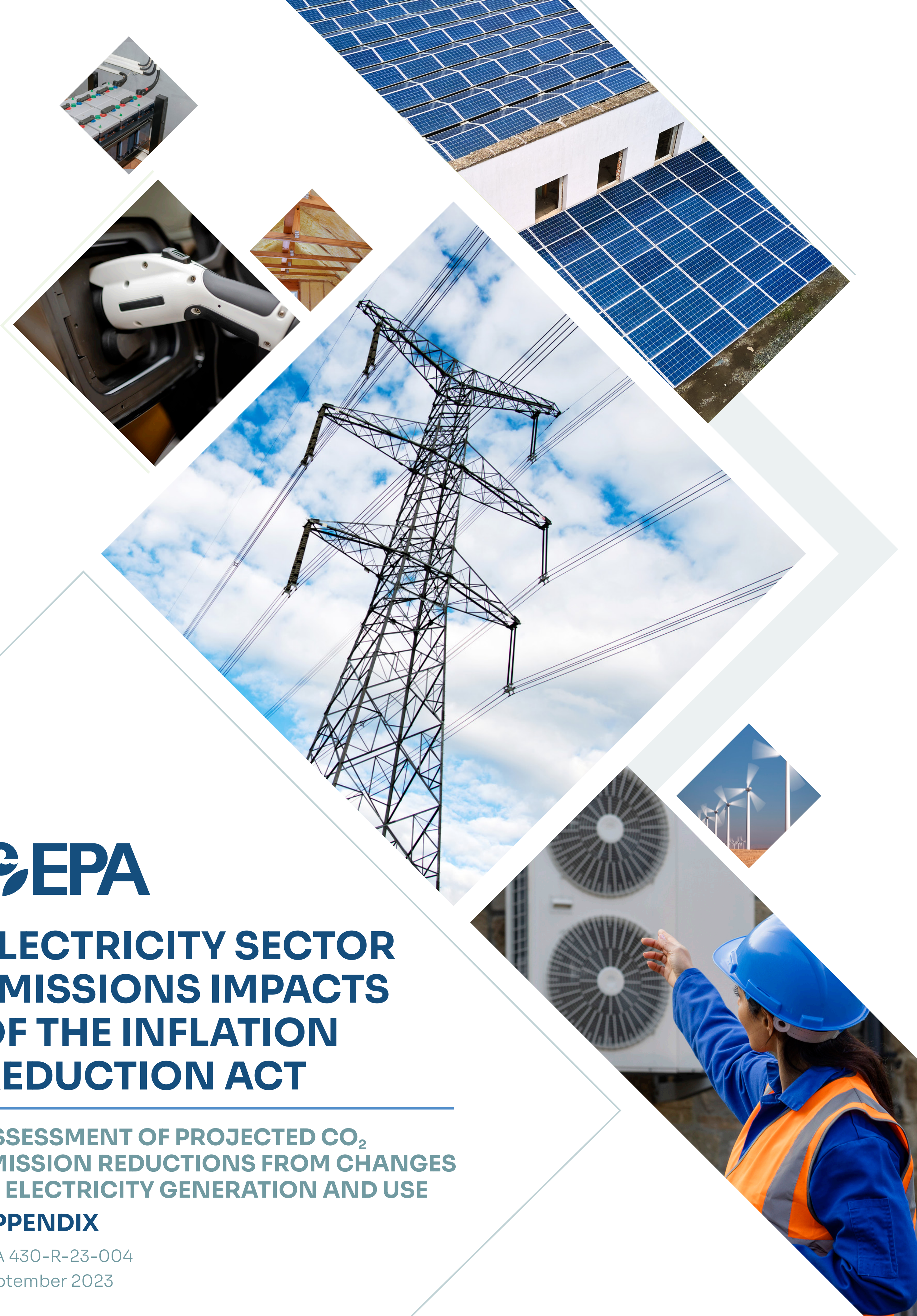

ELECTRICITY SECTOR EMISSIONS IMPACTS OF THE INFLATION REDUCTION ACT

ASSESSMENT OF PROJECTED CO_2 EMISSION REDUCTIONS FROM CHANGES IN ELECTRICITY GENERATION AND USE

APPENDIX

EPA 430-R-23-004
September 2023

This report – Electricity Sector Emissions Impacts of the Inflation Reduction Act - is responsive to the requirement in the Low Emissions Electricity Program under the Inflation Reduction Act section 60107(5), that the Environmental Protection Agency "assess … the reductions in greenhouse gas emissions that result from changes in domestic electricity generation and use that are anticipated to occur on an annual basis through fiscal year 2031."[1]

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[1] P.L. 117-169 (August 16, 2022), 136 STAT. 269, 42 U.S.C. 7435(a)(5), Clean Air Act section 135(a)(5).

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PEER REVIEW

This report was peer reviewed by six external and independent experts in a process independently coordinated by RTI International, Inc. EPA gratefully acknowledges the following peer reviewers for their useful comments and suggestions: Aaron Bergman, John Bistline, Eliot Crowe, Bri-Mathias Hodge, Jared Langevin, and Yuanrong Zhou. The information and views expressed in this report do not necessarily represent those of the peer reviewers, who also bear no responsibility for any remaining errors or omissions. Appendix H provides more information about the peer review.

RECOMMENDED CITATION

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DATA AVAILABILITY

Data from the analyses in this report can be accessed on the following website: https://www.epa.gov/inflation-reduction-act/electric-sector-emissions-impacts-inflation-reduction-act

Appendices

Appendix A: Summary Table of Annual Emissions and Reductions
Appendix B: Supplementary Model Description
Appendix C: IRA Implementation and Sensitivity Assumptions
Appendix D: Input Assumptions
Appendix E: Results by Model
Appendix F: Supplemental Results
Appendix G: Supplemental EPA Analyses
Appendix H: Peer Review Process

Appendix A: Summary Table of Annual Emissions and Reductions

Table A.1.1 Annual economy-wide CO_2 emissions (Mt CO_2/yr).

Year	No IRA			IRA		
	Min	Median	Max	Min	Median	Max
2024	4,471	4,688	4,866	4,354	4,660	4,837
2025	4,284	4,588	4,811	4,127	4,536	4,772
2026	4,262	4,529	4,743	4,001	4,391	4,556
2027	4,225	4,465	4,674	3,874	4,233	4,340
2028	4,181	4,392	4,606	3,747	4,090	4,204
2029	4,138	4,305	4,548	3,620	3,909	4,097
2030	4,094	4,250	4,516	3,494	3,712	4,008
2031	4,032	4,208	4,484	3,441	3,641	3,972
2032	3,971	4,178	4,453	3,321	3,583	3,959
2033	3,888	4,158	4,421	3,135	3,485	3,945
2034	3,799	4,133	4,390	2,949	3,376	3,921
2035	3,710	4,092	4,358	2,763	3,288	3,905

Table A.1.2 Difference between No IRA and IRA economy-wide CO_2 emissions.

Year	Absolute Difference (Mt CO2/yr)			% Difference		
	Min	Median	Max	Min	Median	Max
2024	−75.5	47.9	401.3	−1.6	1.0	8.4
2025	−100.7	67.2	535.0	−2.2	1.4	11.4
2026	26.7	152.7	624.1	0.6	3.4	13.4
2027	88.6	245.2	713.2	2.1	5.4	15.5
2028	123.2	327.3	802.3	2.9	7.3	17.5
2029	158.0	405.2	891.4	3.8	9.4	19.6
2030	192.6	478.6	980.4	4.6	11.4	21.7
2031	302.7	532.8	1,003.1	7.3	12.5	22.4
2032	394.3	550.6	1,025.6	9.1	13.1	23.0
2033	396.3	584.1	1,048.2	9.1	13.9	23.7
2034	411.6	664.4	1,070.7	9.5	16.0	24.4
2035	413.8	750.7	1,093.2	9.6	18.5	25.5

Table A.1.3 Difference in economy-wide CO_2 emissions from 2005 and 2021 for the No IRA scenario (% reduction).

	2005			2021		
Year	Min	Median	Max	Min	Median	Max
2024	20.6	23.5	27.1	3.3	6.8	11.1
2025	21.5	25.2	30.1	4.4	8.9	14.9
2026	22.7	26.1	30.5	5.8	10.0	15.3
2027	23.8	27.2	31.1	7.1	11.2	16.0
2028	24.9	28.4	31.8	8.5	12.7	16.9
2029	25.8	29.8	32.5	9.6	14.4	17.8
2030	26.4	30.7	33.2	10.3	15.6	18.7
2031	26.9	31.4	34.2	10.9	16.4	19.9
2032	27.4	31.9	35.2	11.5	17.0	21.1
2033	27.9	32.2	36.6	12.1	17.4	22.7
2034	28.4	32.6	38.0	12.8	17.9	24.5
2035	28.9	33.2	39.5	13.4	18.6	26.3

Table A.1.4 Difference in economy-wide CO_2 emissions from 2005 and 2021 for the IRA scenario (% reduction).

	2005			2021		
Year	Min	Median	Max	Min	Median	Max
2024	21.1	24.0	29.0	3.9	7.4	13.5
2025	22.2	26.0	32.7	5.2	9.8	18.0
2026	25.7	28.4	34.8	9.5	12.8	20.5
2027	29.2	31.0	36.8	13.8	15.9	23.0
2028	31.5	33.3	38.9	16.5	18.8	25.5
2029	33.2	36.3	41.0	18.6	22.3	28.1
2030	34.6	39.5	43.0	20.4	26.2	30.6
2031	35.2	40.7	43.9	21.1	27.6	31.6
2032	35.4	41.6	45.8	21.3	28.8	34.0
2033	35.7	43.1	48.9	21.6	30.8	37.7
2034	36.1	45.0	51.9	22.1	32.9	41.4
2035	36.3	46.4	54.9	22.4	34.7	45.1

Table A.2.1 Annual electric sector CO_2 emissions (Mt CO_2/yr).

Year	No IRA			IRA		
	Min	Median	Max	Min	Median	Max
2024	1,203	1,388	1,463	1,136	1,284	1,481
2025	1,091	1,332	1,438	1,001	1,192	1,460
2026	1,068	1,305	1,409	937	1,101	1,374
2027	1,046	1,260	1,383	857	1,027	1,339
2028	1,024	1,238	1,379	709	938	1,304
2029	1,002	1,217	1,379	561	857	1,268
2030	980	1,189	1,380	414	755	1,233
2031	940	1,173	1,390	396	708	1,136
2032	899	1,161	1,400	378	676	1,039
2033	857	1,156	1,410	359	623	943
2034	816	1,146	1,420	341	584	846
2035	775	1,133	1,430	323	544	784

Table A.2.2 Difference between No IRA and IRA electric sector CO_2 emissions.

Year	Absolute Difference (Mt CO2/yr)			% Difference		
	Min	Median	Max	Min	Median	Max
2024	−78.2	55.3	243.0	−6.5	4.2	17.6
2025	−104.2	93.1	324.1	−9.6	7.3	24.5
2026	−4.2	143.8	378.3	−0.4	11.0	28.8
2027	39.4	215.8	455.1	2.9	16.5	34.7
2028	75.3	274.6	578.3	5.5	24.0	44.9
2029	102.8	360.6	701.5	8.1	30.2	55.5
2030	125.4	405.8	824.7	10.6	34.1	66.6
2031	219.8	406.6	828.1	18.3	34.2	67.7
2032	272.1	421.5	831.5	25.3	34.8	68.8
2033	283.8	441.5	835.0	26.3	40.0	69.9
2034	295.6	514.4	838.4	27.4	45.6	71.1
2035	307.4	556.8	862.0	28.5	51.8	72.2

Table A.2.3 Difference in electric sector CO_2 emissions from 2005 and 2021 for the No IRA scenario (% reduction).

	2005			2021		
Year	Min	Median	Max	Min	Median	Max
2024	39.0	42.2	49.9	5.0	9.9	21.9
2025	40.1	44.5	54.6	6.7	13.6	29.2
2026	41.3	45.6	55.5	8.6	15.2	30.7
2027	42.4	47.5	56.4	10.3	18.2	32.1
2028	42.5	48.4	57.3	10.5	19.6	33.5
2029	42.5	49.3	58.3	10.5	21.0	35.0
2030	42.5	50.5	59.2	10.5	22.8	36.4
2031	42.1	51.1	60.8	9.8	23.9	39.0
2032	41.7	51.6	62.6	9.2	24.6	41.7
2033	41.3	51.9	64.3	8.5	25.0	44.4
2034	40.8	52.2	66.0	7.8	25.6	47.0
2035	40.4	52.8	67.7	7.2	26.5	49.7

Table A.2.4 Difference in electric sector CO_2 emissions from 2005 and 2021 for the IRA scenario (% reduction).

	2005			2021		
Year	Min	Median	Max	Min	Median	Max
2024	38.3	46.5	52.7	3.9	16.6	26.3
2025	39.1	50.3	58.3	5.2	22.6	35.0
2026	42.7	54.1	61.0	10.8	28.5	39.2
2027	44.2	57.2	64.3	13.1	33.4	44.4
2028	45.7	60.9	70.4	15.4	39.1	54.0
2029	47.2	64.3	76.6	17.7	44.4	63.6
2030	48.6	68.6	82.8	20.0	51.0	73.2
2031	52.7	70.5	83.5	26.3	54.0	74.3
2032	56.7	71.8	84.3	32.5	56.2	75.5
2033	60.7	74.0	85.0	38.8	59.5	76.7
2034	64.7	75.7	85.8	45.1	62.2	77.8
2035	67.3	77.3	86.5	49.1	64.7	79.0

Table A.3.1 Annual transportation CO_2 emissions (Mt CO_2/yr).

	No IRA			IRA		
Year	Min	Median	Max	Min	Median	Max
2024	1,637	1,724	1,819	1,611	1,723	1,812
2025	1,597	1,712	1,839	1,562	1,712	1,830
2026	1,570	1,688	1,804	1,529	1,680	1,780
2027	1,543	1,664	1,769	1,496	1,648	1,746
2028	1,516	1,638	1,743	1,463	1,612	1,715
2029	1,489	1,608	1,721	1,430	1,574	1,678
2030	1,462	1,578	1,701	1,397	1,539	1,657
2031	1,438	1,548	1,682	1,380	1,496	1,639
2032	1,413	1,518	1,664	1,343	1,449	1,625
2033	1,388	1,495	1,646	1,305	1,423	1,613
2034	1,364	1,468	1,623	1,267	1,398	1,602
2035	1,339	1,438	1,615	1,205	1,366	1,593

Table A.3.2 Difference between No IRA and IRA transportation CO_2 emissions.

