Economic and Agricultural Impacts of Decarbonizing the US Economy

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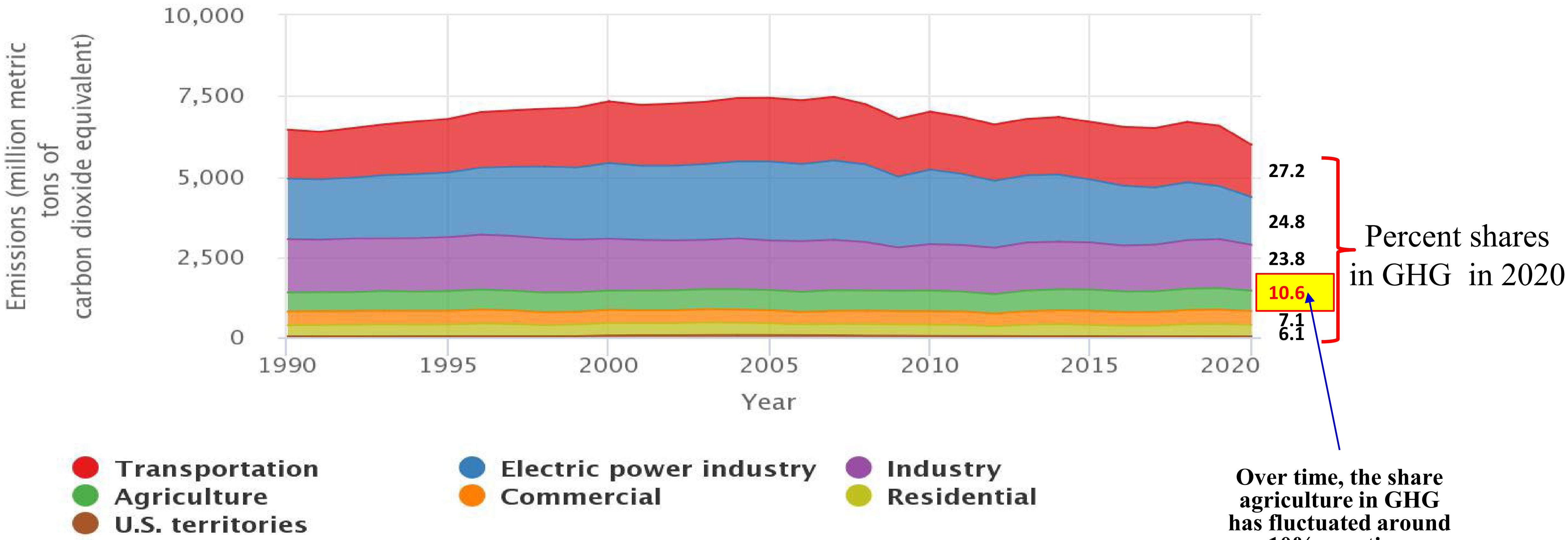
Outline

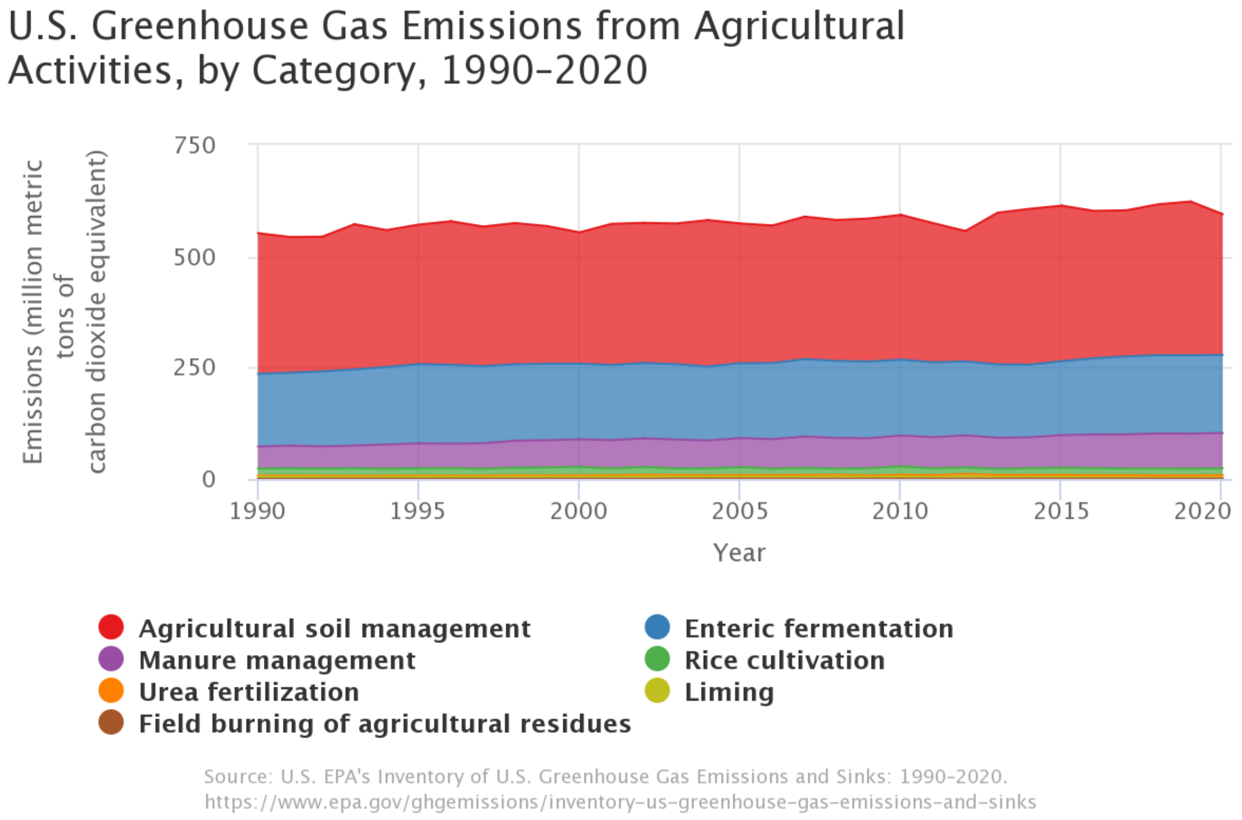
- This presentation covers the following topics
  - A historical review of U.S. GHG emissions
  - The U.S. targets for emissions reductions
  - Climate change interactions with agriculture, forestry sequestration, and food security: A global prospective
  - The U.S. agriculture, productivity growth, land availability, and potentials for decarbonization

