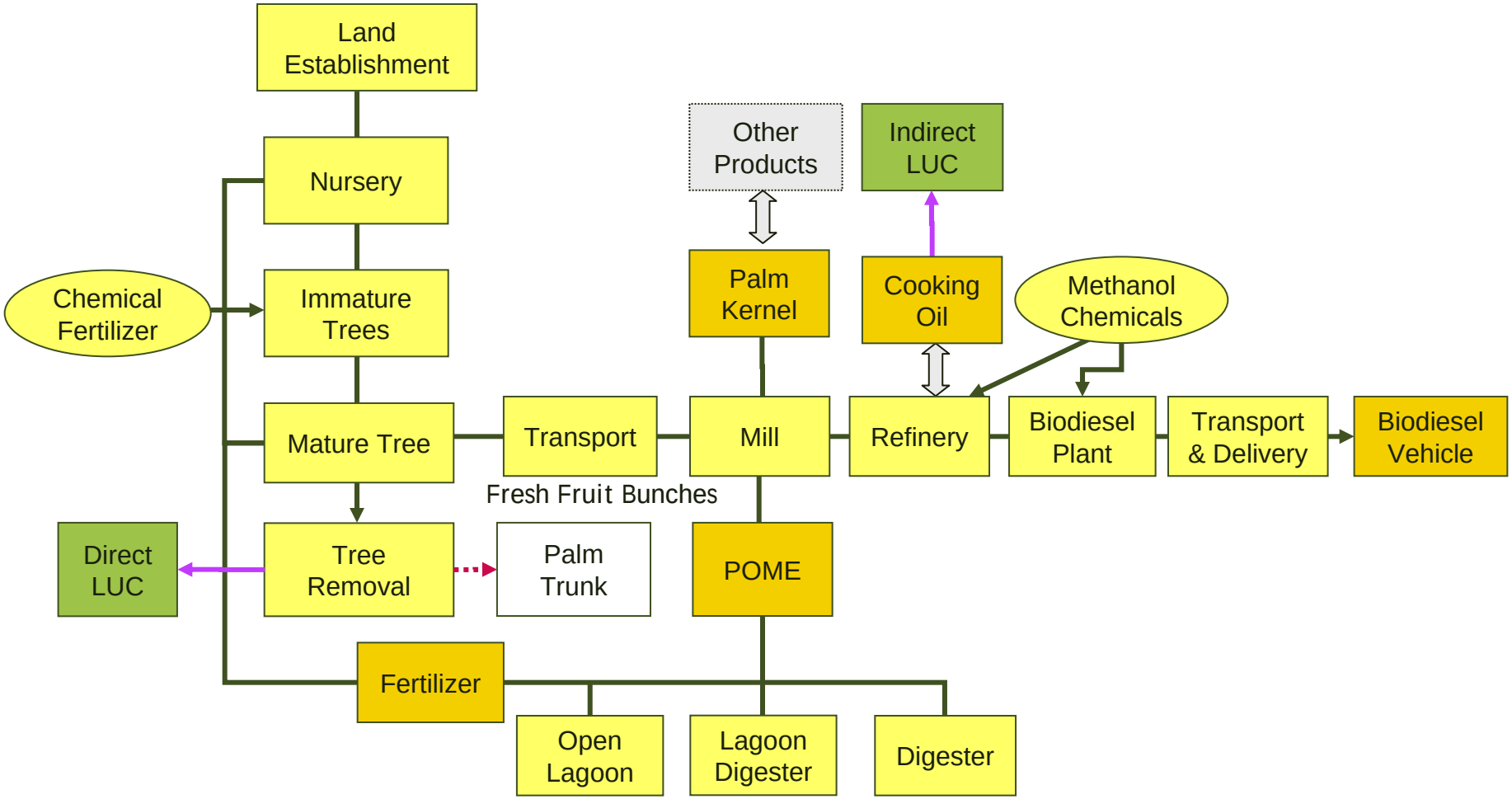
LCA Study Objectives

- Provide information and documentation on palm biodiesel/ renewable diesel to ARB, CEC, in support of the LCFS and EPA for RFS
- Develop GREET model tab for palm oil pathways
- Perform GREET model calculations and supply supporting documentation of inputs and model operation
- Perform an analysis of Land Use Conversion including GTAP analysis