	Absolute Difference (Mt CO2/yr)			% Difference		
Year	Min	Median	Max	Min	Median	Max
2024	-6.9	3.6	39.7	-0.4	0.2	2.4
2025	-9.2	3.2	53.0	-0.5	0.2	3.3
2026	-2.9	9.8	64.0	-0.2	0.6	4.0
2027	3.2	16.8	74.9	0.2	0.9	4.8
2028	7.2	21.5	85.8	0.5	1.2	5.5
2029	11.2	28.4	96.7	0.7	1.8	6.3
2030	15.0	35.5	107.8	0.9	2.4	7.2
2031	15.2	48.9	111.6	0.9	3.3	6.9
2032	15.0	62.5	144.0	0.9	4.2	9.1
2033	16.5	71.6	176.4	1.0	4.8	11.5
2034	19.4	73.1	208.8	1.2	5.0	14.0
2035	22.6	84.0	241.2	1.4	5.9	16.7

Table A.3.3 Difference in transportation CO_2 emissions from 2005 and 2021 for the No IRA scenario (% reduction).

Year	2005			2021		
	Min	Median	Max	Min	Median	Max
2024	2.4	7.5	12.1	−3.5	2.0	6.8
2025	1.3	8.1	14.3	−4.6	2.6	9.1
2026	3.2	9.4	15.7	−2.6	4.0	10.7
2027	5.1	10.7	17.2	−0.6	5.3	12.2
2028	6.5	12.1	18.6	0.8	6.8	13.7
2029	7.6	13.7	20.1	2.1	8.5	15.3
2030	8.7	15.3	21.5	3.2	10.2	16.8
2031	9.7	17.0	22.9	4.3	11.9	18.2
2032	10.7	18.6	24.2	5.3	13.7	19.6
2033	11.7	19.8	25.5	6.3	14.9	21.0
2034	12.9	21.2	26.8	7.6	16.4	22.4
2035	13.3	22.8	28.1	8.1	18.1	23.8

Table A.3.4 Difference in transportation CO_2 emissions from 2005 and 2021 for the IRA scenario (% reduction).

Year	2005			2021		
	Min	Median	Max	Min	Median	Max
2024	2.8	7.5	13.5	−3.1	2.0	8.3
2025	1.8	8.2	16.2	−4.1	2.6	11.1
2026	4.4	9.8	17.9	−1.3	4.4	13.0
2027	6.3	11.6	19.7	0.6	6.2	14.9
2028	7.9	13.5	21.5	2.4	8.3	16.8
2029	9.9	15.5	23.3	4.5	10.4	18.6
2030	11.1	17.4	25.0	5.7	12.4	20.5
2031	12.0	19.7	26.0	6.7	14.8	21.5
2032	12.8	22.2	27.9	7.5	17.5	23.6
2033	13.4	23.6	30.0	8.2	19.0	25.7
2034	14.0	25.0	32.0	8.8	20.5	27.9
2035	14.5	26.6	35.3	9.4	22.2	31.4

Table A.4.1 Annual buildings CO_2 emissions (Mt CO_2/yr).

Year	No IRA			IRA		
	Min	Median	Max	Min	Median	Max
2024	1,421	1,518	1,678	1,340	1,430	1,681
2025	1,349	1,467	1,692	1,241	1,362	1,696
2026	1,328	1,427	1,617	1,158	1,290	1,575
2027	1,291	1,393	1,542	1,075	1,233	1,454
2028	1,254	1,366	1,512	992	1,146	1,334
2029	1,217	1,342	1,495	910	1,073	1,213
2030	1,181	1,307	1,479	827	1,018	1,141
2031	1,165	1,297	1,469	795	985	1,112
2032	1,150	1,296	1,459	763	942	1,107
2033	1,135	1,282	1,449	730	888	1,101
2034	1,120	1,260	1,439	698	836	1,086
2035	1,105	1,238	1,429	666	769	1,077

Table A.4.2 Difference between No IRA and IRA buildings CO_2 emissions.

Year	Absolute Difference (Mt CO2/yr)			% Difference		
	Min	Median	Max	Min	Median	Max
2024	−53.3	19.9	231.9	−3.7	1.4	14.7
2025	−71.1	42.2	309.3	−5.2	3.0	19.8
2026	16.1	90.8	358.3	1.2	6.2	23.2
2027	59.9	151.6	407.3	4.6	10.6	26.7
2028	76.2	217.6	456.4	6.1	15.4	30.2
2029	92.5	270.8	505.4	7.6	20.1	33.8
2030	108.8	303.6	554.4	9.2	23.0	37.5
2031	160.4	313.6	578.7	13.8	24.0	39.4
2032	212.0	316.6	603.1	18.4	24.7	41.3
2033	263.6	349.9	627.4	19.6	28.1	43.3
2034	267.8	370.7	651.7	20.4	30.7	45.3
2035	243.4	389.4	676.1	20.1	33.3	47.3

Table A.4.3 Difference in buildings CO_2 emissions from 2005 and 2021 for the No IRA scenario (% reduction).

	2005			2021		
Year	Min	Median	Max	Min	Median	Max
2024	25.3	32.4	36.7	−2.5	7.2	13.2
2025	24.6	34.6	39.9	−3.3	10.4	17.6
2026	28.0	36.5	40.9	1.2	12.9	18.9
2027	31.3	38.0	42.5	5.8	14.9	21.1
2028	32.7	39.1	44.1	7.7	16.5	23.4
2029	33.4	40.2	45.8	8.7	18.0	25.6
2030	34.1	41.8	47.4	9.6	20.1	27.9
2031	34.6	42.2	48.1	10.2	20.8	28.8
2032	35.0	42.3	48.8	10.9	20.8	29.7
2033	35.5	42.9	49.4	11.5	21.7	30.7
2034	35.9	43.9	50.1	12.1	23.0	31.6
2035	36.3	44.8	50.8	12.7	24.4	32.5

Table A.4.4 Difference in buildings CO_2 emissions from 2005 and 2021 for the IRA scenario (% reduction).

	2005			2021		
Year	Min	Median	Max	Min	Median	Max
2024	25.1	36.3	40.3	−2.7	12.6	18.2
2025	24.5	39.3	44.7	−3.6	16.8	24.2
2026	29.8	42.5	48.4	3.8	21.2	29.3
2027	35.2	45.1	52.1	11.2	24.6	34.3
2028	40.6	49.0	55.8	18.5	30.0	39.4
2029	46.0	52.2	59.5	25.9	34.5	44.4
2030	49.2	54.7	63.2	30.3	37.8	49.5
2031	50.5	56.1	64.6	32.1	39.8	51.5
2032	50.7	58.0	66.0	32.4	42.5	53.4
2033	51.0	60.5	67.5	32.8	45.8	55.4
2034	51.6	62.8	68.9	33.7	49.0	57.3
2035	52.0	65.7	70.3	34.2	53.0	59.3

Table A.5.1 Annual industry CO_2 emissions (Mt CO_2/yr).

	No IRA			IRA		
Year	Min	Median	Max	Min	Median	Max
2024	1,125	1,233	1,407	1,098	1,167	1,347
2025	1,094	1,237	1,470	1,057	1,149	1,390
2026	1,089	1,229	1,475	1,041	1,117	1,368
2027	1,084	1,220	1,481	1,026	1,085	1,346
2028	1,080	1,211	1,487	1,004	1,056	1,324
2029	1,075	1,202	1,492	958	1,033	1,315
2030	1,069	1,194	1,498	911	1,014	1,315
2031	1,060	1,187	1,505	867	1,013	1,296
2032	1,050	1,181	1,512	822	1,016	1,278
2033	1,040	1,175	1,519	777	1,018	1,259
2034	1,030	1,168	1,526	733	1,018	1,241
2035	1,020	1,162	1,533	688	1,019	1,222

Table A.5.2 Difference between No IRA and IRA industry CO_2 emissions.

	Absolute Difference (Mt CO2/yr)			% Difference		
Year	Min	Median	Max	Min	Median	Max
2024	−21.3	18.3	127.3	−1.9	1.5	9.0
2025	−28.4	30.4	169.7	−2.6	2.4	11.5
2026	2.9	46.2	198.3	0.2	3.9	13.4
2027	7.6	62.3	227.0	0.6	5.6	15.3
2028	12.2	89.6	255.5	0.9	7.5	17.2
2029	16.8	113.8	284.1	1.3	9.6	19.0
2030	21.5	134.0	312.8	1.6	11.6	20.9
2031	46.3	146.2	321.9	3.4	12.6	21.4
2032	71.2	157.0	331.1	5.3	13.1	21.9
2033	96.0	176.6	340.3	7.1	13.9	25.3
2034	96.2	184.8	349.4	8.9	15.6	28.9
2035	95.8	191.4	358.6	9.2	16.9	32.6

Table A.5.3 Difference in industry CO_2 emissions from 2005 and 2021 for the No IRA scenario (% reduction).

	2005			2021		
Year	Min	Median	Max	Min	Median	Max
2024	11.3	22.3	29.1	−15.3	−1.0	7.8
2025	7.4	22.0	31.1	−20.4	−1.4	10.4
2026	7.0	22.5	31.4	−20.9	−0.7	10.8
2027	6.7	23.1	31.7	−21.3	0.1	11.2
2028	6.3	23.7	32.0	−21.8	0.8	11.5
2029	6.0	24.2	32.2	−22.3	1.5	11.9
2030	5.6	24.8	32.6	−22.7	2.2	12.4
2031	5.2	25.2	33.2	−23.3	2.8	13.2
2032	4.7	25.6	33.9	−23.9	3.2	14.0
2033	4.3	26.0	34.5	−24.5	3.8	14.8
2034	3.8	26.4	35.1	−25.0	4.2	15.6
2035	3.4	26.8	35.7	−25.6	4.8	16.4

Table A.5.4 Difference in industry CO_2 emissions from 2005 and 2021 for the IRA scenario (% reduction).

	2005			2021		
Year	Min	Median	Max	Min	Median	Max
2024	15.1	26.5	30.8	−10.4	4.3	10.1
2025	12.4	27.5	33.4	−13.8	5.8	13.4
2026	13.8	29.6	34.4	−12.0	8.5	14.7
2027	15.2	31.6	35.4	−10.2	11.2	16.0
2028	16.6	33.5	36.7	−8.4	13.4	17.7
2029	17.1	34.9	39.7	−7.7	15.4	21.5
2030	17.2	36.1	42.6	−7.7	17.0	25.4
2031	18.3	36.2	45.4	−6.2	17.0	29.0
2032	19.5	36.0	48.2	−4.7	16.8	32.7
2033	20.7	35.9	51.0	−3.2	16.6	36.3
2034	21.8	35.9	53.8	−1.6	16.6	40.0
2035	23.0	35.8	56.6	−0.1	16.5	43.6

Appendix B: Supplementary Model Description

Table B.1 Model representations of emerging technologies.

The following abbreviations are used in the table below: CCS, carbon capture and storage; H_2, hydrogen; T&S, transport and storage; O&M, operations and maintenance. Electric sector models are designated with * (others are energy system models).

Analysis Abbreviation	CCS Technologies	CO_2 Transport and Storage	H_2 Production	H_2 Transport and Storage	Carbon Dioxide Removal	Energy Storage Technologies
EPS-EI	▪ Power: Fossil fuel (not included in IRA analysis) ▪ Industrial: Fossil fuel use and processes ▪ Direct air capture (not included in IRA analysis)	Not explicitly modeled, but costs are included in CCS costs.	H_2 can be produced via five different production pathways, including steam methane reforming and electrolysis	None	DAC: One representative technology powered by electricity	Battery storage, existing pumped hydro
GCAM-CGS	▪ -Power: CCS for new coal, NGCC, and biomass with different capture assumptions ▪ -Industrial processes ▪ -Liquid fuel production	CO_2 T&S on a regional basis with costs for investments in pipeline and injection capacity, as well as ongoing O&M costs.	H_2 can be produced with electrolysis.	Exogenously specified H_2 transport costs.	BECCS: Power generation or liquid fuel production	Battery storage, concentrated solar power

Analysis Abbreviation	CCS Technologies	CO_2 Transport and Storage	H_2 Production	H_2 Transport and Storage	Carbon Dioxide Removal	Energy Storage Technologies
GCAM-PNNL	▪ Power: CCS for new coal, NGCC, and biomass with different capture assumptions ▪ Industrial processes ▪ Liquid fuel production	CO_2 T&S on a regional basis with costs for investments in pipeline and injection capacity, as well as ongoing O&M costs.	H_2 can be produced with fossil resources, biomass, or electrolysis. Fossil and biomass H_2 technologies can be used with CCS.	Endogenous representation of H_2 transport and storage with new dedicated infrastructure.	▪ DAC: Three representative technologies (high-temperature with heat provided by natural gas or electricity and low-temperature with electricity) ▪ BECCS: Power generation, liquid fuel production, or hydrogen production	Battery storage, concentrated solar power
MARKAL-NETL	▪ -Power: CCS for new coal, NGCC, and biomass; retrofits for coal and NGCC ▪ -Industrial processes ▪ -Hydrogen production ▪ -Direct air capture	Fixed cost of CO_2 transport, injection, and long-term monitoring. CO_2 storage reservoir capacity varies by region	H_2 can be produced with fossil resources, biomass, or electrolysis. Fossil and biomass H_2 technologies can be used with CCS. Local, midsize, and central production options.	Transport costs from central H_2 vary by settlement type. Liquid H_2 can be imported by truck or pipeline. Distributed production technologies combine production and refueling capabilities.	DAC: High temperature with heat from natural gas	Battery storage, H_2 storage, existing pumped hydro
NEMS-EIA	▪ Power: CCS for new and retrofit coal, NGCC, petroleum ▪ Industry: CCS for EOR	Transport and storage costs differentiated by region	None	None	None	Diurnal (battery) storage, pumped hydro