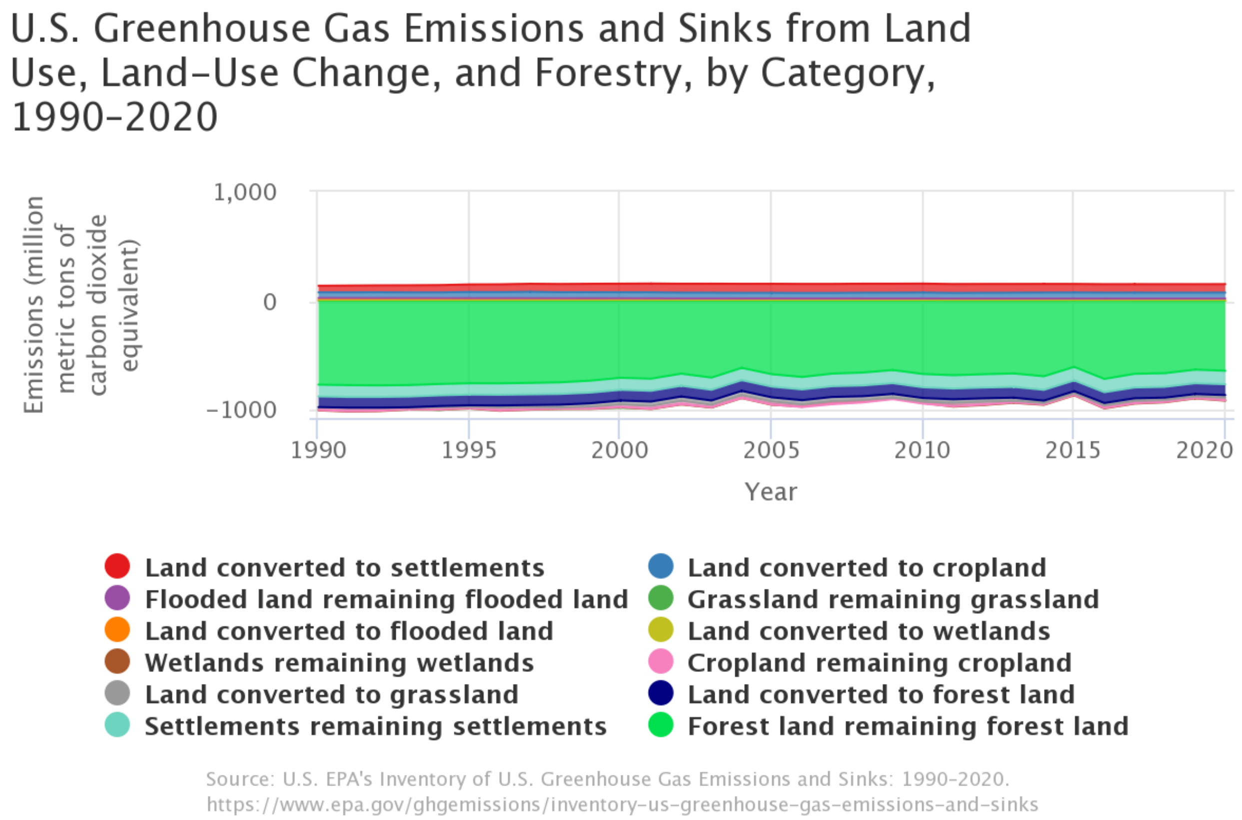
U.S. Greenhouse Gas Emissions by Economic Sector, 1990-2020