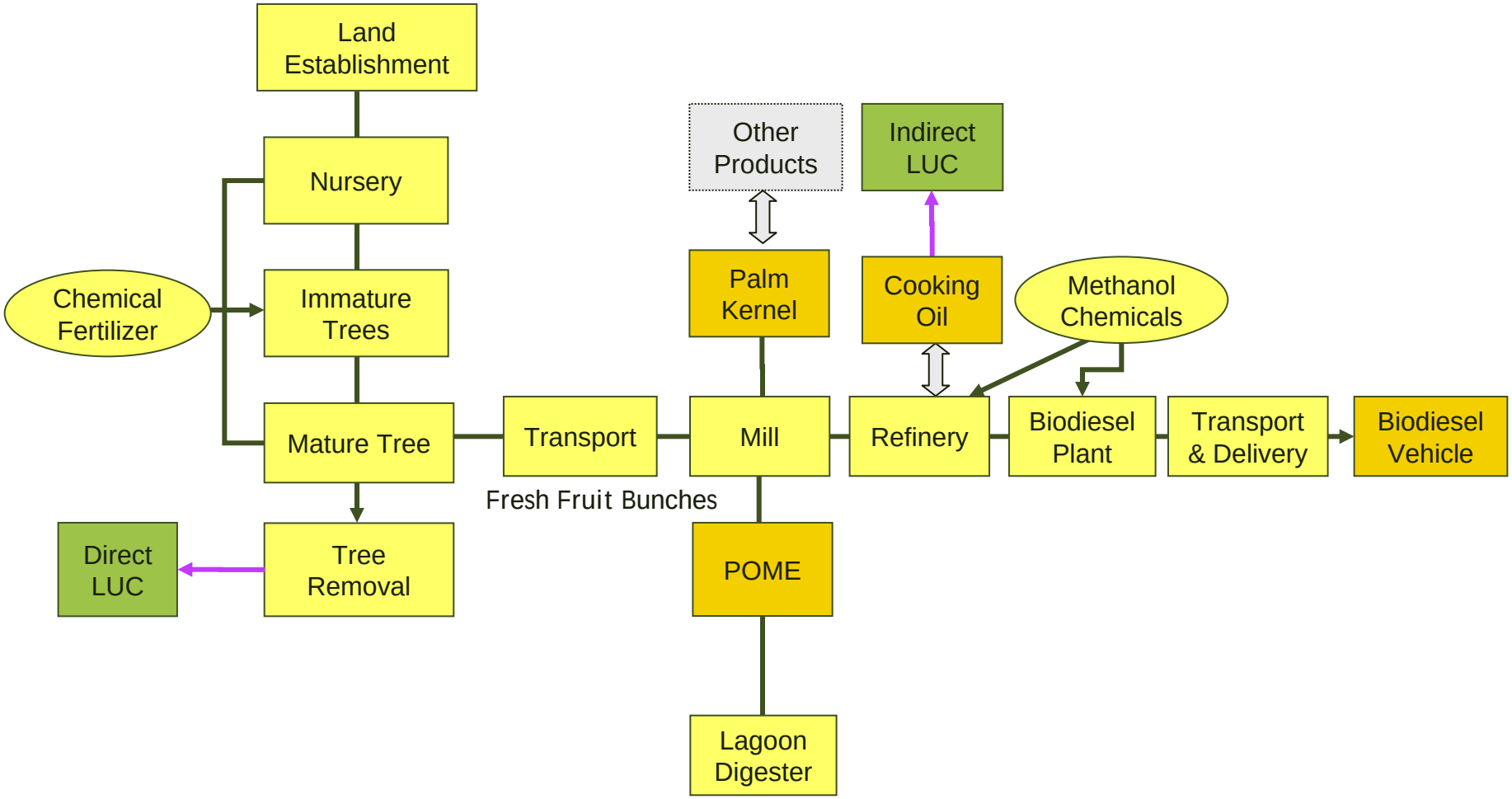
General Biofuel System Boundary



Palm Oil System Boundary



Palm Oil System Boundary



LCFS Pathway Description

Table B. GHG Emissions Summary for Sugar Cane Ethanol

Sugar Cane Ethanol Components	GHGs* (g CO_2e/MJ) (Anhydrous)	% Emission Contribution
Sugar Cane Farming	9.74	41.1%
Ag Chemicals Production and Use Impacts	8.73	36.8%
Sugar Cane Transportation	1.90	8.0%
Ethanol Production	0.03	0.1%
Ethanol T&D	3.3	13.9%
Total Well-to-Tank	23.7	100%
Total Tank-to-wheel	0	0%
Total Well-to-Wheel	23.7	100%

- Detailed description of
  - Inputs
  - Calculations
  - Data sources
- Regionally specific

Table 1.01. Primary Energy Inputs by Fuel/Energy Input Type for Farm Operations

Fuel Type	Fuel Share	Formula	Primary Energy Input (Btu/tonne)	Primary Energy Input (Btu/mmBtu)
Residual Oil	0%	41,592*0%	0	0
Diesel Fuel	38.3%	41,592*38.3%	15,930	9,858
Gasoline	12.3%	41,592*12.3%	5,116	3,166
Natural Gas	21.5%	41,592*21.5%	8,942	5,534
Coal	0%	41,592*0%	0	0
Liquefied Petroleum Gas	18.8%	41,592*18.8%	7,819	4,839
Electricity	9%	41,592*9%	3,743	2,316
Direct Energy Consumption for Sugar Cane Cultivation (unadjusted)			**41,550**	**22,681**

Life Cycle Inventory Data

- Process Inputs
  - Agricultural inputs
  - Chemicals and Fertilizers
  - Transport diesel
  - Electricity
  - Fuel oil
  - Methanol
- Co-product Credits
  - Palm Kernel
  - Glycerin

GREET Model Inputs

- EtOH Process Data
  - Inputs
  - Fuel_Prod_TS
  - EtOH
- T&D
- Fuel properties
- Emission factors
- Other fuels

	A	B	C	D	E	F	G	H
196		**7.2) Farming Energy Use and Fertilizer use**						
197			Corn (per bushel)	Trees (per d.ton)	H. Biomass (per d.ton)	Corn Stover (per d.ton)	Residue (per d.ton)	Cane (per tonne)
198		Farming Energy Use: Btu	22,500	234,770	217,230	235,244	612,700	41,592
199		Fertilizer Use						
200		Grams of Nitrogen	420.0	709.0	10,635	3,175		1091.7
201		Grams of P2O5	149.0	189.0	142.0	1,633		120.8
202		Grams of K2O	174.0	331.0	226.0	8,346		193.6
203		Grams of $CaCO_3$	1202.0	0.0	0.0			5337.7
204		Pesticide Use						
205		Grams of Herbicide	8.10	24.00	28.00	0.00		26.90
206		Grams of Insecticide	0.68	2.00	0.00	0.00		2.21