Analysis Abbreviation	CCS Technologies	CO_2 Transport and Storage	H_2 Production	H_2 Transport and Storage	Carbon Dioxide Removal	Energy Storage Technologies
NEMS-OP	▪ Power: CCS for new and retrofit coal, NGCC, biomass ▪ Industry: cement, iron and steel, refining (e.g., hydrogen, ethanol) ▪ Direct Air Capture	Transport and storage costs differentiated by region	Hydrogen produced via fossil resources, biomass, or electrolysis	Available but not used for this analysis	Direct air capture using electricity or natural gas	Diurnal (battery) storage, pumped hydro
NEMS-RHG	▪ Power: CCS for new coal and NGCC (Allam cycle); retrofits for coal and NGCC ▪ Industrial processes ▪ Hydrogen production ▪ Direct air capture	Regional CO_2 T&S costs	H_2 can be produced with fossil resources or electrolysis. Fossil can be retrofitted with CCS.	Representation of existing infrastructure.	DAC: Median cost estimate among DAC technology pathways	Battery storage, concentrated solar power, existing pumped hydro
REGEN-EPRI	▪ Power: CCS for new coal, NGCC, and biomass with different capture assumptions; retrofits for existing coal and NGCC ▪ Industrial processes ▪ Hydrogen production ▪ -Direct air capture	Regional CO_2 T&S with costs for investments in pipeline and injection capacity, as well as O&M costs. Investments in inter-regional CO_2 pipeline capacity can be made to access capacity in neighboring regions.	H_2 can be produced with fossil resources, biomass, or electrolysis. Fossil and biomass H_2 technologies can be used with CCS.	Endogenous representation of H_2 transport and storage with new dedicated infrastructure or blending gas commodities through existing natural gas infrastructure.	▪ DAC: Four representative technologies (high-temperature with heat provided by natural gas or electricity and low-temperature with gas and/or electricity) ▪ BECCS: Power generation or hydrogen production	Battery storage (endogenous duration), concentrated solar power, compressed air, H_2 storage, existing pumped hydro

Analysis Abbreviation	CCS Technologies	CO_2 Transport and Storage	H_2 Production	H_2 Transport and Storage	Carbon Dioxide Removal	Energy Storage Technologies
RIO-REPEAT	▪ Power: CCS for new NGCC and new biomass with different capture assumptions; retrofits for existing coal and NGCC; repowering existing gas and coal to NGCC with CCS ▪ -Industrial processes ▪ -Hydrogen production	Inter-zonal CO_2 T&S through the expansion of a CO_2 transport network, including pipeline capital and O&M costs, injection costs, and spur line costs to connect into the trunkline system.	H_2 can be produced from natural gas (steam methane reformation with or without CCS, autothermal reformation with CCS), biomass with CCS or electrolysis.	Endogenous representation of H_2 transport with dedicated infrastructure or limited blending in existing natural gas infrastructure. Endogenous hydrogen storage technologies.	▪ Direct air capture ▪ BECCS: Power generation, H_2 production, or H_2 production with renewable fuel production.	Battery storage (endogenous duration), thermal energy storage, H_2 storage, existing pumped hydro
USREP-ReEDS	Energy-intensive industries, oil and gas, electricity. For ReEDS, the Standard Scenario 2022 version was used (plant-specific upgrades are not available in this version).	Explicitly modeled for electricity (see ReEDS); Not explicitly modeled for other sectors.	None	None	DAC: One representative technology powered by electricity	ReEDS pump-storage hydro, batteries, and compressed air energy storage
Haiku-RFF*	▪ Power: CCS for new coal and NGCC	EPA CO_2 T&S costs (step function for each state). Total CO_2 storage and utilization options is scaled to 100 million short tons in 2030, doubling every five years thereafter.	None	None	None	Battery storage (4-hr duration), existing pumped hydro

Analysis Abbreviation	CCS Technologies	CO_2 Transport and Storage	H_2 Production	H_2 Transport and Storage	Carbon Dioxide Removal	Energy Storage Technologies
IPM-EPA*	▪ Power: CCS for new and existing coal, and new and existing NGCC with different capture assumption	▪ Power: Detailed modeling of different carbon sinks and the costs of building CO_2 pipelines from source to sink.	Not captured. Hydrogen is modeled exogenously and assumed to be available at $1/kg delivered price to the power sector.	Not captured. Hydrogen is modeled exogenously and assumed to be available at $1/kg delivered price to the power sector.	None	Battery storage of varying duration, pumped hydro.
IPM-NRDC*	▪ Power: CCS retrofits (90% and 99% capture) for coal and NGCC, CCS for new NGCC	Assumptions for CO_2 storage capacity/cost from based on GeoCAT (2021) in 37 of 48 states. CO_2 transport based on $228k/in-mi for pipelines.	None	None	None	Battery storage (4/8/10-hr duration), paired 4-hr battery with solar, existing pumped hydro and other storage
ReEDS-NREL*	▪ Power: CCS for new and retrofits for coal and NGCC ▪ New biomass with CCS, DAC, and H_2 production modeled but not considered in this analysis	Spatially explicit cost, investment, and operation for CO_2 T&S, including capital and O&M of pipeline, injection, and storage. Pipelines can be built between any ReEDS regions, as well as between a region and a storage reservoir.	Available in ReEDS but not considered in this analysis.	Available in ReEDS but not considered in this analysis.	Available in ReEDS but not considered in this analysis.	Battery storage, pumped hydro storage (existing and new/uprates), compressed air, concentrated solar power

Table B.2 Policy representation in No IRA scenario and calibration assumptions.

Analysis Abbreviation	Federal Policies	State/Local Policies	Other Calibration Assumptions
EPS-EI	Policies and regulations through August 2022, which includes key components of IIJA that have quantifiable emissions reductions	State-level renewable portfolio standards are aggregated and represented.	Calibrated to the 2022 AEO High Oil and Gas Supply scenario. GDP projections correspond closely to CBO. Technology costs were calibrated based on NREL ATB 2022.
GCAM-CGS	Corporate Average Fuel Economy Standards BIL EV charging infrastructure See tables 2-6 of The Beyond 50 Scenario: Technical Appendix	State-level renewable portfolio standards modeled. Local policies were aggregated at the state level or assumed to be embedded in federal or state policy.	GDP, population, primary energy prices, and hydro generation from EIA AEO 2022.
GCAM-PNNL	Corporate Average Fuel Economy Standards BIL EV charging infrastructure See tables 2-6 of The Beyond 50 Scenario: Technical Appendix	State-level renewable portfolio standards modeled. Local policies were aggregated at the state level or assumed to be embedded in federal or state policy.	GDP, population, primary energy prices, and hydro generation from EIA AEO 2023.
MARKAL-NETL	All policies enacted as of September 2022, with exception to IRA and BIL	State-level renewable portfolio standards modeled. Local policies were aggregated from the state levels to the Census regions levels.	EIA AEO 2021 for energy demand.
NEMS-EIA	All policies and regulations enacted as of September, 2022.	State-level renewable portfolio standards and clean energy standards State and regional GHG programs State LDV GHG standards and LDV, MDV, and HDV ZEV mandates State low-carbon fuel standards	Macro outlook from S&P Global IHS Markit from September 2022.
NEMS-OP	All policies and regulations represented in AEO 2022 and including EPA LDV standards for MY23-26, exclusive of BIL/IIJA.	State-level renewable portfolio standards and clean energy standards State and regional GHG programs State LDV GHG standards and LDV, MDV, and HDV ZEV mandates State low-carbon fuel standards	Electric sector technology costs based on NREL ATB 2022. EV costs based on Argonne National Laboratory estimates.

Analysis Abbreviation	Federal Policies	State/Local Policies	Other Calibration Assumptions
NEMS-RHG	All policies enacted as of June 2022, inclusive of IIJA, EPA LDV standards for MY23-26, and Good Neighbor program.	State-level renewable portfolio standards and clean energy standards as of June 2022 State and regional GHG programs State LDV GHG standards and LDV, MDV, and HDV ZEV mandates State low-carbon fuel standards	GDP aligned with EIA AEO 2022 Low Economic Growth case. Oil and gas resource availability aligned with EIA AEO 2022 Reference case. NREL ATB 2022 moderate costs for most low- and zero-emitting generation costs; RHG analysis for CCS costs. Conventional fossil generator costs aligned with EIA AEO 2022 Reference case.
REGEN-EPRI	Policies and regulations through September 2022, including BIL/IIJA.	State and regional portfolio standards, technology mandates, and carbon pricing (electric sector and economy-wide).	EIA AEO 2021 for service demand growth and fuel prices. EPRI data for technology cost and performance.
RIO-REPEAT	Policies and regulations as of January 2021 including: ▪ EPA final rule on HFCs ▪ Bipartisan Infrastructure Law	Policies and regulations as of January 2021	EIA AEO 2021 NREL ATB 2021
USREP-ReEDS	ReEDS: All policies enacted as of September 2022, with exception to IRA and BIL. USREP: CAFE and GHG Emissions standards for light-duty vehicles as reflected in AEO 2023	State-level renewable portfolio standards modeled.	GDP and emissions projections calibrated to EIA AEO 2023
Haiku-RFF*	Policies in AEO 2021 that affect electricity demand are implicit in parameters	State RPS's are aggregated to regional levels	EIA AEO 2021 for NG and coal fuel prices, electricity demand, Initial calibration to AEO2021 for state level generation, national generation for NG and coal NREL ATB 2022 for Solar, Wind, and CCS capital costs

Analysis Abbreviation	Federal Policies	State/Local Policies	Other Calibration Assumptions
IPM-EPA*	All policies enacted as of Summer 2022. Includes proposed Good Neighbor Program.	State-level renewable portfolio standards and clean energy standards modeled as of summer 2022. State and regional GHG programs including Colorado (HB21-1266), Massachusetts (Massachusetts Senate Bill 9), North Carolina (North Carolina House Bill 951), Oregon (Oregon House Bill 2021), and Washington (Washington state SB5126)	Electricity demand data from EIA AEO 2021 augment with incremental electricity demand from EV's as a result of EPA's Final Rule to Revise Existing National GHG Emissions Standards for Passenger Cars and Light Trucks Through Model Year 2026 (not reflected in AEO 2021).
IPM-NRDC*	All policies enacted as of November 2021including BIL/IIJA.	State RPS/CES is explicitly modeled reflecting state CES/RPS as of April 2022. ZEV mandates are included through AEO 2022 electricity demand projections.	EIA AEO for electricity demand and conventional technology costs. NREL ATB 2021 for renewables and storage costs. Firm builds and retirements based multiple sources. Tends to have more retirements than NEEDS database.
ReEDS-NREL*	All policies enacted as of September 2022, except for IRA and BIL.	All policies enacted as of September 2022, with exception to IRA and BIL.	EIA AEO 2022

Appendix C: IRA Implementation and Sensitivity Assumptions

Table C.1 IRA provision implementation for GCAM-PNNL, USREP-ReEDS[1], and IPM-EPA.[2]

Section	Program	GCAM-PNNL	USREP-ReEDS	IPM-EPA
Electricity				
13101	Production tax credit (PTC) for electricity from renewables (45)	Modeled as a $26/MWh subsidy for solar, wind and geothermal technologies through 2024. Assume that all projects pay prevailing wages. A 7.5% reduction in the credit value is assumed due to the transferability provision.	Assume PWA requirements are met. Apply $27.5/MWh to onshore wind, utility-scale PV, and biopower. Vary reduction in the credit due transferability and addition in credit for energy community and domestic content credit among scenarios.	Assume PWA requirements are met. Apply $27.5/MWh to onshore wind, utility-scale PV, and biopower. 10% bonus energy communities' credit is provided to all storage technologies and prorated based on share of the total IPM regional land area that qualifies as an energy community for solar and wind units.
13102	Investment tax credit (ITC) for energy property (48)	Modeled as a 30% subsidy for offshore wind and storage technologies through 2024, with the simplifying assumption that all projects pay prevailing wages. A 7.5% reduction in the credit value is assumed due to the transferability provision.	Assume PWA requirements are met. Apply 30% credit to offshore wind, CSP, geothermal, hydropower, nuclear, pumped storage, battery storage, and distributed PV. Vary reduction in the credit due transferability and addition in credit for energy community and domestic content credit among scenarios.	Assume PWA requirements are met. Apply 30% credit to offshore wind, CSP, geothermal, hydropower, nuclear, pumped storage, battery storage, and distributed PV. 10% bonus energy communities' credit is provided to all storage technologies and prorated based on share of the total IPM regional land area that qualifies as an energy community for solar and wind units.

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[1] For additional detail, see the USREP-ReEDS documentation for this work, entitled Economic and Environmental Impacts of the Inflation Reduction Act: USREP-ReEDS Modeling Framework. https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=358898&Lab=OAP

[2] Details on the IRA scenario may be found here: https://www.epa.gov/power-sector-modeling/post-ira-2022-reference-case. For the No IRA scenario see: https://www.epa.gov/power-sector-modeling/pre-ira-2022-reference-case.

Section	Program	GCAM-PNNL	USREP-ReEDS	IPM-EPA
13103	Solar and wind facilities placed in low-Income communities (45(e), 45E(h))		0.9 GW per year (50% of the maximum total annual capacity allowed to receive the low-income community bonus) of distributed PV added to the dGen projections through 2032.	
13105	Zero-emission nuclear power PTC (45U)	Modeled as a $15/MWh subsidy for nuclear technologies through 2030, with the simplifying assumption that all projects pay prevailing wages. Assume in combination with non-federal incentives and zero-emission credits, this provision prevents the economic retirement of nuclear plants. As such, model Georgia Vogtle units 3&4 coming online by 2025 and maintain nuclear capacity at today's levels.	Assume PWA requirements are met. Apply $27.5/MWh to nuclear power production	No endogenous nuclear retirements are allowed over the forecast period.
13701	New clean electricity PTC (45Y)	Same as 13101 through 2030, with phasedown after 2030.	Same as 13101	Same as 13101
13702	New clean electricity ITC (48E)	Same as 13102 through 2030, with phasedown after 2030.	Same as 13102	Same as 13102
13703	Cost recovery for qualified property (168(e)(3)(B))		Captured in ReEDS with the financing calculations according to Ho et al.[3]	
22004	USDA assistance for rural electric cooperatives		Not included.	
50151	Transmission facility financing		Not included.	