Over time, the share agriculture in GHG has fluctuated around 10% overtime

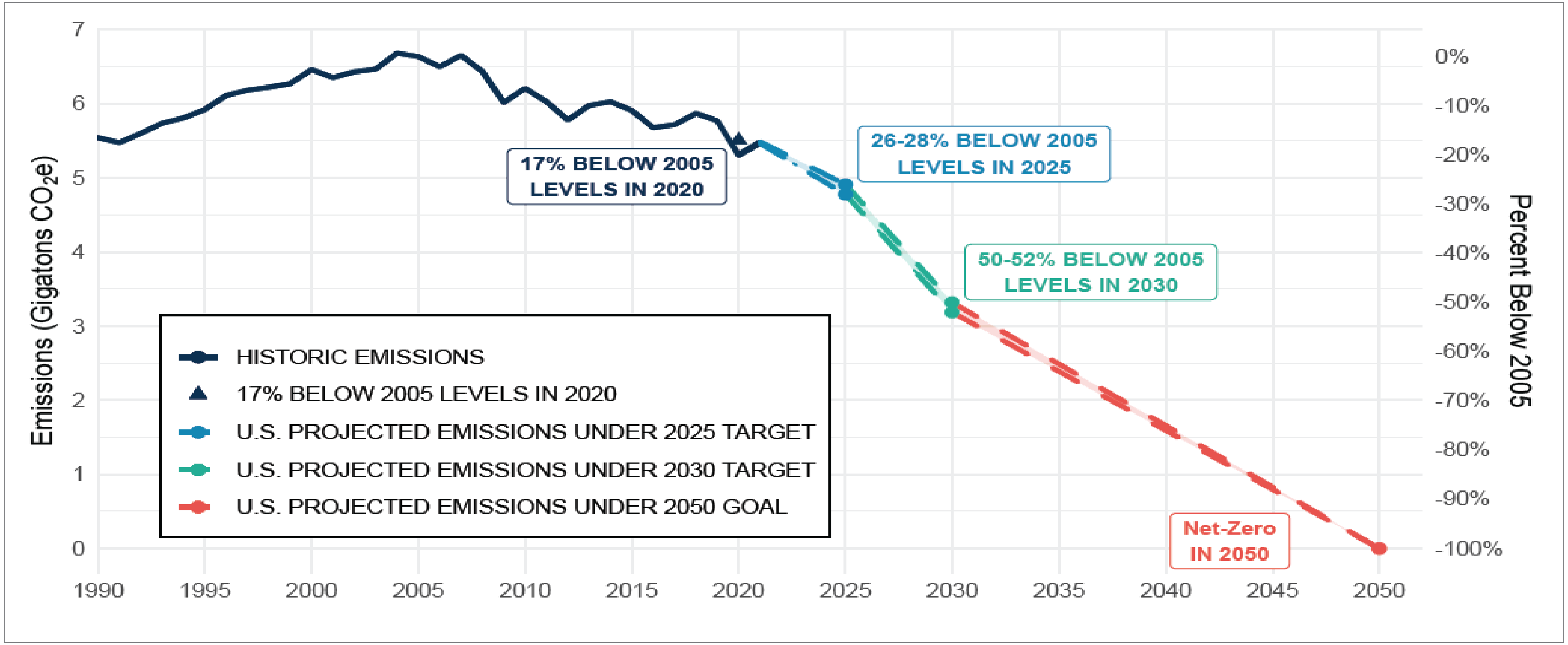
Source: U.S. EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020.
https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks





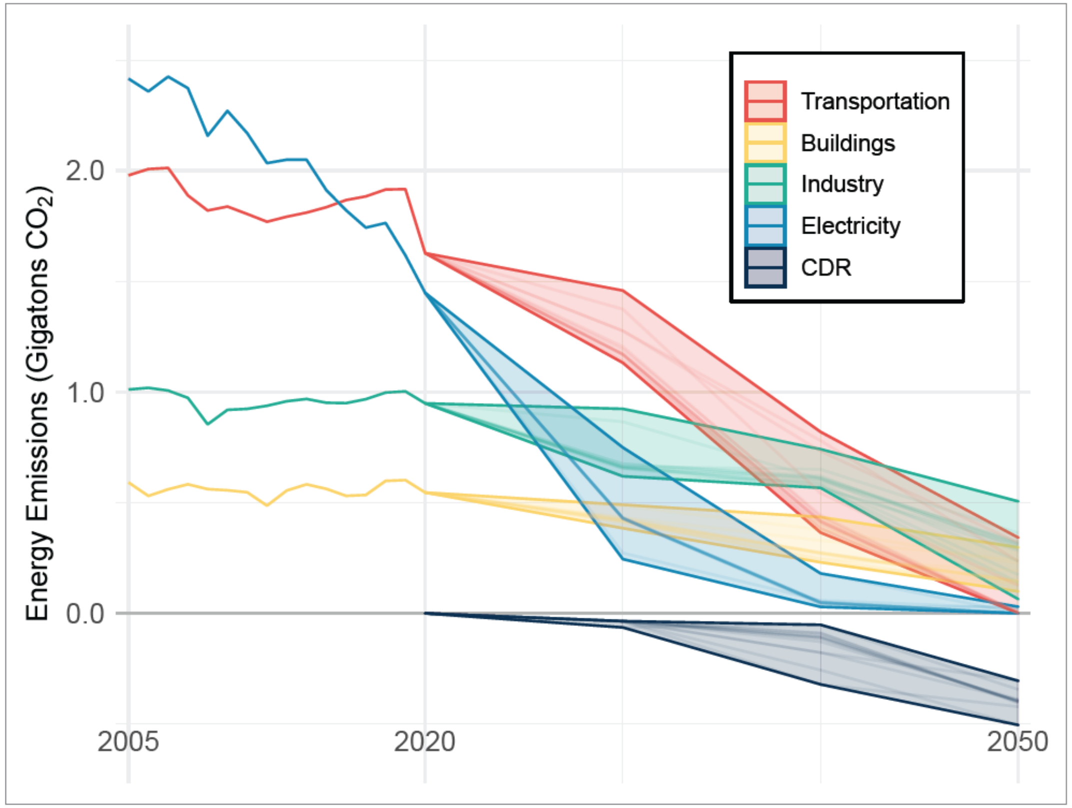
Historically, net emissions from agriculture and land use, land use-change, and forestry have been negative

United States historic emissions and periodic emissions under 2050 goal for net-zero