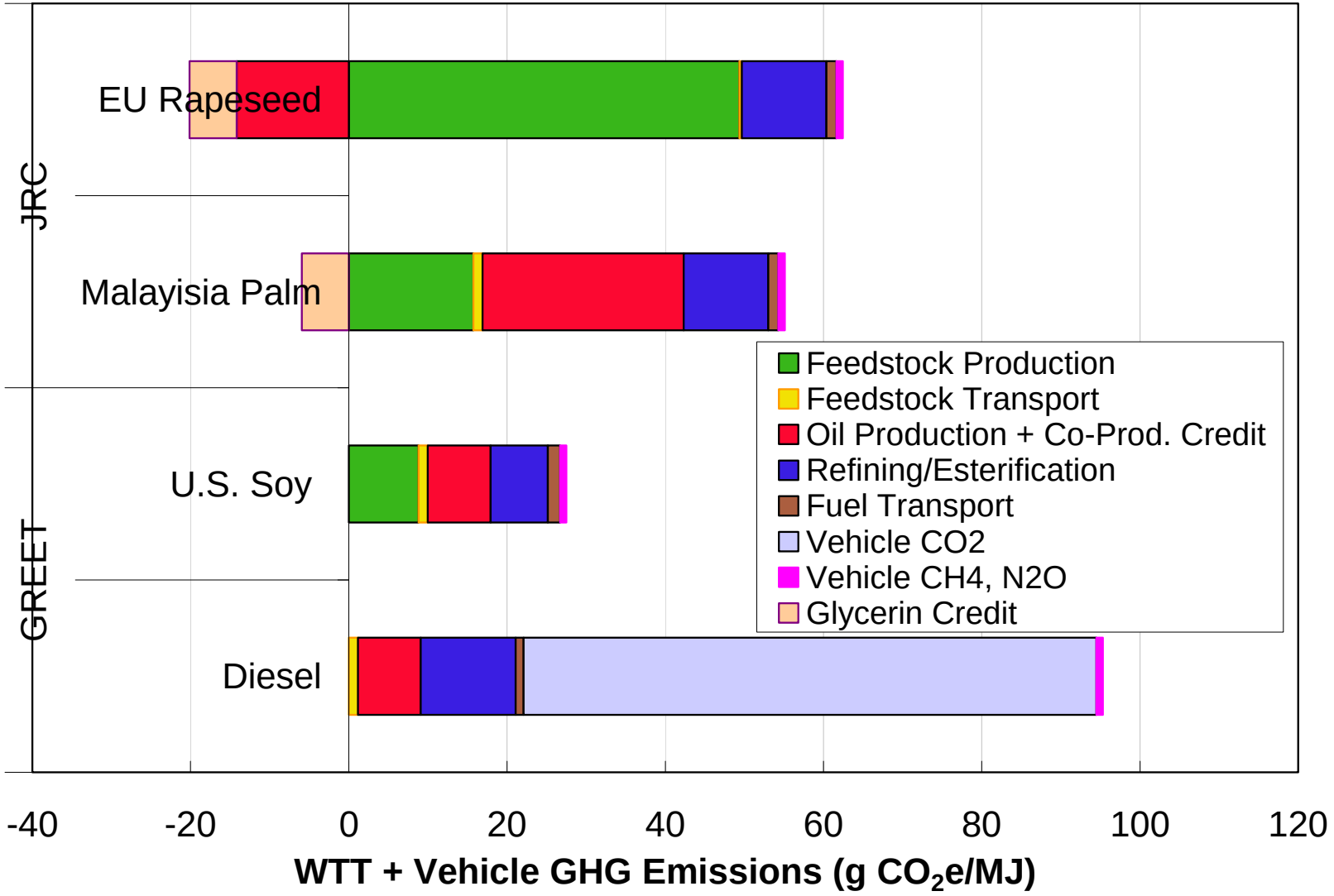
	B	C	D
299	**7.11.b) Ethanol Yield: Gallons per Dry Ton of Biomass**		
300		Fermentation	Gasification
301	Farmed Trees Plant	90.0	87.0
302	Herbaceous Biomass Plant	95.0	91.5
303	Corn Stover Plant	95.0	91.5
304	Forest Residue Plant	92.8	90.4
305	**7.11.c) Amount of Electricity Co-Produced**		
306		Fermentation	Gasification
307	Farmed Trees Plant	-1.145	-1.145
308	Herbaceous Biomass Plant	-0.572	-0.572
309	Corn Stover Plant	-0.572	0.000
310	Forest Residue Plant	-1.145	0.000