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[3] Ho, J., Becker, J., Brown, M., Brown, P., Chernyakhovskiy, I., Cohen, S., … Zhou, E. (2021). *Regional Energy Deployment System (ReEDS) Model Documentation: Version 2020* (NREL/TP-6A20-78195). NREL. https://www.nrel.gov/docs/fy21osti/78195.pdf

Section	Program	GCAM-PNNL	USREP-ReEDS	IPM-EPA
Multi-Sector				
13104	Credit for carbon oxide sequestration (45Q)	**Electricity sector:** Extension of existing credits for captured CO_2 at \$85/metric ton is implemented through 2030. Assume this subsidy will result in sequestration levels consistent with analyses by Rhodium Group and Edmonds et al.[4,5] Modeled this exogenously by specifying sequestration across various industrial sectors, resulting in 130 $MTCO_2$ and 140 $MTCO_2$ annual sequestration. **Industrial Sector:** Same as power sector with exogenously by specifications for sequestration across various industrial sectors, resulting in 93 $MtCO_2$ and 89 $MtCO_2$ annual sequestration.	Assume PWA requirements are met. Apply \$85/metric ton credit to industrial and power applications. Assume -7.5% credit for cost of monetization in the power sector. Industrial CCS cost assumptions based on National Energy Laboratory's (NETL) report on the cost of CCS by industry. Apply \$180/metric ton credit for DAC.	Assume PWA requirements are met. Apply \$85/metric ton credit to industrial and power applications. Power sector CCS cost assumptions based on Sargent and Lundy analysis in support of EPA's IPM 2022 post-IRA Reference Case.
13204	Clean hydrogen PTC (45V)	Modeled as different subsidies to hydrogen technologies depending on their carbon intensities. Assume that fossil hydrogen without CCS doesn't qualify and fossil hydrogen with CCS claims 45Q instead, and that 50% of projects pay prevailing wages.	Not applicable.	Hydrogen is available at a delivered cost of \$1/kg within the power sector consistent with DOE Hydrogen Shot goal.

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[4] Larsen, J., King, B., Hiltbrand, G., & Herndon, W. (2021). *Capturing the moment: Carbon capture in the American Jobs Plan.* Rhodium Group. https://rhg.com/research/carbon-capture-american-jobs-plan/

[5] Edmonds, J., Nichols, C., Adamantiades, M., Bistline, J., Huster, J., Iyer, G., Johnson, N., Patel, P., Showalter, S., Victor, N., Waldhoff, S., Wise, M., & Wood, F. (2020). Could congressionally mandated incentives lead to deployment of large-scale CO_2 capture, facilities for enhanced oil recovery CO_2 markets and geologic CO_2 storage? *Energy Policy, 146.* https://doi.org/10.1016/j.enpol.2020.111775

Section	Program	GCAM-PNNL	USREP-ReEDS	IPM-EPA
22001	Electric loans for renewable energy		Loans are treated as an interest rate reduction be calculating the cumulative value of interest to be paid on capital expenditures for solar and wind capacity, deducting the value of loans, and calculating the implied (lower) interest rate.	
50141	Funding for DOE Loan Programs Office		Loans are treated as an interest rate reduction be calculating the cumulative value of interest to be paid on capital expenditures for solar and wind capacity, deducting the value of loans, and calculating the implied (lower) interest rate. About 80% of DOE LPO funding to-date has been spent on electricity-related technologies.	
50144	Energy infrastructure reinvestment financing	Modeled as $250 billion in loans and guarantees used to accelerate the retirement of coal-fired power generation and fund the construction of renewable electricity-generating capacity. Estimate this to accelerate the retirement of 38 GW of additional coal-fired capacity beyond already-scheduled retirements by 2030.	Loans are treated as an interest rate reduction by calculating the cumulative value of interest to be paid on capital expenditures for solar and wind capacity, deducting the value of loans, and calculating the implied (lower) interest rate.	
50145	Tribal energy loan guarantee program		Loans are treated as an interest rate reduction by calculating the cumulative value of interest to be paid on capital expenditures for solar and wind capacity, deducting the value of loans, and calculating the implied (lower) interest rate.	

Section	Program	GCAM-PNNL	USREP-ReEDS	IPM-EPA
Transportation				
13201	Biodiesel and renewable fuels PTC (40A, others)	Implemented as subsidies for biodiesel, cellulosic ethanol, FT biofuels, cellulosic ethanol with CCS, and FT biofuels with CCS. Assume that jet fuel is the first market for FT biofuel, and FT biofuels therefore receive the aviation fuel credit.	Not applicable.	
13202	Second-generation biofuels PTC (40)	See 13201	Not applicable.	
13203	Sustainable aviation fuel PTC (40B)	See 13201	Not applicable.	
13401	Clean vehicle credit (30D)	This tax credit has a maximum value of $7,500 with an EV being eligible for half of the credit if its battery meets domestic assembly requirements and other half of the credit is contingent upon a specific share of the minerals used in the battery being sourced for North American or other free trade countries. Assume that the U.S. auto manufacturing sector will reorient itself so that all new EVs produced by 2030 will meet domestic assembly and mineral requirements, and that by 2025, half of EVs sold will meet these requirements. Assume 89% of Americans meet the income eligibility requirement. Altogether, this yields an EV tax credit with an effective value of $6,673, implemented as a capital cost reduction. Assume that for the 2031-2035 model period that the tax credit takes on a value 40% of the 2030 value because it is scheduled to expire in 2032.	Assume $5625 to reflect moderate assumption on vehicles meeting critical battery and mineral component requirements.	

Section	Program	GCAM–PNNL	USREP-ReEDS	IPM-EPA
13402	Credit for previously owned clean vehicles (25E)		Not applicable	
13403	Qualified commercial clean vehicle credit (45W)	This tax credit is modeled as a $40,000 capital cost reduction for electric heavy-duty freight trucks, and a $7,500 capital cost reduction for electric medium-duty and light-duty freight trucks. Assume that for the 2031-2035 model period that the tax credit takes on a value 40% of the 2030 value because it is scheduled to expire in 2032.	Apply $40,000 as a reduction in costs for all heavy-duty EVs. Apply as a percent reduction in cost based on a weighted average cost of heavy-duty vehicles from NREL ATB transportation data.	
13404	Alternative fuel vehicle refueling property credit (30C)	This credit is assumed to be a $1,000 property credit available for light duty vehicle charging infrastructure for individuals in rural and low-income census tracts. Based on census data, 17.4% of Americans live in counties that are either rural or low-income, so the $1,000 property credit is modeled as a weighted average national subsidy of $174 for capital infrastructure cost for EVs. Assume that for the 2031-2035 model period that the tax credit takes on a value 40% of the 2030 value because it is scheduled to expire in 2032.	Not included.	
13704	New clean fuel PTC (45Z)	See 13201	Not applicable.	

Section	Program	GCAM-PNNL	USREP-ReEDS	IPM-EPA
60101	Clean heavy-duty vehicles		$1B grant over 10 years (2022-2031) assigned to the purchase of new zero-emission buses. Apportioned spending and infrastructure costs based on proportion used to support USPS fleet (section 70002), so $433M for vehicle purchases and $567M for charging infrastructure.	
70002	U.S. Postal Service clean fleets		$1.3B grant allocated for the purchase of new zero-emission USPS vehicles and $1.7B for fleet infrastructure and charging. Used ATB vehicle cost data and USPS VMT data to determine number of vehicles purchased and gas saved through replacement with EVs. Then calculated the decline in oil demand and increase in electricity demand and introduce as an exogenous shift to the model.	
Buildings				
13301	Energy efficient home improvement PTC (25C)	Modeled by improving shell efficiency in residential buildings based on the AEO 2022 "Alternative Policies – Extended Credit" case.[6]	Apportion CBO estimated outlays for this program ($12.5B) to residential electrification, weatherization, and energy efficiency programs (with applicability and leverage assumptions) and apply exogenous shift in energy demand to the model. Assume 80% applicability, 3.3 private: public leverage.	

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[6] U.S. Energy Information Administration (2022). *Annual energy outlook 2022*. https://www.eia.gov/outlooks/aeo/tables_ref.php

Section	Program	GCAM-PNNL	USREP-ReEDS	IPM-EPA
13302	Residential clean energy PTC (25D)	Modeled by updating the rooftop ITC, which results in an additional 0.7GW/yr increase in electricity generation from rooftop PV on the lifetime of the credit through 2035.	Apportion CBO estimated outlays for this program ($22.0B) to residential electrification, weatherization, and energy efficiency programs (with applicability and leverage assumptions) and apply exogenous shift in energy demand to the model. Assume 80% applicability, 3.3 private: public leverage.	
13303	Energy efficient commercial buildings deduction (179D)	This provision is estimated to reduce commercial HVAC costs by 3%. Modeled this provision as a 3% subsidy for commercial high-efficiency heating and cooling technologies in 2025 and 2030.	Apportion CBO estimated outlays for this program ($362M) to commercial energy efficiency programs (with applicability and leverage assumptions) and apply exogenous shift in energy demand to the model. Assume 80% applicability, 3.3 private: public leverage.	
13304	New energy efficient homes credit (45L)	Same as 13301	Apportion CBO estimated outlays for this program ($2B) to residential electrification, weatherization, and energy efficiency programs (with applicability and leverage assumptions) and apply exogenous shift in energy demand to the model. Assume 80% applicability, 1.0 private: public leverage.	

Section	Program	GCAM-PNNL	USREP-ReEDS	IPM-EPA
30002	Green and resilient (HUD) retrofit program		Apportion CBO Budget Authority for this program ($990M) to residential electrification, weatherization, and energy efficiency programs (with applicability and leverage assumptions) and apply exogenous shift in energy demand to the model. Assume 50% applicability, 4.0 private: public leverage.	
50121	Home energy performance-based, whole-house rebates	Same as 13301	Apportion CBO Budget Authority for this program ($4.3B) to residential electrification, weatherization, and energy efficiency programs (with applicability and leverage assumptions) and apply exogenous shift in energy demand to the model. Assume 80% applicability, 1.6 private: public leverage.	
50122	High-efficiency electric home rebate program	Modeled as a subsidy to high-efficiency technologies in residential buildings in 2025 and 2030. We assume that two-thirds of consumers are eligible for this credit, so we implemented this as a weighted average across all consumers with the effective value of the credit modeled to be 66% of each of the following: $1,750 to electric heat pump water heaters, $4,000 to electric heat pumps for space heating, $420 to electric ovens, $420 to electric heat pump clothes dryers, $1,600 for high-efficiency air conditioning.	Apportion CBO Budget Authority for this program ($4.5B) to residential electrification, weatherization, and energy efficiency programs (with applicability and leverage assumptions) and apply exogenous shift in energy demand to the model. Assume 80% applicability, 1.4 private: public leverage	

Section	Program	GCAM-PNNL	USREP-ReEDS	IPM-EPA
60502	Assistance for federal buildings		Apportion CBO Budget Authority for this program ($3B) to government energy efficiency programs (with applicability and leverage assumptions) and apply exogenous shift in energy demand to the model. Assume 50% applicability, 1.0 private: public leverage	
Industry				
13501	Advanced energy project credit (48C)		Used data from Berkley National Laboratory to determine the cost of saved electricity in industrial sectors. Applied an applicability haircut and private leverage ratio to CBO Budget Authority ($10B) and applied an exogenous shift in electricity demand to the model.	
13502	Advanced manufacturing production credit (45X)		Calculated the implied cost savings for wind and solar capacity based on component-level tax credits and new capacity cost shares from NREL's JEDI model. The discounts are applied to the overnight capital cost of these technologies in ReEDS. For batteries, we calculated the value of the $10/kW credit as a share of total vehicle cost based on NREL ATB transportation data.	
50161	Advanced industrial facilities deployment program		Used data from Berkley National Laboratory to determine the cost of saved electricity in industrial sectors, take an applicability haircut and private leverage to CBO Budget Authority ($5.8B), and applied an exogenous shift in electricity demand to the model.	

Section	Program	GCAM–PNNL	USREP-ReEDS	IPM-EPA
60113	Methane emissions reduction program	This provision has a waste emissions charge of \$1,500/tCH_4 (\$60/tCO_2e) on fugitive methane, which was modeled to reduce 2.92 MtCH_4 (73 MTCO_2e) in the oil and gas sector, using the EPA's MAC curves for methane.[7] Because this waste emissions charge only applies to sources covered under the EPA's GHG Reporting Program and that exceed statutorily-specified waste emissions thresholds, we assume that only 39% of the emissions reductions are achieved,[8] resulting in a reduction of 1.14 MtCH_4 (28 MtCO_2e) by 2030.	Not included.	
Multiple	Vehicle manufacturing loans/grants			
Multiple	Low-carbon materials			
Multiple	Agriculture and forestry provisions	Allocate \$8.5 billion to Environmental Quality Incentives Program, in which distribution of funds is prioritized for reducing enteric methane emissions from ruminants. This was modeled as a 0.63 MtCH_4 (16 MtCO_2e) reduction in livestock methane emissions in 2030.		
Multiple	Oil and gas lease sales			

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[7] United States Environmental Protection Agency (2022). U.S. State-level Non-CO_2 Greenhouse Gas Mitigation Potential: 2025-2050. United States Environmental Protection Agency. Retrieved from https://www.epa.gov/global-mitigation-non-co2-greenhouse-gases/us-state-level-non-co2-ghg-mitigation-report

[8] Jenkins, Jesse D.; Farbes, Jamil; Jones, Ryan; and Mayfield, Erin N. (2022), *REPEAT Project Section-by-Section Summary of Energy and Climate Policies in the 117th Congress*, REPEAT Project, http://bit.ly/REPEAT-Policies. doi: 10.5281/zenodo.6993118

Section	Program	GCAM-PNNL	USREP-ReEDS	IPM-EPA
Other				
60103	Greenhouse gas reduction fund		Apportion CBO Budget Authority for this program ($27B) to residential electrification, weatherization, and energy efficiency programs (with applicability and leverage assumptions) and apply exogenous shift in energy demand to the model. Assume 80% applicability, 3.0 private: public leverage	
60114	Climate pollution reduction grants		Apportion CBO Budget Authority for this program ($5B) to residential electrification, weatherization, and energy efficiency programs (with applicability and leverage assumptions) and apply exogenous shift in energy demand to the model. Assume 80% applicability, 1.0 private: public leverage	
60201	Environmental and climate justice block grants		Apportion CBO Budget Authority for this program ($3250M) to government electrification, weatherization, and energy efficiency programs (with applicability and leverage assumptions) and apply exogenous shift in energy demand to the model. Assume 50% applicability, 2.0 private: public leverage.	