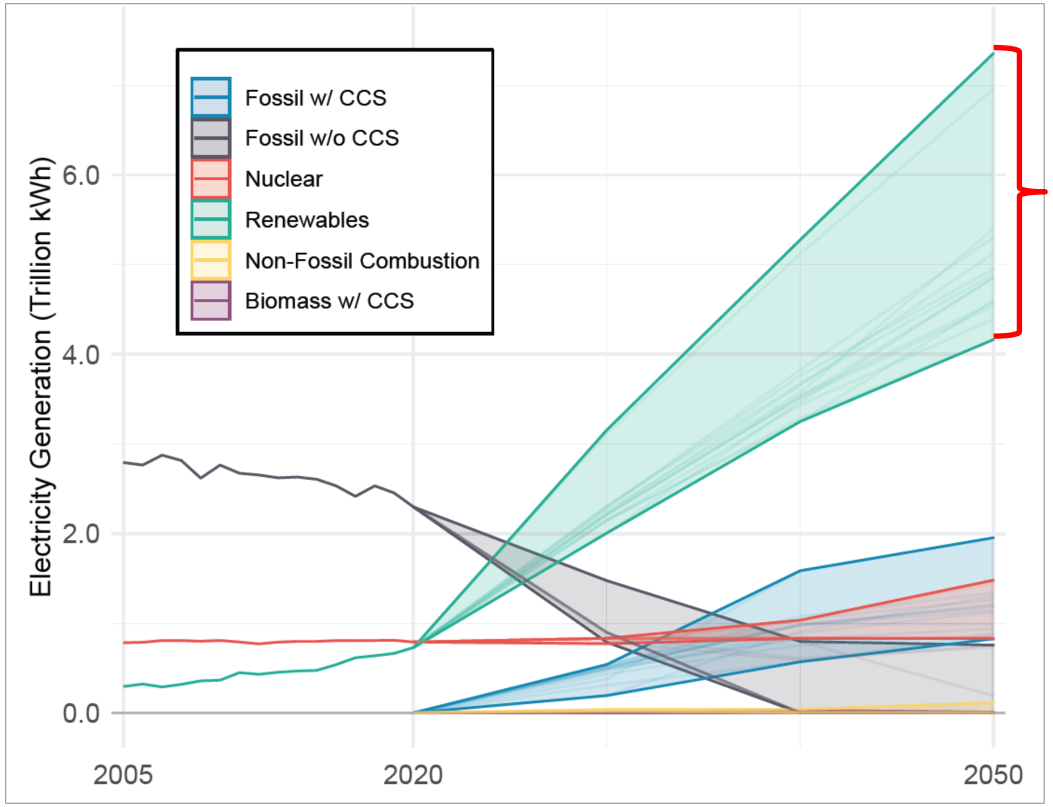


Source: The Long-Term Strategy of the United States: Pathways to Net-Zero Greenhouse Gas Emissions by 2050. Published by the United States Department of State and the United States Executive Office of the President, Washington DC. November 2021.

U.S. Energy CO_2 emissions 2005-2050



U.S. Electricity generation 2005-2050



Wind and solar electricity could generate major demand for land

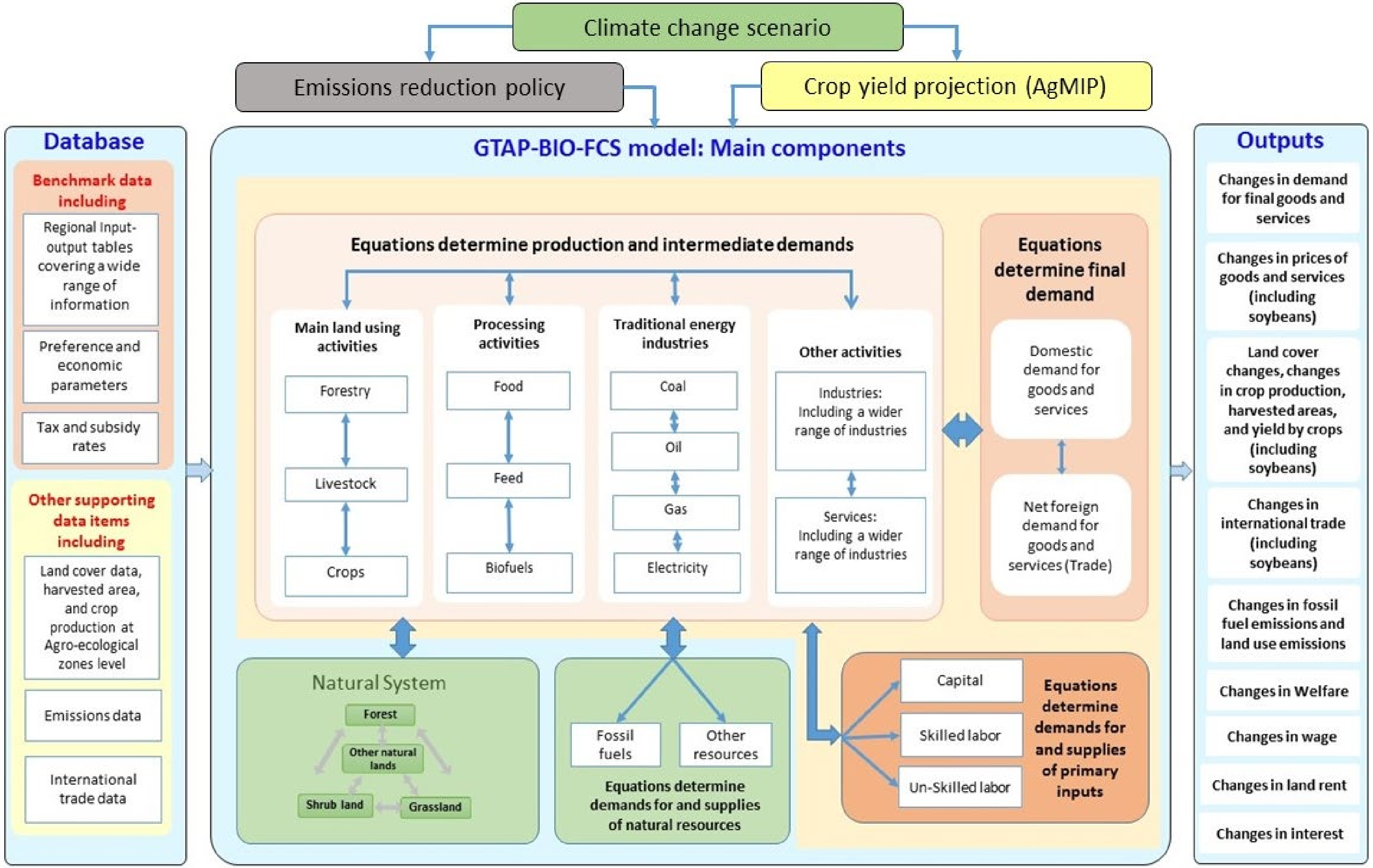
Source: The Long-Term Strategy of the United States: Pathways to Net-Zero Greenhouse Gas Emissions by 2050. Published by the United States Department of State and the United States Executive Office of the President, Washington DC. November 2021.