87.0

90.0

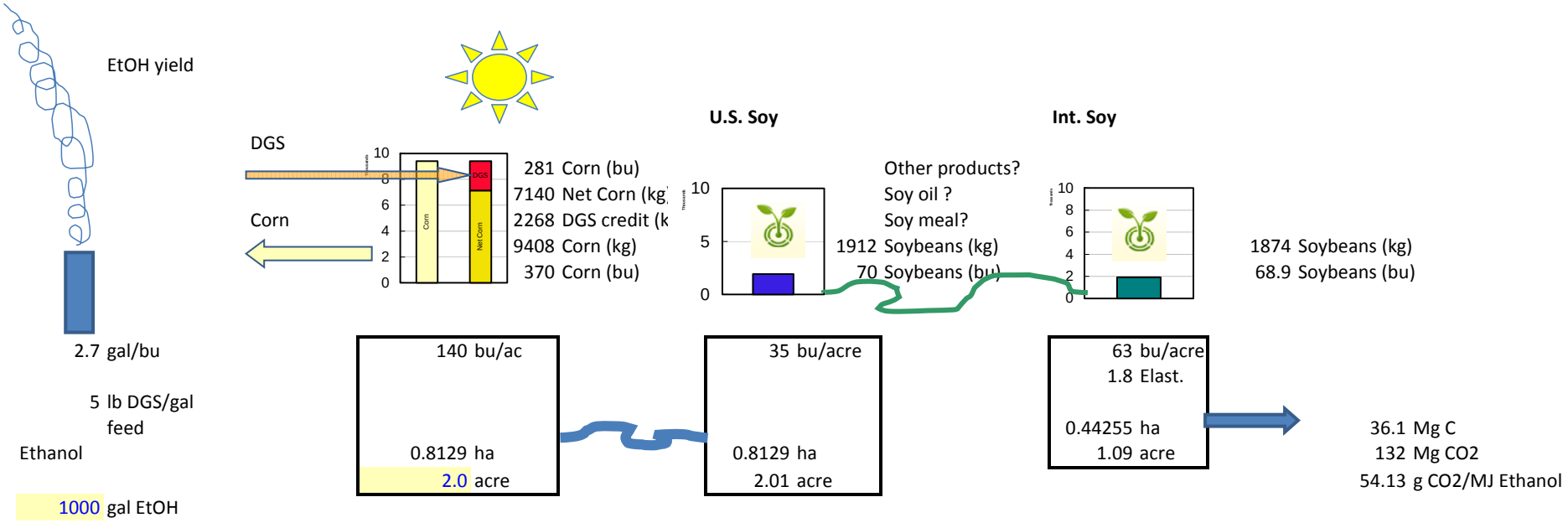
5-year period	EtOH Yield of Farmed Trees Fermentation EtOH Plant: gal/dry ton	Relative Efficiency (to yr 2010)
1990	82.0	91.1%
1995	83.0	92.2%
2000	84.0	93.3%
2005	85.0	94.4%
2010	**90.0**	**100.0%**
2015	95.0	105.6%
2020	100.0	111.1%

Comparison of LCA Study Results



Land Use Emissions

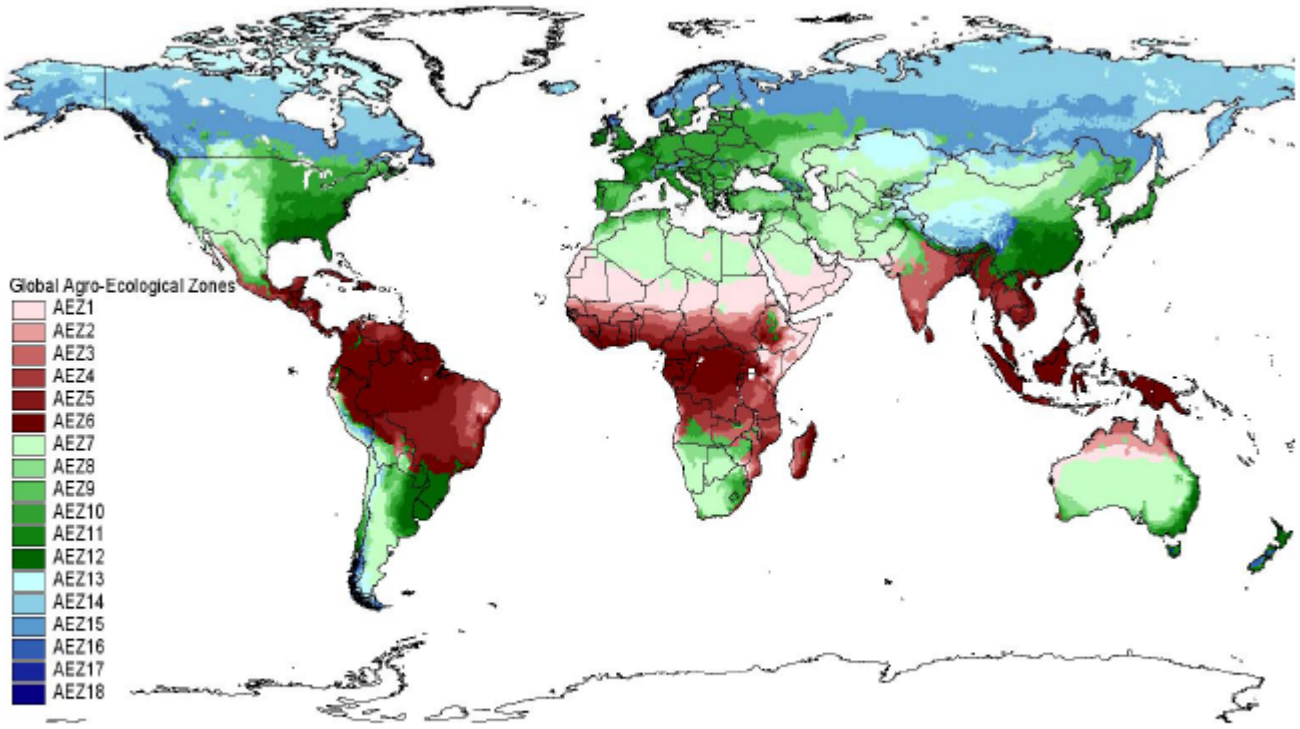
- Opportunity cost for land
- Displaced crop or feedstock
- Affected land is not clear