Table C.2 USREP-ReEDS IRA sensitivity assumptions.

Section	Description	Scenarios {Pessimistic, Moderate, Optimistic}
Electricity		
13101	Production tax credit (PTC) for electricity from renewables (45)	{-12.5, -10.0, -7.5} % for monetization {5, 10, 15} % for bonus credits
13102	Investment tax credit (ITC) for energy property (48)	{-12.5, -10.0, -7.5} % for monetization {5, 10, 15} % for bonus credits
13103	Solar and wind facilities placed in low-Income communities (45(e), 45E(h))	
13105	Zero-emission nuclear power PTC (45U)	
13701	New clean electricity PTC (45Y)	{-12.5, -10.0, -7.5} % for monetization {5, 10, 15} % for bonus credits
13702	New clean electricity ITC (48E)	{-12.5, -10.0, -7.5} % for monetization {5, 10, 15} % for bonus credits
13703	Cost recovery for qualified property (168(e)(3)(B))	
22004	USDA Assistance for Rural Electric Cooperatives	Not Modeled
50151	Transmission facility financing	Not Modeled
Multi-Sector		
13104	Credit for carbon oxide sequestration (45Q)	{-12.5, -10.0, -7.5} % for monetization in power sector
13204	Clean hydrogen PTC (45V)	Not Modeled
22001	Electric loans for renewable energy	
50141	Funding for DOE Loan Programs Office	
50144	Energy infrastructure reinvestment financing	
50145	Tribal energy loan guarantee program	
Transportation		
13201	Biodiesel and renewable fuels PTC (40A, others)	Not Modeled
13202	Second-generation biofuels PTC (40)	Not Modeled
13203	Sustainable aviation fuel PTC (40B)	Not Modeled
13401	Clean vehicle credit (30D)	{$3750, $5625, $7500}
13402	Credit for previously owned clean vehicles (25E)	Not Modeled
13403	Qualified commercial clean vehicle credit (45W)	
13404	Alternative fuel vehicle refueling property credit (30C)	Not Modeled

Section	Description	Scenarios {Pessimistic, Moderate, Optimistic}
13704	New clean fuel PTC (45Z)	Not Modeled
60101	Clean heavy-duty vehicles	
70002	U.S. Postal Service clean fleets	
Buildings		
13301	Energy efficient home improvement PTC (25C)	{-20, 0, 20} % federal spending
13302	Residential clean energy PTC (25D)	{-20, 0, 20} % federal spending
13303	Energy efficient commercial buildings deduction (179D)	{-20, 0, 20} % federal spending
13304	New energy efficient homes credit (45L)	{-20, 0, 20} % federal spending
30002	Green and resilient (HUD) retrofit program	{-20, 0, 20} % applicability
50121	Home energy performance-based, whole-house rebates	{-20, 0, 20} % leverage
50122	High-efficiency electric home rebate program	{-20, 0, 20} % leverage
60502	Assistance for federal buildings	{-20, 0, 20} % applicability
Industry		
13501	Advanced energy project credit (48C)	{10, 25, 40} % applicability
13502	Advanced manufacturing production credit (45X)	{-1.32, -3.06, -4.80} % solar capital cost credit {-3.56, -4.42, -5.27} % wind capital cost credit Wind and solar vary by domestic production assumptions. No variation for electric vehicles or offshore wind.
50161	Advanced industrial facilities deployment program	{25, 50, 75} % applicability
60113	Methane emissions reduction program	Not Modeled
Multiple	Vehicle manufacturing loans/grants	Not Modeled
Multiple	Low-carbon materials	Not Modeled
Multiple	Agriculture and forestry provisions	Not Modeled
Multiple	Oil and gas lease sales	Not Modeled
Other		
60103	Greenhouse gas reduction fund	{-20, 0, 20} % leverage {-20, 0, 20} % applicability
60114	Climate pollution reduction grants	{-20, 0, 20} % leverage
60201	Environmental and climate justice block grants	{-20, 0, 20} % leverage {-20, 0, 20} % applicability

Table C.3 IRA sensitivities for Bistline et al. (2023).

Pessimistic and Optimistic IRA sensitivities are intended to illustrate how alternate assumptions about IRA implementation and related assumptions can alter the emissions and energy system impacts of IRA. Guidance for these harmonized scenarios is flexible, given the variation across models in their scope, representation of IRA provisions, and specifications for central estimates.[9] In these scenarios, "Low" refers to the scenario with lower IRA impacts.

Assumption	Description	Pessimistic (Low in Bistline)	Optimistic (High in Bistline)
Transferability Penalty for Tax Credits (PTC/ITC/45Q/45V)	% loss in credit value	2x central	0.5x central
Energy Communities Bonus Eligibility for PTC/ITC	%	max(-20% from central, 0% of credit)	min(+20% from central, 100% of credit)
Domestic Content Bonus Eligibility for PTC/ITC	%	max(-20% from central, 0% of credit)	min(+20% from central, 100% of credit)
1706 Coverage Multiplier	%	-25% from central	+25% from central
Build Rates for Renewables	Upper bound on CAGR	-7% from central	Unconstrained
Build Rates for Transmission	Upper bound on CAGR	1%	Unconstrained
CCS Availability[10]		None through 2030	Unconstrained
EVs Eligible for Qualifying Bonus Credits	% new sales	-25% from central	+25% from central
Demand-Side Incentive Haircuts for Program Uptake[11]	% loss in credit value	+20% from central	-10% from central

Note:
All other external uncertainties (e.g., fuel prices, service demand, technological costs) are held fixed across these IRA sensitivities.
Low and high values are specified in relative terms from the central scenario since modeling teams may assume different parameter values in their central cases.

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[9] We aimed to make these specifications directionally consistent with scenarios from teams that have already conducted these sensitivities so that they do not need to re-run these scenarios.

[10] Note that a central case likely has constraints on CCS deployment before 2030 due to project lead times and potentially growth rates associated with CO_2 transport and storage, though there is likely variation across models.

[11] Combination of program overhead, participation given the pool of eligible participants, and other factors. Note that models with exogenous electricity demand can either choose not to adjust these dimensions across low and high sensitivities or to use outputs from another model to inform electricity demand projections.

Appendix D: Input Assumptions

Appendix D presents input assumptions for natural gas price and capital costs for electricity generation by model.

Figure D.1 Natural gas price assumptions.

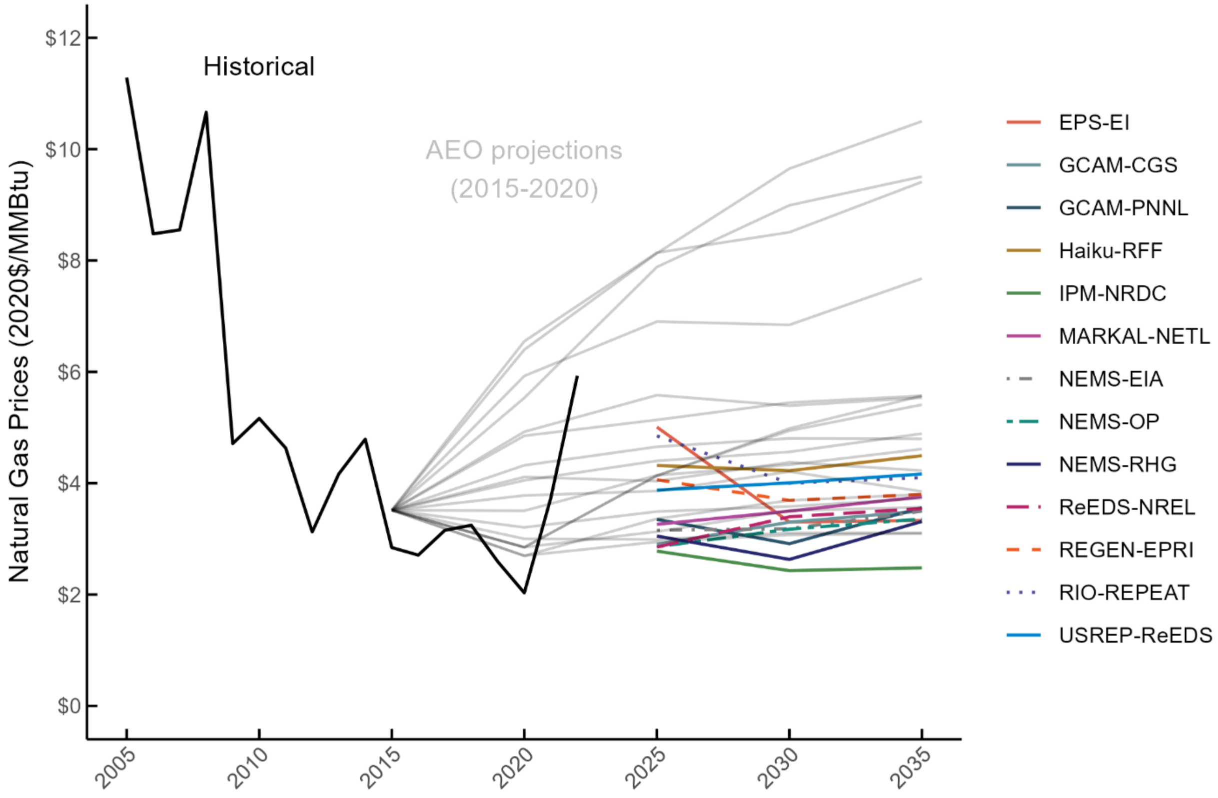


Figure D.2 Capital costs for battery storage, NGCC, solar PV, and onshore wind.

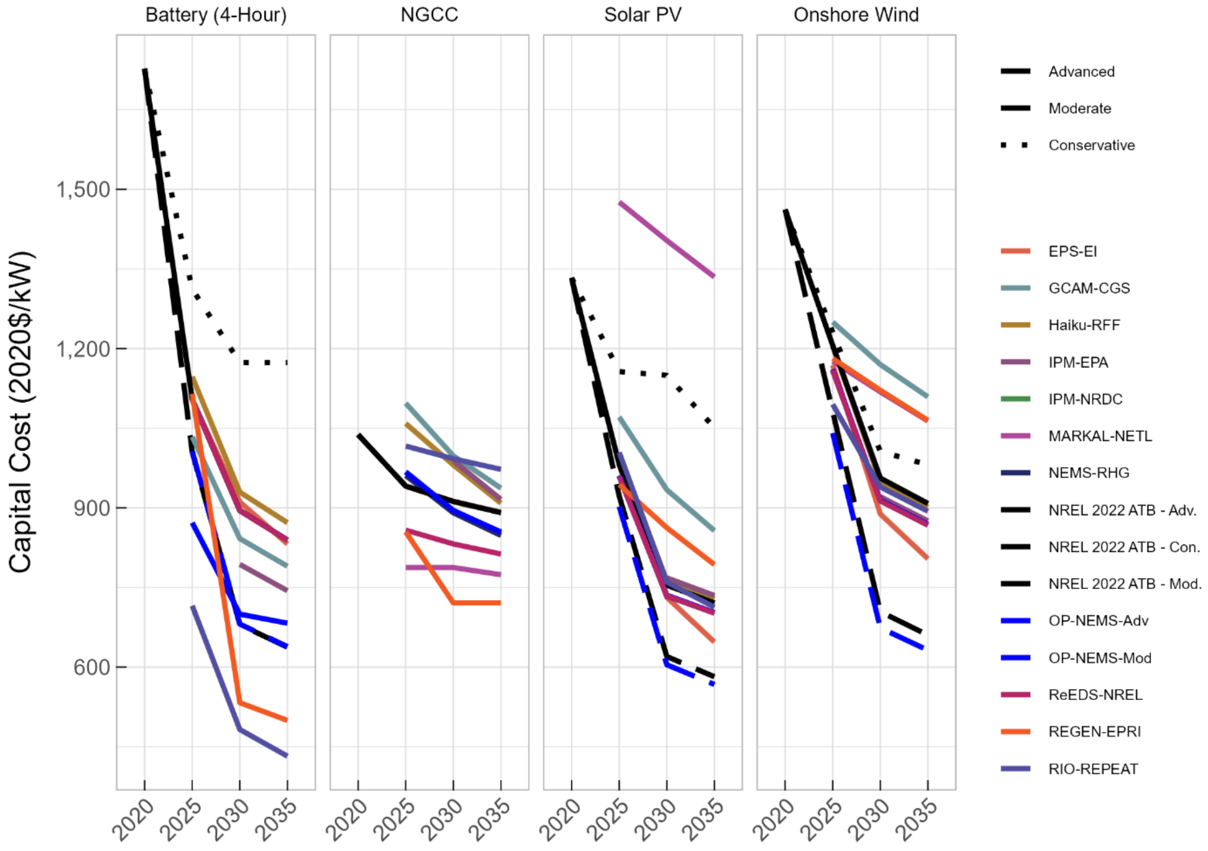
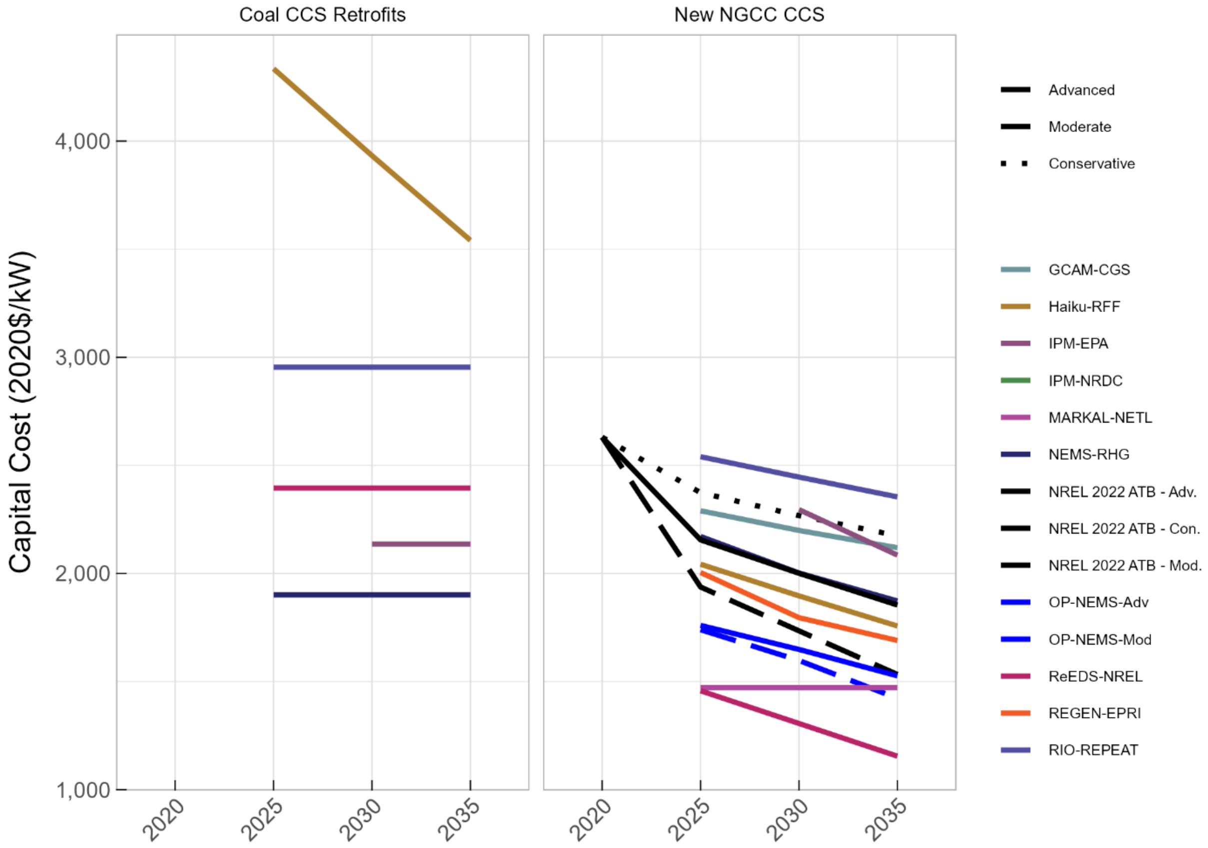