Climate change interactions with agriculture, forestry sequestration, and food security: A global prospective based on: Pena-Levano, Taheripour, and Tyner (2019)

- A quick literature review:
  - **Finding 1:** Climate change can negatively affect crop productivity decreasing food production.
  - **Finding 2:** Forest carbon sequestration (FCS) is a good low cost alternative to mitigate climate change.
  - **Finding 3:** FCS could **moderately** increase food prices and reduce food security.
- The literature mentioned above has ignored that:
  - In the presence climate change, an aggressive FCS policy could significantly increase food prices and badly reduce food security.
- What is our major finding:
  - With the climate induced yield shocks, **food price increases are huge**-so large that it is clear this approach could not be adopted in the real world.

Review of Pena-Levano, Taheripour, and Tyner (2019)

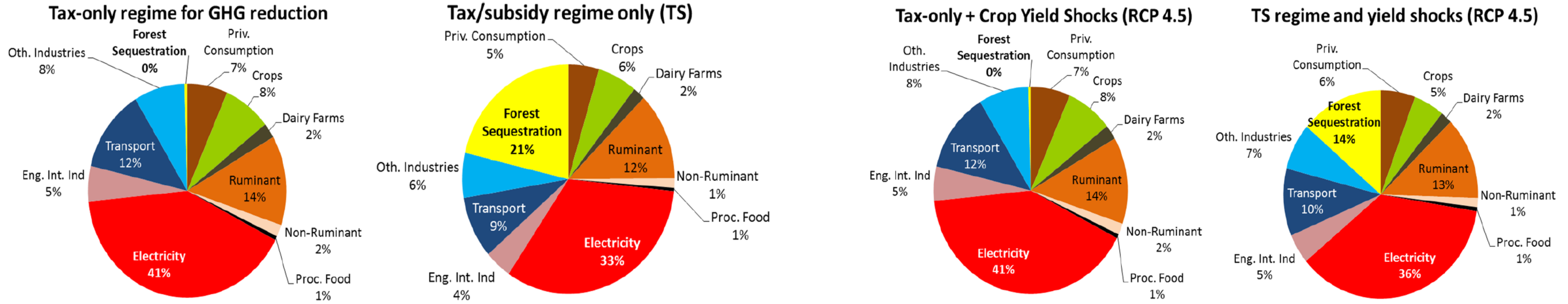
- A well-known Computable General Equilibrium (CGE) model (GTAP-BIO-FCS) and a global data set on climate induced yield effects were used to answer the following questions:
  - What are the economic costs of Paris accord emissions targets (50% emissions reduction) under alternative climate scenarios (**RCP5.5 and RCP8.5**) and emissions control policies including: **A emission tax and an emission tax supported by a FCS subsidy**.



Pena-Levano, Taheripour, and Tyner (2019): Major Findings

- Tax and tax-subsidy required to achieve 50% emission reduction:
  - Ignoring climate induced yield shocks:
    - A uniform emissions tax of \$150/tCO_2e and no FCS subsidy
    - A uniform emissions tax of \$80/tCO_2e and an equivalent FCS subsidy
  - Taking into account climate induced yield shocks:
    - A uniform emissions tax of \$155/tCO_2e and no FCS subsidy
    - A uniform emissions tax of \$100/tCO_2e and an equivalent FCS subsidy