LUC and Soil Carbon

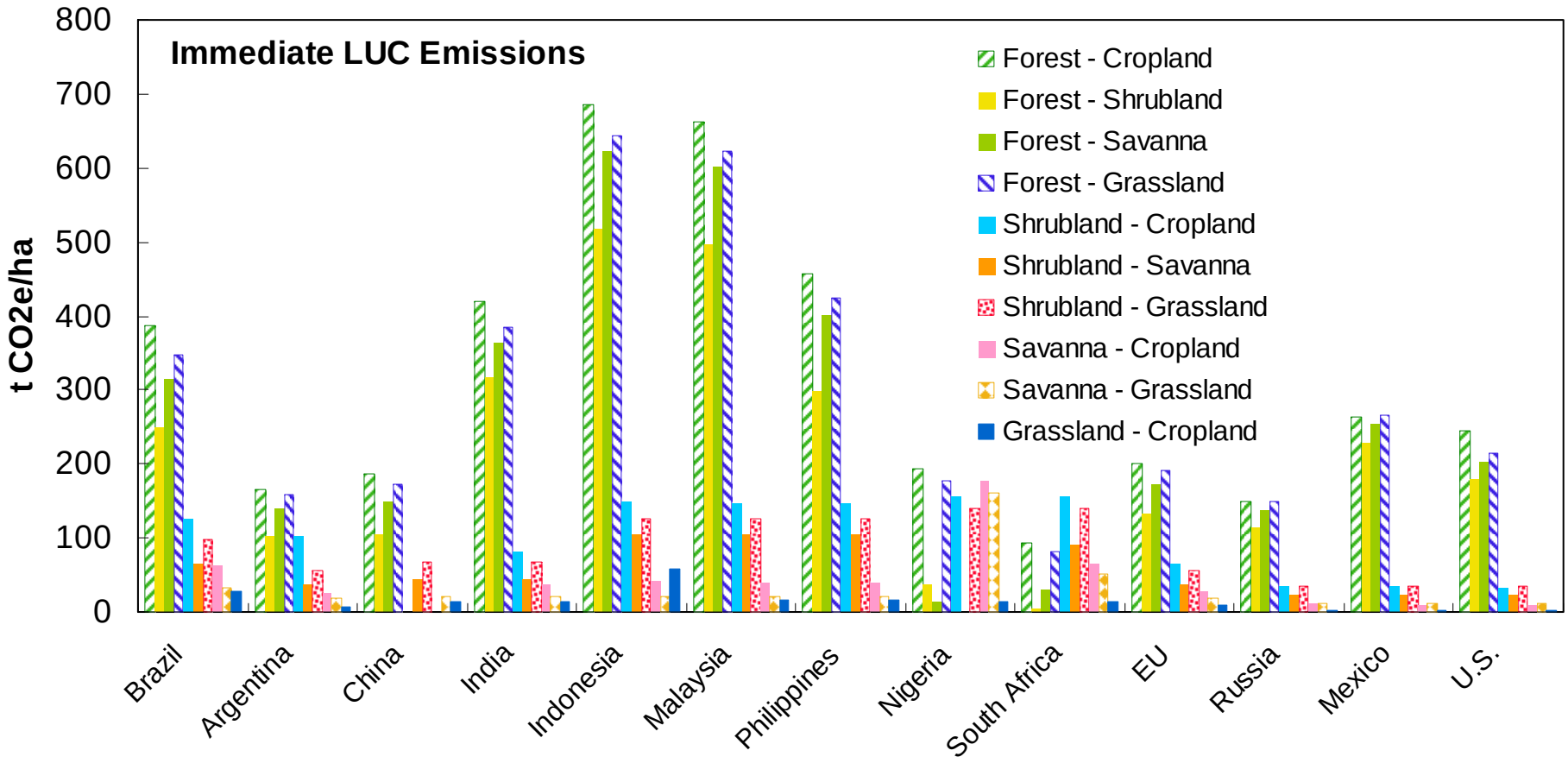
- Avoided land
  - Reserve agriculture
  - Displaced exports
  - Crop shifts
  - Agroeconomic models (FAPRI, FASOM, GTAP)
- Soil carbon stocks include above & below ground soil measurements
  - Soil measurement
  - Assume 25% SOC conversion
  - Soil carbon storage from biomass growth
  - Relate to satellite data or land type