Figure D.3 Capital costs for coal CCS retrofits and natural gas CCS.



Appendix E: Results by Model

Appendix E figures show results presented in this report by model.

Figure E.1 Economy-wide CO_2 emissions. Shown for the No IRA and IRA scenarios, along with the absolute and percent differences between the two scenarios. Black dots represent median values.

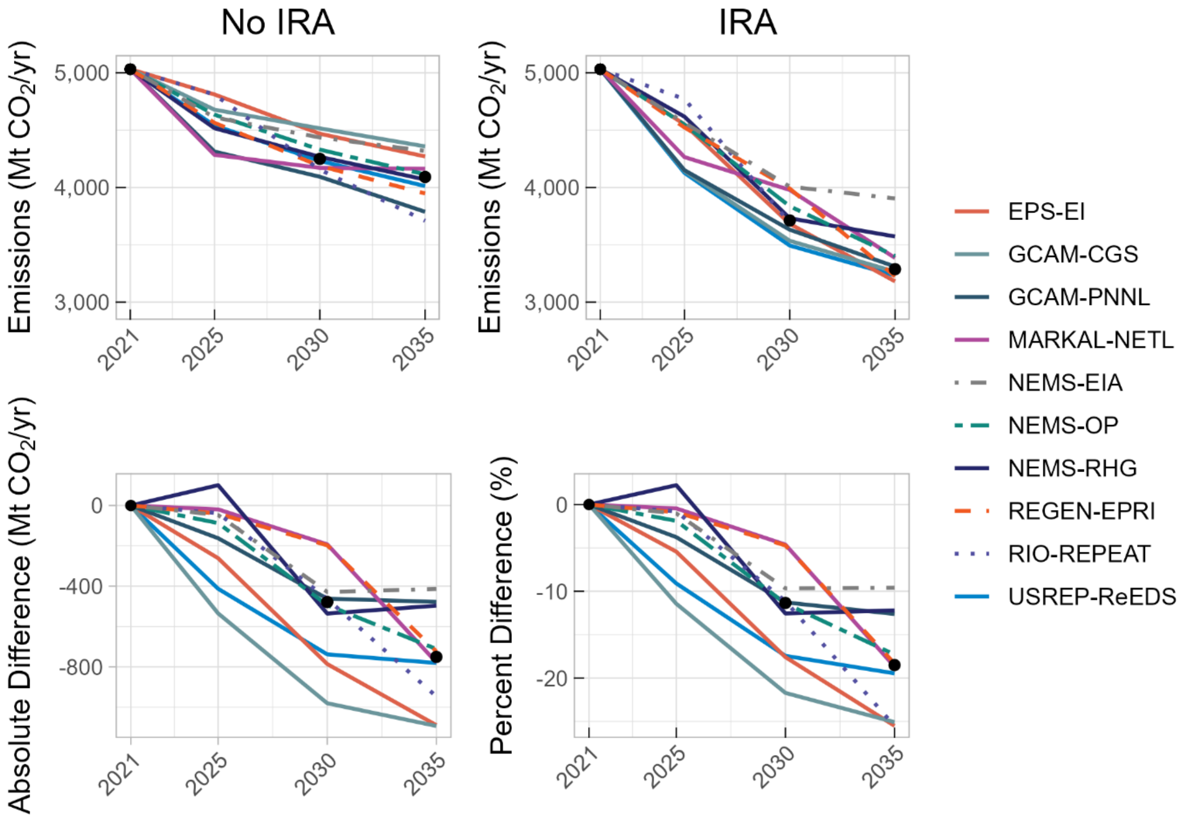


Figure E.2 Electricity sector CO_2 emissions. Shown for the No IRA and IRA scenarios, along with the absolute and percent differences between the two scenarios. Black dots represent median values.

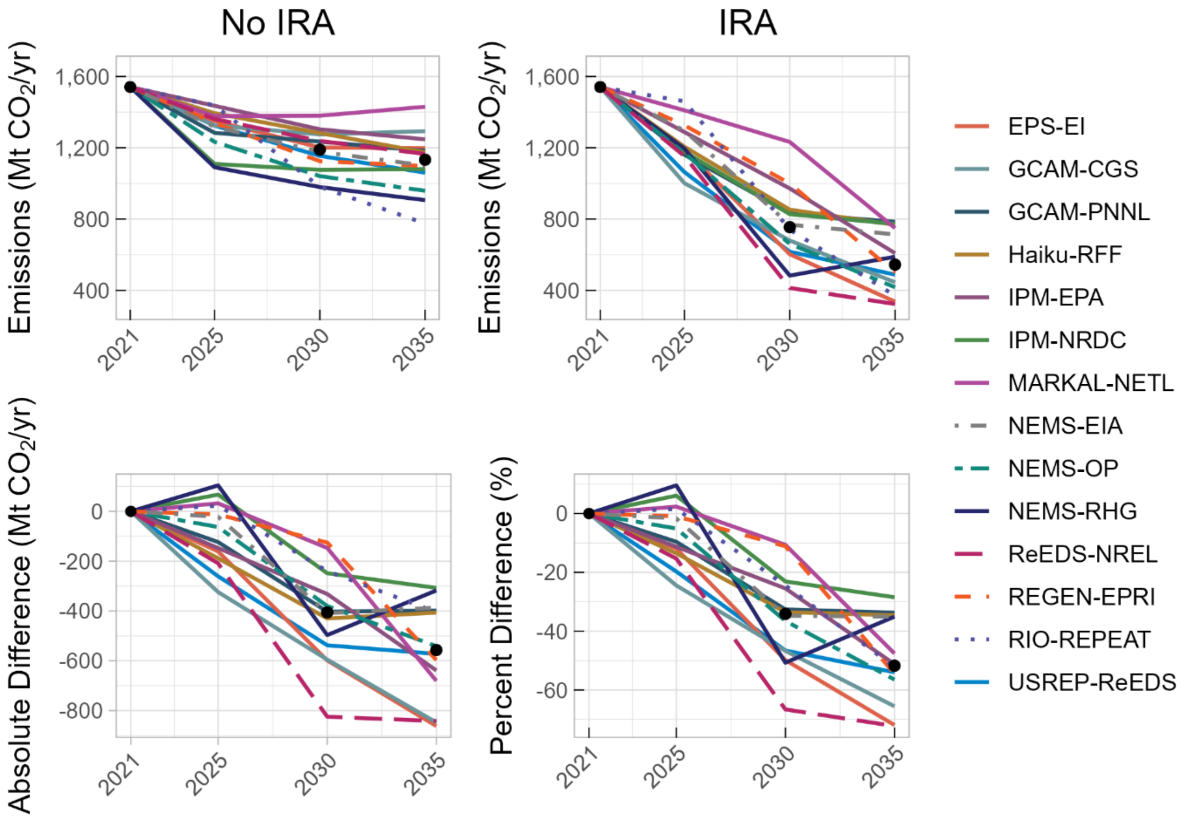


Figure E.3 Transportation sector CO_2 emissions. Shown for the No IRA and IRA scenarios, along with the absolute and percent differences between the two scenarios. Black dots represent median values.

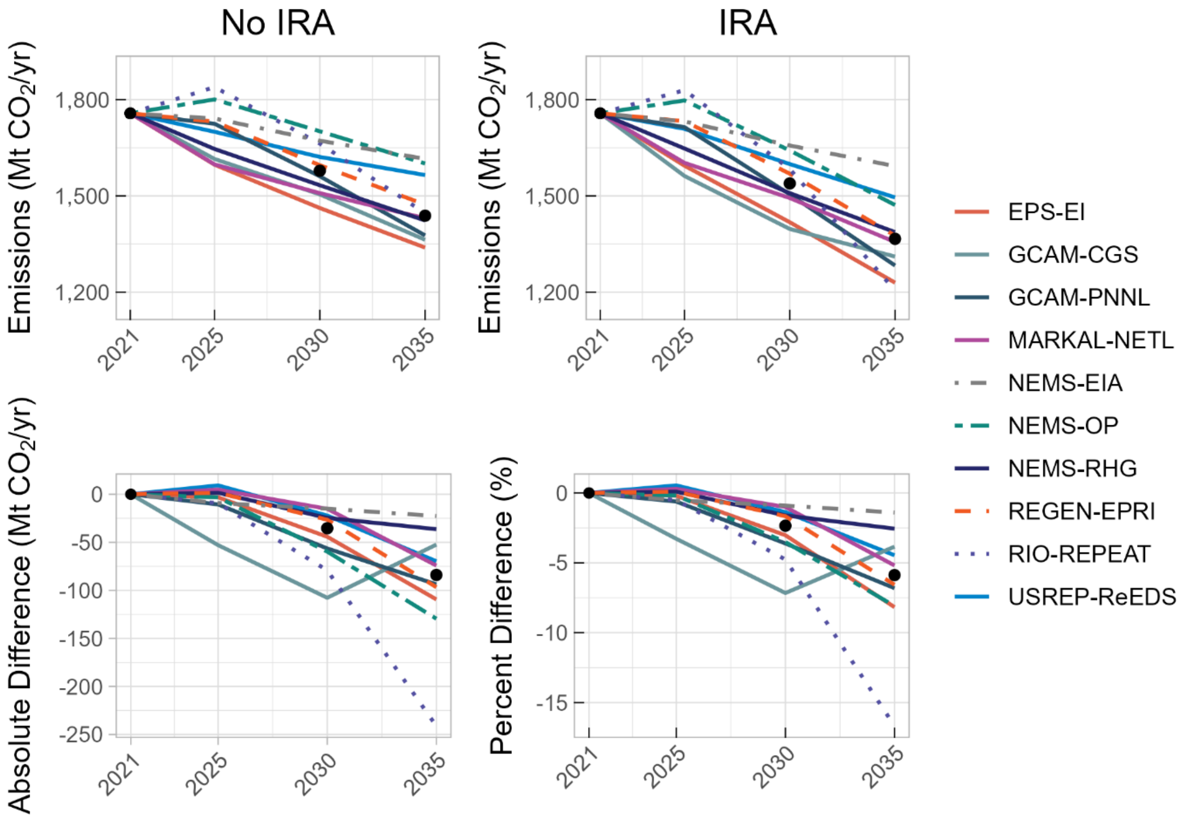


Figure E.4 Buildings sector CO_2 emissions. Shown for the No IRA and IRA scenarios, along with the absolute and percent differences between the two scenarios. Black dots represent median values.