Sectoral shares (%) in global GHG reduction



Pena-Levano, Taheripour, and Tyner (2019): Major Findings

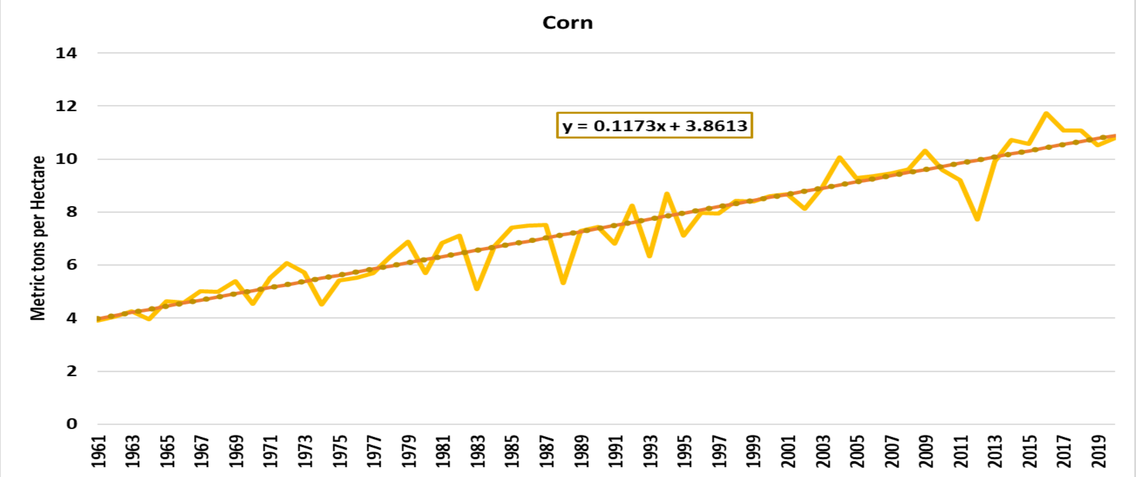
Price impacts of 50% emissions reductions

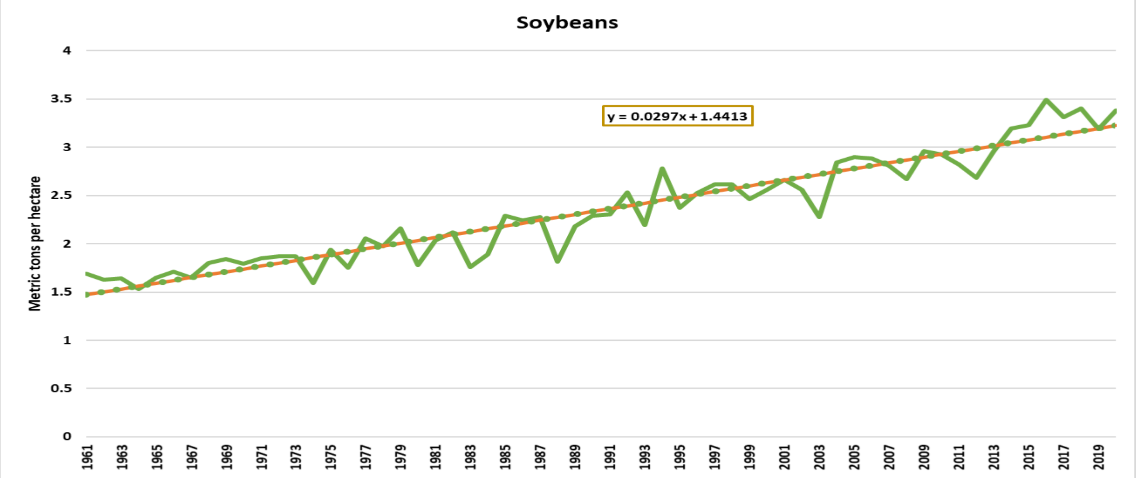
Region	% Changes in prices					
	Tax regime + CY			Tax-subsidy + CY scenario		
	Rice	Crops*	Livestock	Rice	Crops*	Livestock
United States	106	46	41	250	145	44
European Union	87	47	40	147	105	37
Brazil	79	36	278	213	166	224
Canada	28	44	45	44	126	54
Japan	36	25	31	98	83	40
China	172	22	49	184	97	55
India	470	84	77	517	196	100
Central America	96	23	56	316	167	68
South America	163	46	139	367	203	151
East Asia	134	57	51	216	132	64
Malaysia and Indonesia	154	49	37	211	142	56
South East Asia	194	28	87	222	107	75
South Asia	161	39	65	290	99	67
Russia	132	40	36	141	84	43
Other Central Europe	110	41	34	108	90	61
Other European countries	16	34	36	10	88	36
Middle East S and N Africa	57	32	34	95	93	55
Sub-Saharan Africa	171	35	272	299	164	200
Oceania	141	37	73	160	159	61

- Price impact varies across regions
- Price impact is large with FCS subsidy
- With the climate induced yield shocks, **food price increases are huge**-so large that it is clear this approach could not be adopted in the real world.
- What is missing in our analyses:
  - **Technological progress in agricultural activities.**
- Technological progress could play a crucial role in designing emissions reduction policies for the U. S.
- In particular, compared to many other countries, the U.S. agriculture has major advantages in technological progress.

Productivity improvement in crop and livestock sectors

Historical observations on corn and soybeans yields since 1961





Historical observations on productivity improvement in livestock production

Year	Production of animal- based calories over crop feed calories in %	Production of animal- based calories over area of pastureland (Pcal/1000 hectares)
1961	11.3	399.4
1970	11.0	438.7
1980	11.8	530.1
1990	12.0	629.1
2000	13.5	808.9
2010	15.2	951.0
2014	14.6	1017.2

- Major intensification has happened in crop and livestock production over time.
- Between 2000-2020 corn yield has increased by 27.5%.
- Between 2000-2020 soybean yield has increased by 22.6%.
- Over time major productivity improvements occurred in animal-based products.
- **Productivity gains provided major saving in land use**