Global Distribution of AEZs

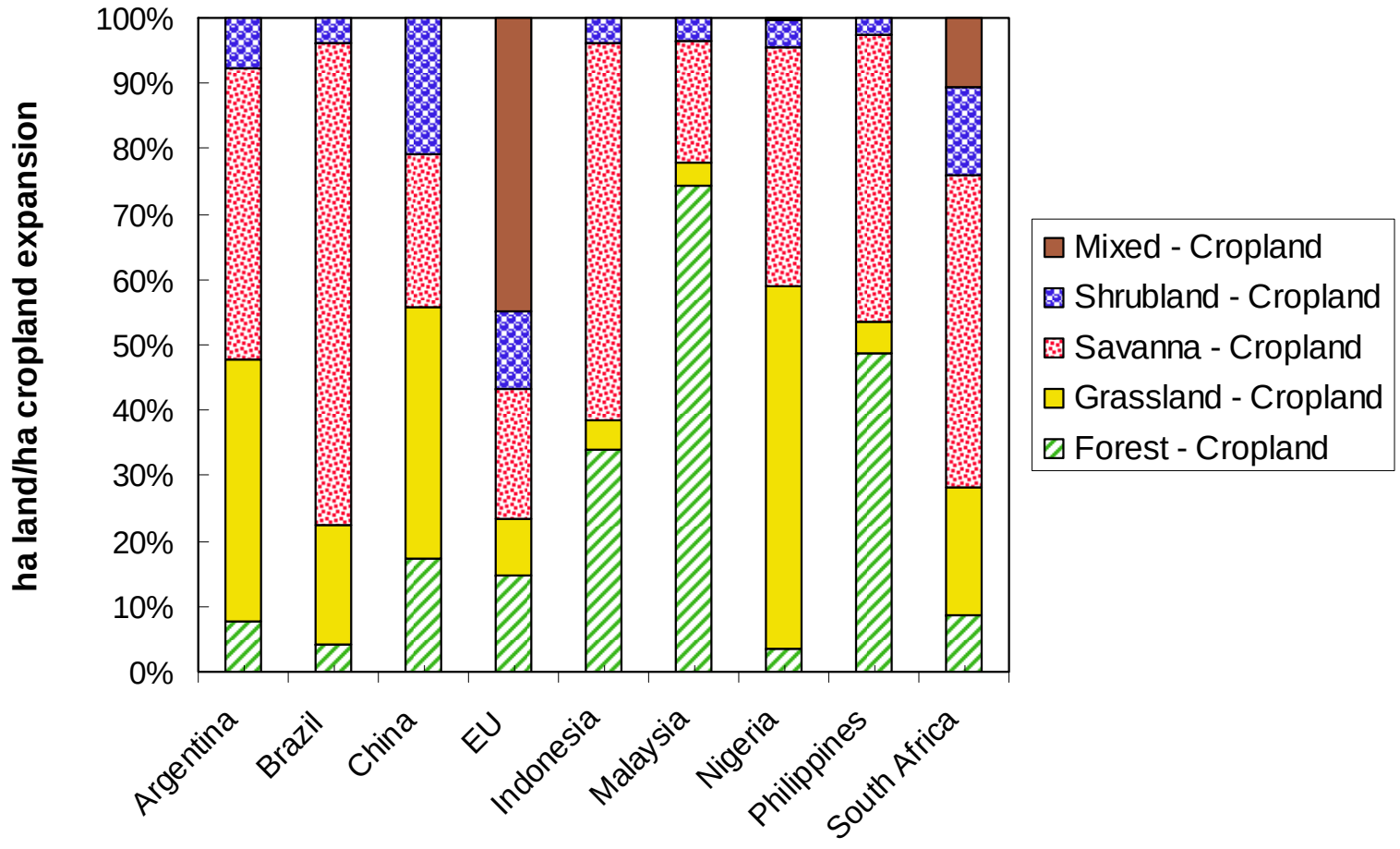


Source: Lee *et al*. 2005

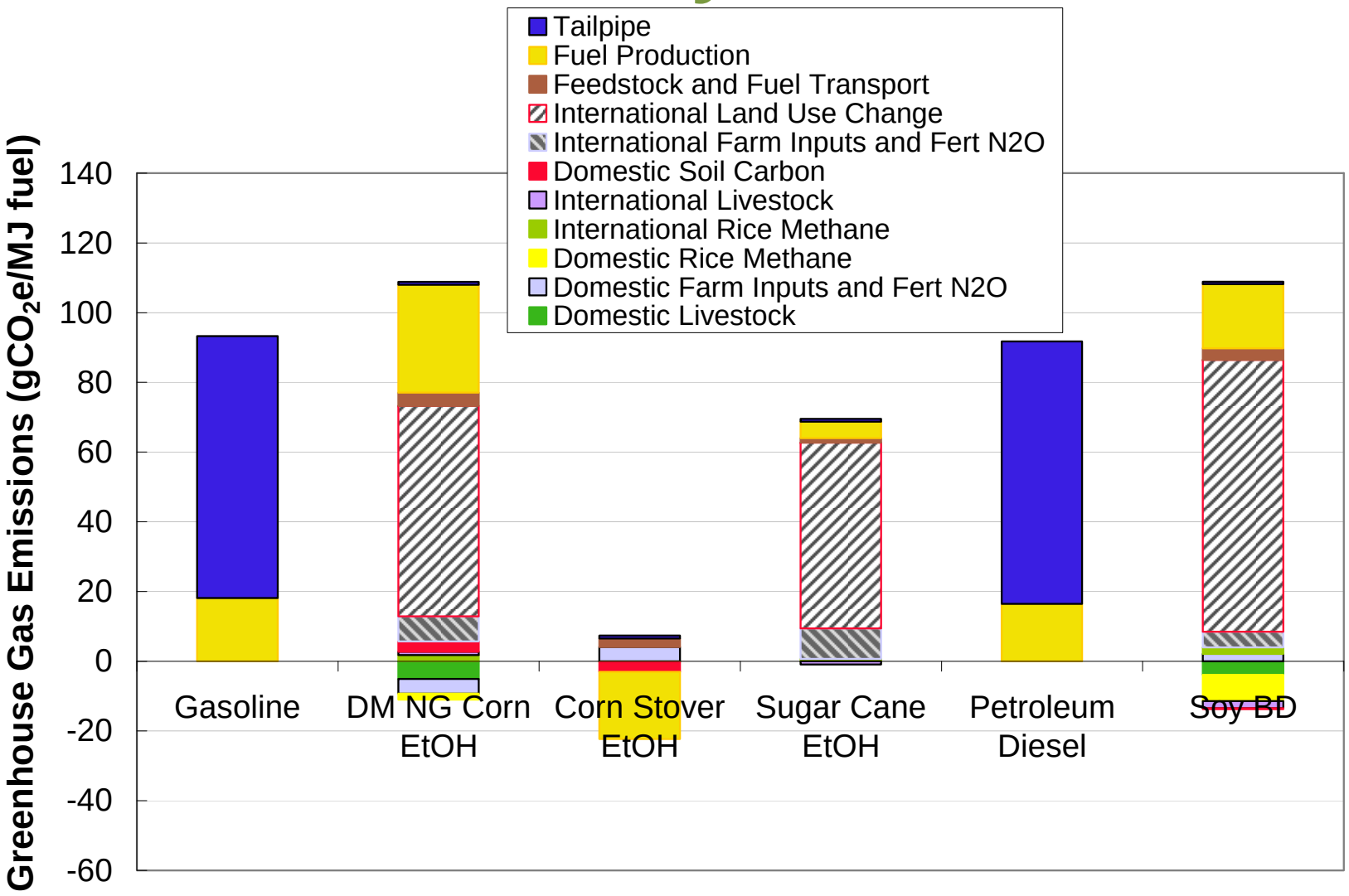
Winrock Soil Carbon Analysis



Cropland Expansion



EPA RFS2 Analysis



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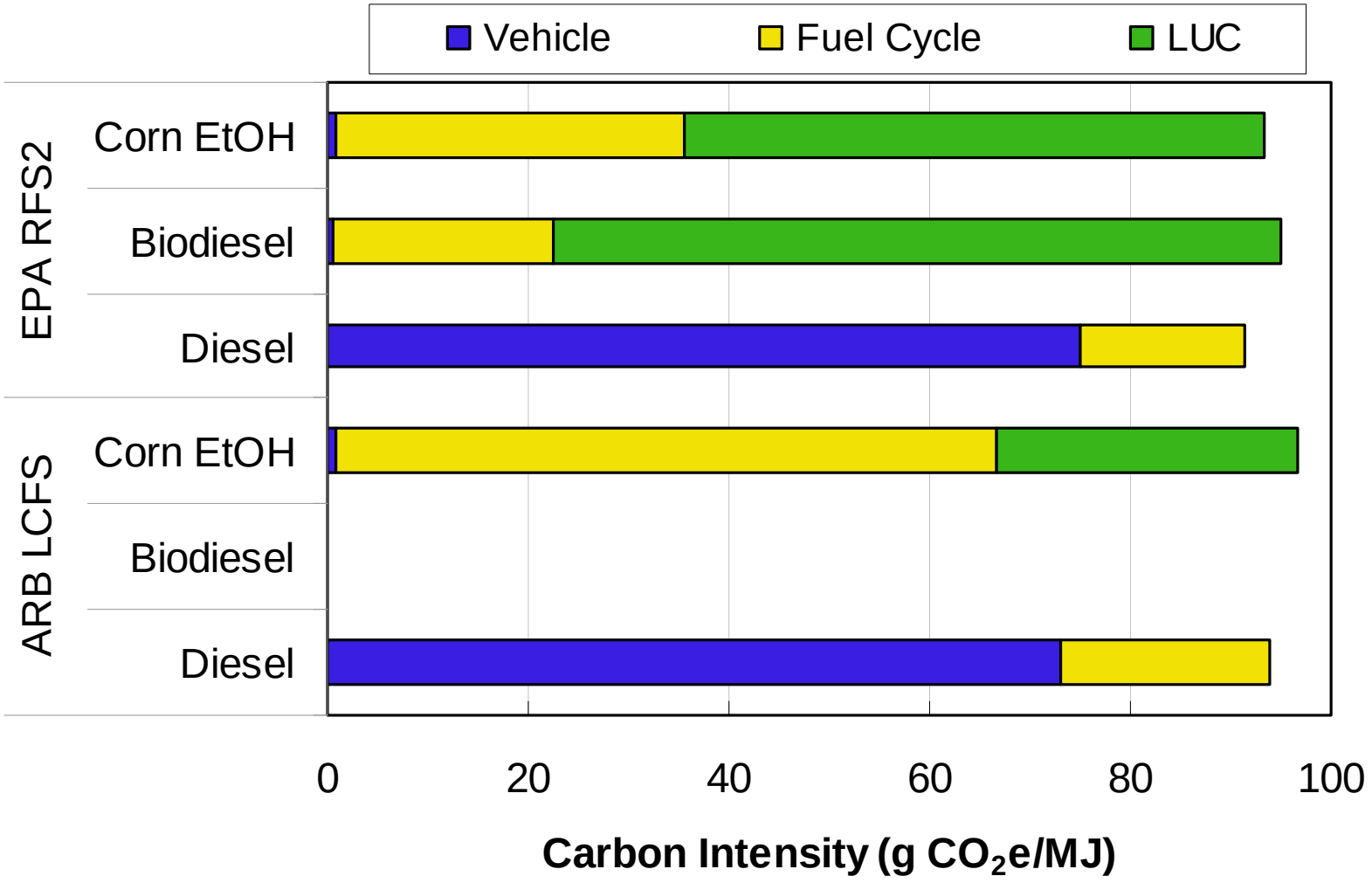
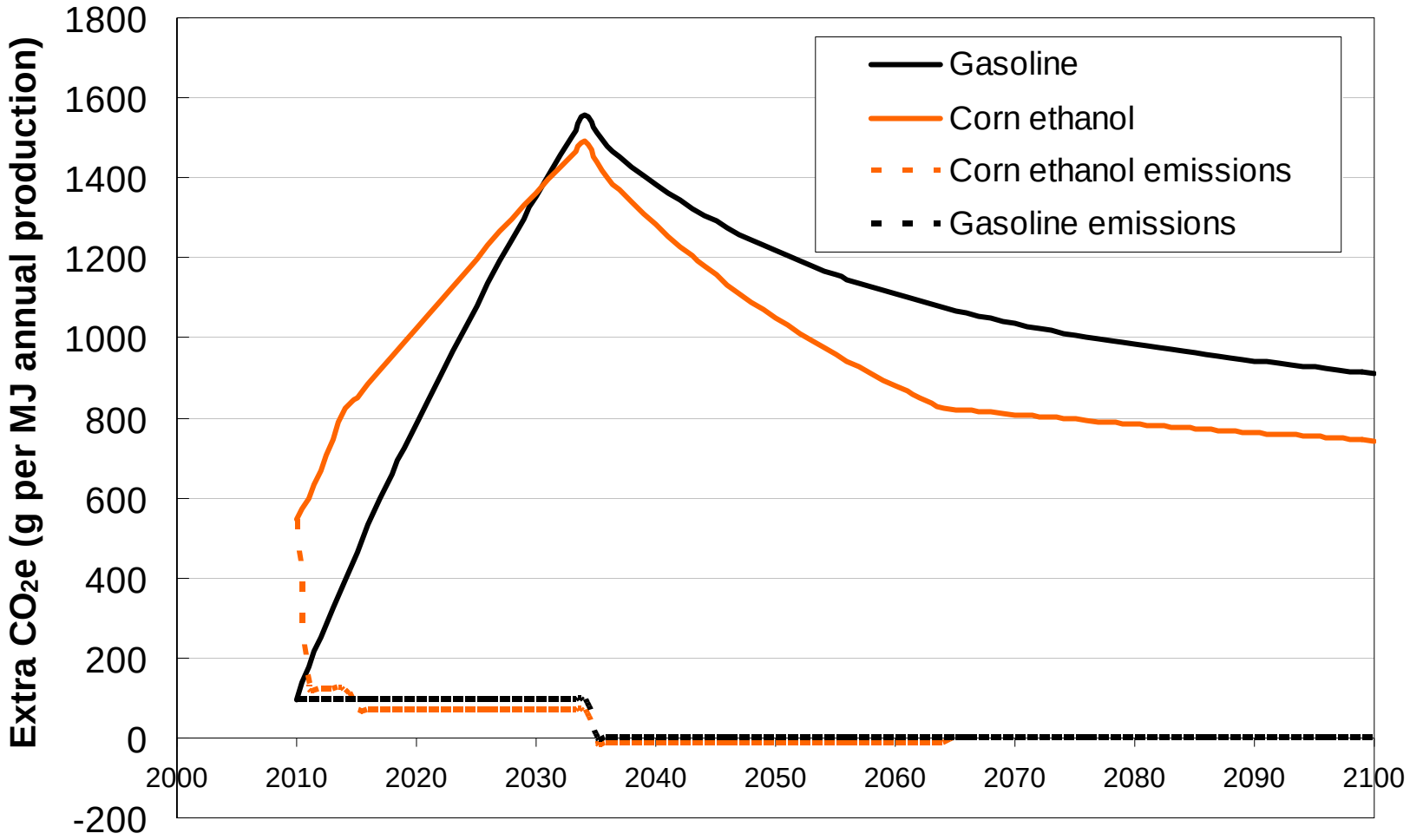


Time Horizon



LUC Impacts of Palm Oil

- Direct Land Impacts
  - Biogenic carbon uptake
  - Fuel combustion
  - Tree decomposition
  - Roots
- Land Use impacts
  - Palm oil substitution for soy oil
  - Palm land intensification (improved yield)
  - Palm land extensification (more land)

Immature Tree

Fruit Bunch

Life Cycle Associates

Palm Trees

Soil Carbon Storage

Chipped Trunks

Repeat the Process

Observations

- Fuel LCA issues remain critical for biofuels
- New science
- Analysis methods result in range of results
  - Co-product credits
  - Aggregation of technologies
  - Land use modeling
  - Soil carbon
- Range in palm production technologies
  - Pathway specific categories will support innovation