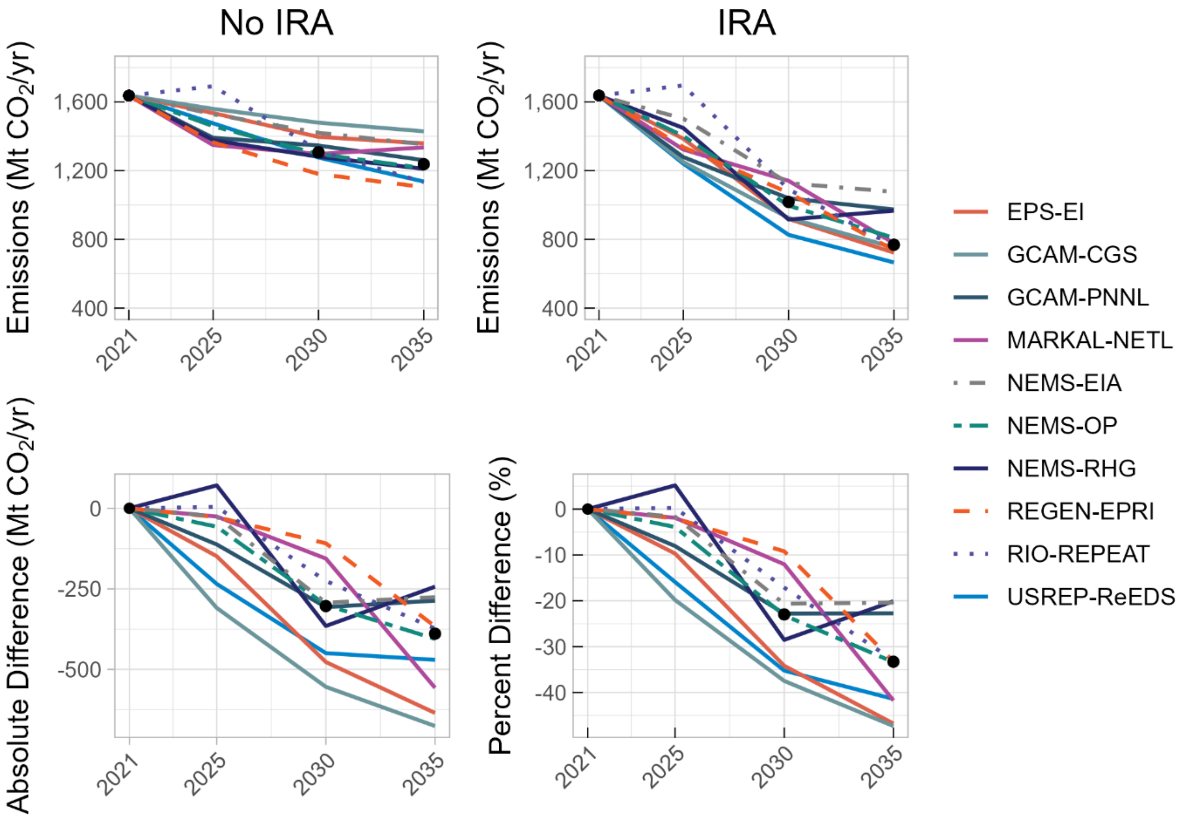


Figure E.5 Industrial sector CO_2 emissions. Shown for the No IRA and IRA scenarios, along with the absolute and percent differences between the two scenarios. Black dots represent median values.

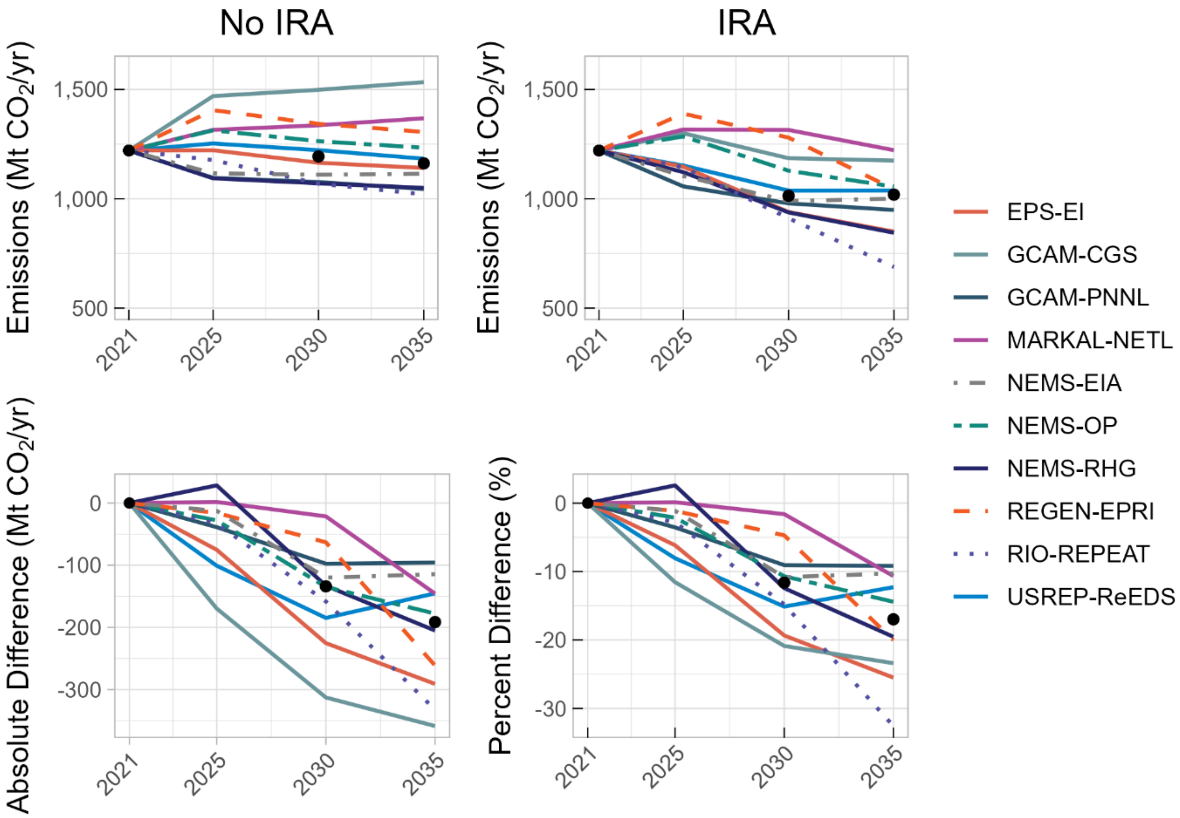


Figure E.6 Coal Primary Energy. Shown for the No IRA and IRA scenarios, along with the absolute and percent differences between the two scenarios. Black dots represent median values.

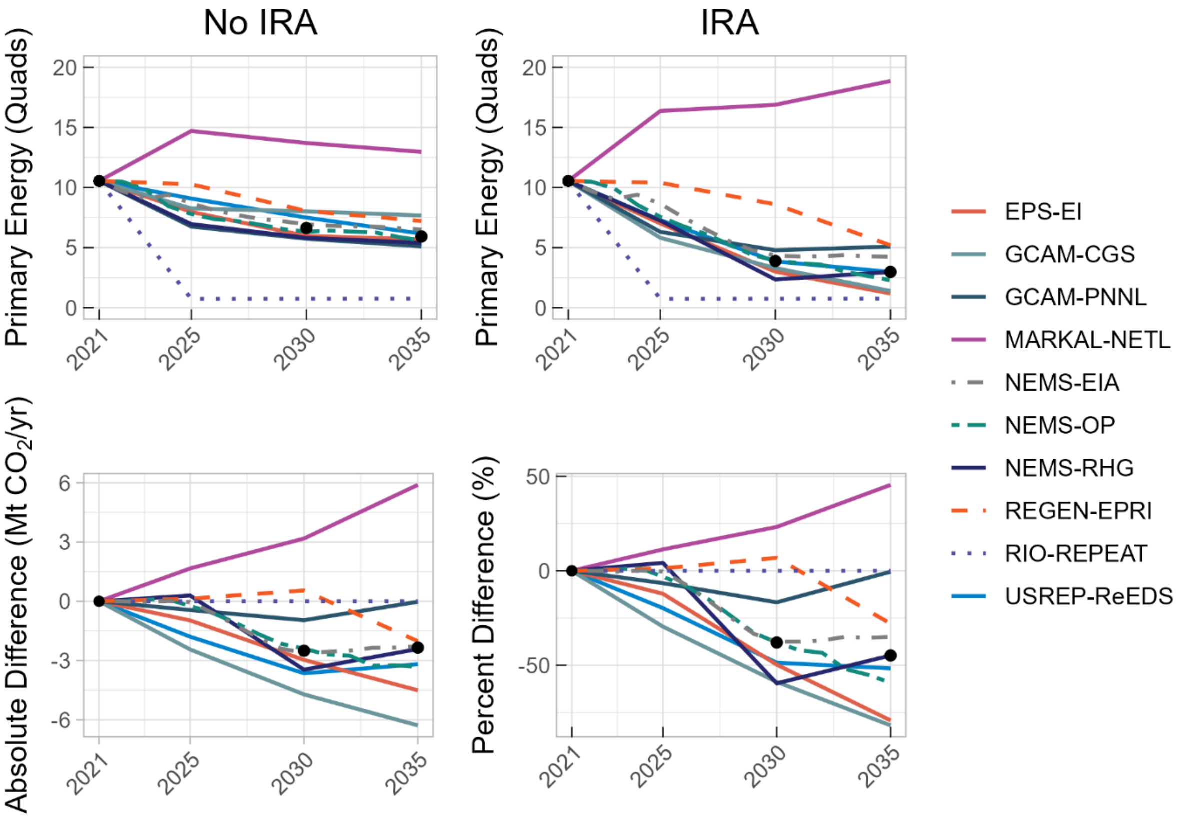


Figure E.7 Natural Gas Primary Energy. Shown for the No IRA and IRA scenarios, along with the absolute and percent differences between the two scenarios. Black dots represent median values.

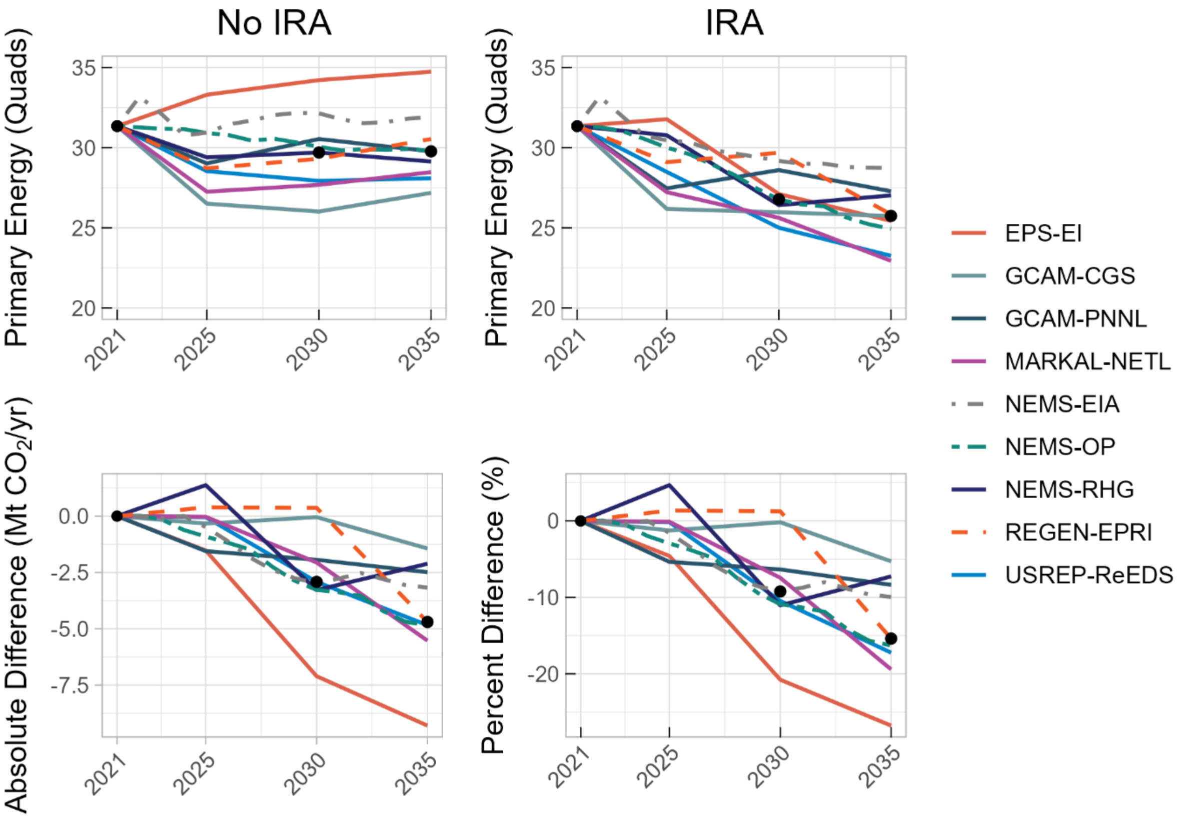


Figure E.8 Petroleum Primary Energy. Shown for the No IRA and IRA scenarios, along with the absolute and percent differences between the two scenarios. Black dots represent median values.

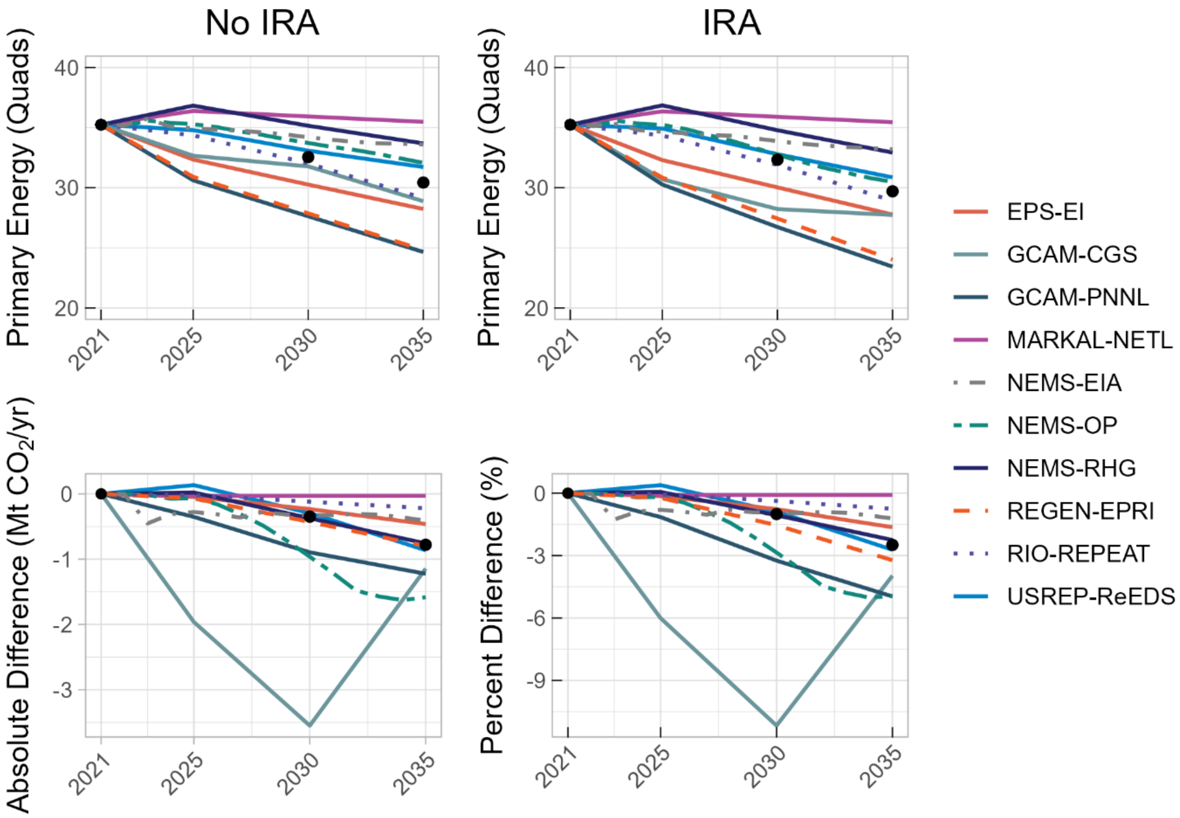


Figure E.9 Electricity generation from nuclear energy. Shown for the No IRA and IRA scenarios, along with the absolute and percent differences between the two scenarios. Black dots represent median values.