U.S. agriculture, productivity growth, land availability, and decarbonization

- The U.S. agricultural sector could make significant contribution in emissions reduction policies by:
  - Reduction in GHG emissions associated with food change;
  - Providing feedstock for biofuels and aviation biofuels;
  - Supporting carbon sequestration on agricultural land.
- The last two items will be discussed in what follows through the US Grand Challenge to extend production of Sustainable Aviation Fuel (SAF) in collaboration with the ICAO of UN (International Civil Aviation Organization if the United Nations).
- The SAF Grand Challenge (GD) is the results of DOE DOT(FAA) and USDA collaboration.
- The SAF GD has the following goals:
  - **A 50% reduction in life cycle GHG emissions compared to conventional fuel;**
  - **Supply sufficient SAF to meet 100% of aviation fuels uplift by 2050.**
- **These goals could have major implications for the U.S. agriculture.**

U.S. SAF pathways and their life cycle GHG emissions gCO_2e/MJ

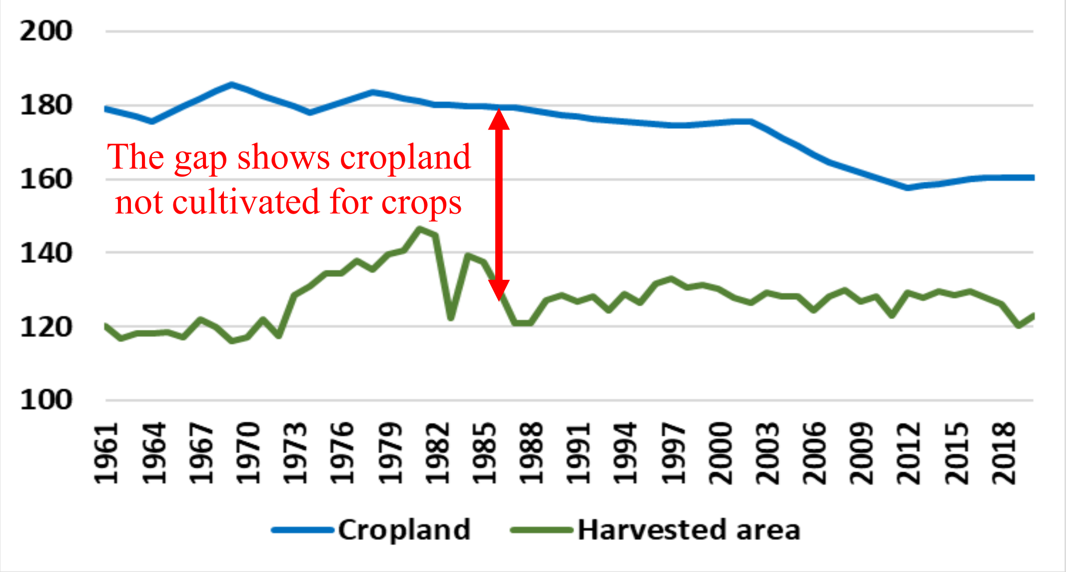
- Conventional jet fuel emissions: 89 gCO_2e/MJ
- All pathways pass the CORSIA 10% emissions reduction, except corn ETJ
- All pathways pass the US grand challenge 50% emissions reduction, except soy oil HEFFA, corn pathways
- Improvements in LCA of corn and soybeans pathways due to technological progress could help top pass the 50% emissions reduction target.

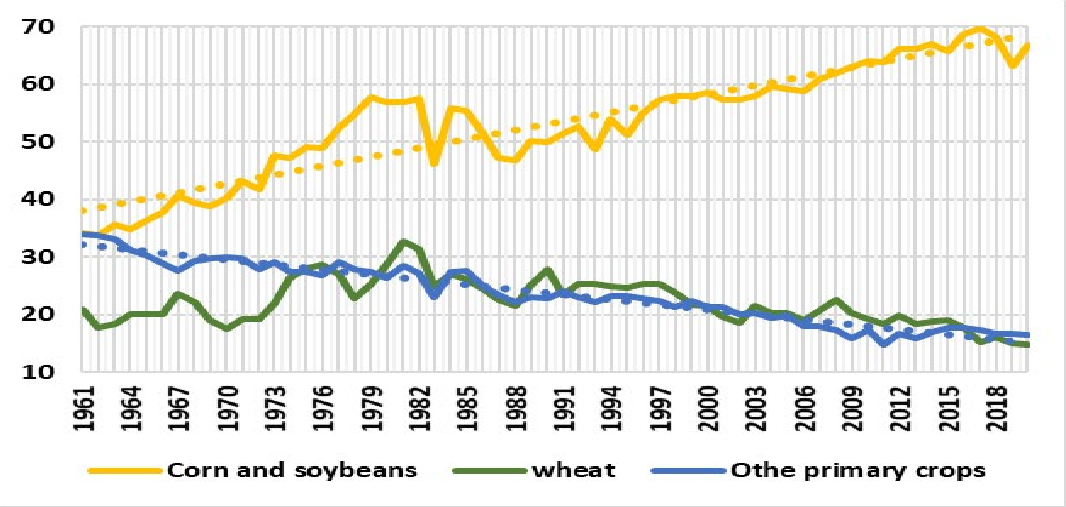
Description	Pathway	Technology	Core LCA	ILUC	LS_f
Global pathways that can be produced in the US	Agri. residues	FTJ	7.7		7.7
	Fore. residues	FTJ	8.3		8.3
	Municipal solid waste	FTJ	5.2		5.2
	Tallow	HEFA	22.5		22.5
	Used cooking oil	HEFA	13.9		13.9
	Palm fatty acid distillate	HEFA	20.7		20.7
	Corn oil: Dry mill ethanol	HEFA	17.2	0.0	17.2
	Agri. residues	ATJ	29.3		29.3
	Fore. residues	ATJ	23.8		23.8
	Agri. residues standalone	ETJ	39.7		39.7
	Agri. residues integrated	ETJ	24.6		24.6
	Fore. residues standalone	ETJ	40.0		40.0
	Fore. residues integrated	ETJ	24.9		24.9
US lignocellulosic pathways	Poplar	FTJ	12.2	-5.2	7.0
	Miscanthus	FTJ	10.4	-32.9	-22.5
	Switchgrass	FTJ	10.4	-3.8	6.6
	Brassica carinata oil	HEFA	34.4	-21.4	13.0
	Miscanthus	ATJ	43.4	-54.1	-10.7
	Switchgrass	ATJ	43.4	-14.5	28.9
	Miscanthus	ETJ	43.3	-42.6	0.7
	Miscanthus	ETJ	28.3	-42.6	-14.3
	Switchgrass	ETJ	43.9	-10.7	33.2
	Switchgrass	ETJ	28.9	-10.7	18.2
US corn and oilseeds pathways	Carinata oil	HEFA	34.4	-21.4	13.0
	Soybean oil	HEFA	40.4	24.5	64.9
	Corn grain	ATJ	55.8	22.1	77.9
	Corn gain	ETJ	65.1	25.1	90.8

Potential increases in aviation fuels that can be produced from improvements in corn and soybeans yields in the U.S. (million gallons)

Year	Full allocation to aviation		50% allocation to aviation	
	Corn ETJ	HEFA	Corn ETJ	HEFA
2023	693	165	347	82
2024	925	220	462	110
2025	1,156	275	578	137
2026	1,387	330	693	165
2027	1,618	384	809	192
2028	1,849	439	925	220
2029	2,080	494	1040	247
2030	2,311	549	1156	275
2031	2,543	604	1271	302
2032	2,774	659	1387	330
2033	3,005	714	1502	357
2034	3,236	769	1618	384
2035	3,467	824	1734	412

Cropland, harvested area, and unused cropland over time (million hectares)





- In 2017 we have about 31 million **hectares** of unused cropland, more than total are of Iowa and Illinois (30 million hectares).
- Available area of unused cropland could support feedstock production for SAF.
- **Over time total area of corn and soybeans followed increasing trend due to reductions in unwanted feed crops and conversion of unused land to active cropland.**
- **Total area of corn and soybeans will continue to grow.**

Potential SAF production due to increases in areas of corn and soybeans (million gallons)

Year	Full allocation to aviation		50% allocation to aviation	
	Corn ETJ	HEFA	Corn ETJ	HEFA
2023	1,098	334	549	167
2024	1,269	385	635	192
2025	1,440	435	720	218
2026	1,611	485	806	243
2027	1,782	536	891	268
2028	1,953	586	977	293
2029	2,124	636	1062	318
2030	2,295	687	1148	343
2031	2,466	737	1233	368
2032	2,637	787	1319	394
2033	2,808	838	1404	419
2034	2,979	888	1489	444
2035	3,150	938	1575	469

Corn ethanol and excess supply of corn ethanol in million gallons

Year	Production	Consumption	Net Export
2000	1,622	1,653	-5
2001	1,765	1,741	-13
2002	2,140	2,073	-13
2003	2,804	2,826	-12
2004	3,404	3,552	-149
2005	3,904	4,059	-136
2006	4,884	5,481	-731
2007	6,521	6,886	-439
2008	9,309	9,683	-530
2009	10,938	11,037	-198
2010	13,298	12,858	383
2011	13,929	12,893	1,023
2012	13,218	12,882	247
2013	13,293	13,216	242
2014	14,313	13,444	772
2015	14,807	13,947	741
2016	15,413	14,356	1,134
2017	15,936	14,485	1,313
2018	16,091	14,420	1,655
2019	15,778	14,552	1,272
2020	13,941	12,681	1,163

Potential SAF production due to expansion in demand for electric cars (million gallons)

Year	Reduction in demad for ethanol due to EV		
	5%	10%	15%
2023	54	108	163
2024	108	217	325
2025	163	325	488
2026	217	434	651
2027	271	542	814
2028	325	651	976
2029	380	759	1,139
2030	434	868	1,302
2031	488	976	1,465
2032	542	1,085	1,627
2033	597	1,193	1,790
2034	651	1,302	1,953
2035	705	1,410	2,116

Other potential sources of contributions

- Various types of second oil crops (carinata, camelina, and pennycress) could be produced in rotation with corn and soybeans. **Up to 29 million hectares**. (Taheripour et al. 2022).
- With proper agricultural policies, these crops can help to expand SAF with no additional demand for land (Taheripour et al. 2022)
- Currently, within the ICAO-CORSIA we are working on a SAF pathway (Power to Liquid) that demands renewable electricity.
- This pathway could significantly increases demand for agricultural land for producing renewable wind and solar electricity.

Conclusions

- The US emissions reduction plan provides significant opportunities for the US agriculture to contribute, gain and grow.
- The US agriculture has the resources (technology, land, and equipment) to make significant contributions.
- Continuation of technological progress could help significantly.
- **Provisions in the recently passed Inflation Reduction Act (IRA) seek to provide incentives to boost domestic production of SAF from agricultural resources, and bridge the cost gap between SAF and petroleum jet fuel.**

Thanks

Questions and Comments