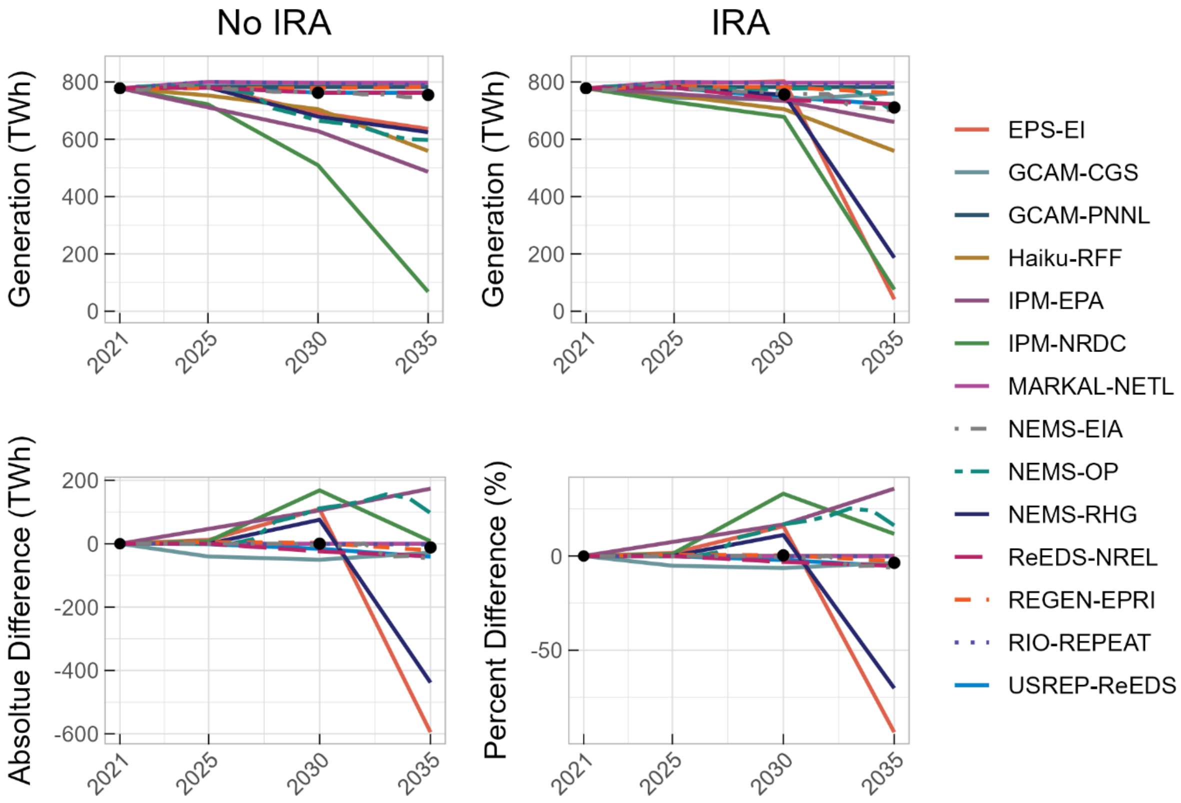


Figure E.10 Electricity generation from solar power. Shown for the No IRA and IRA scenarios, along with the absolute and percent differences between the two scenarios. Black dots represent median values.

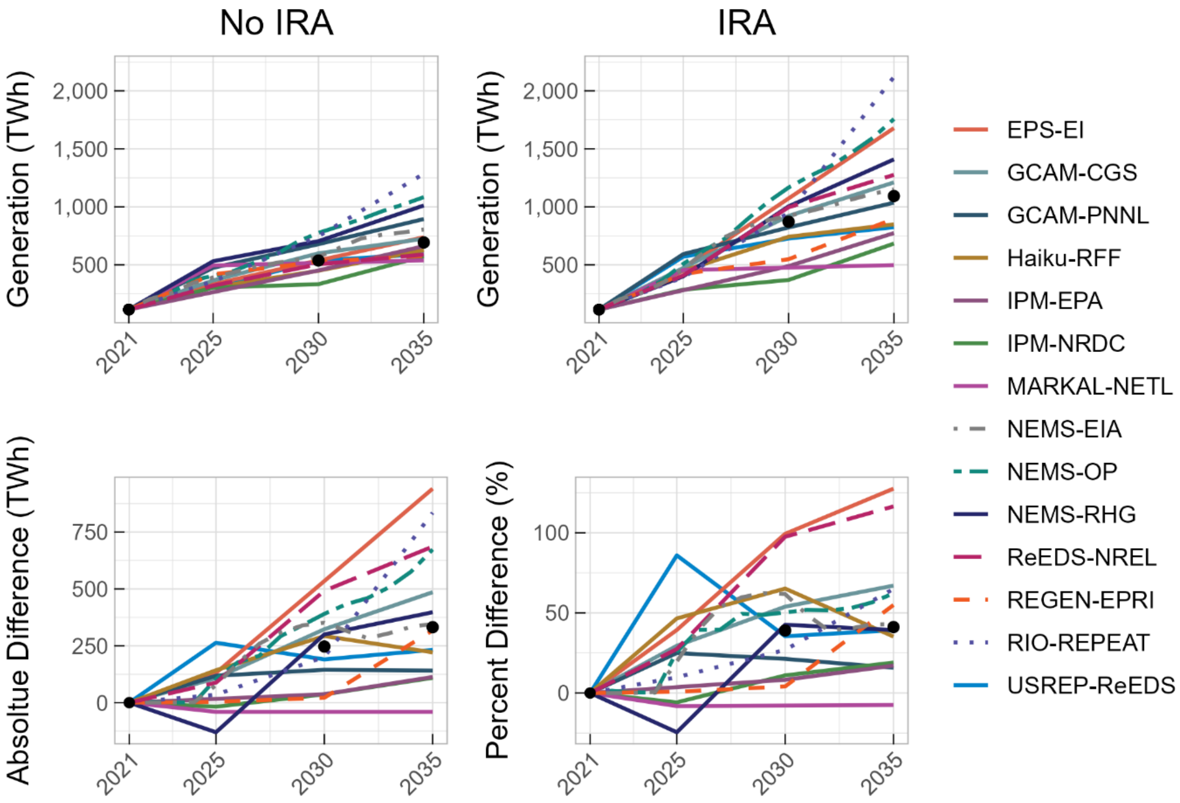


Figure E.11 Electricity generation from wind energy. Shown for the No IRA and IRA scenarios, along with the absolute and percent differences between the two scenarios. Black dots represent median values.

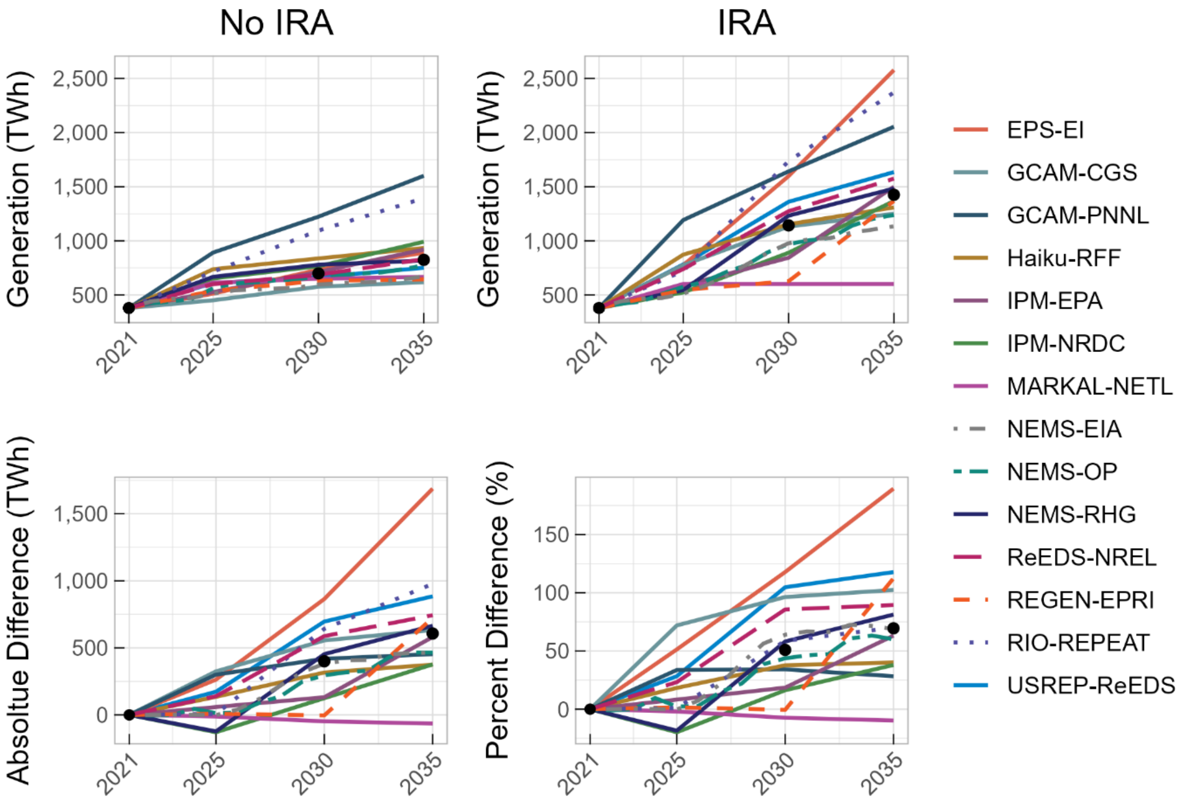


Figure E.12 Electricity generation from coal with CCS. Shown for the No IRA and IRA scenarios, along with the absolute differences between the two scenarios. Black dots represent median values.

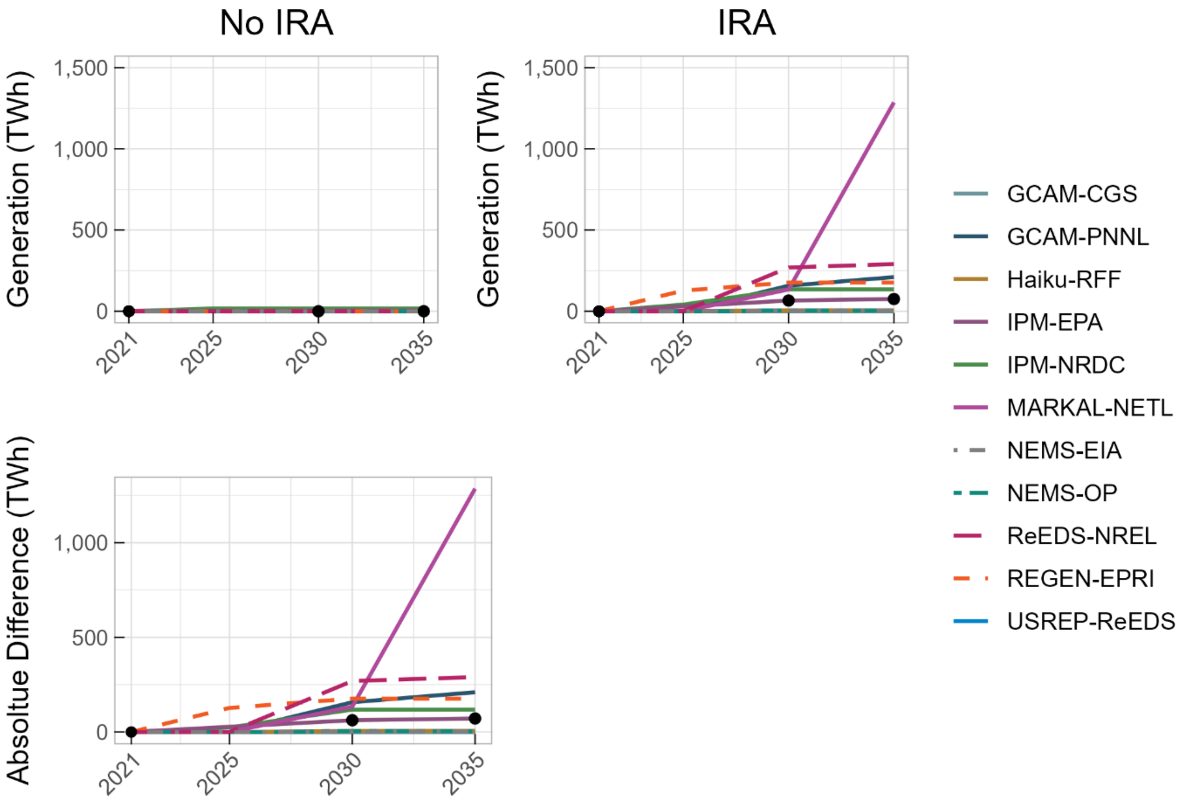


Figure E.13 Electricity generation from gas with CCS. Shown for the No IRA and IRA scenarios, along with the absolute differences between the two scenarios. Black dots represent median values.

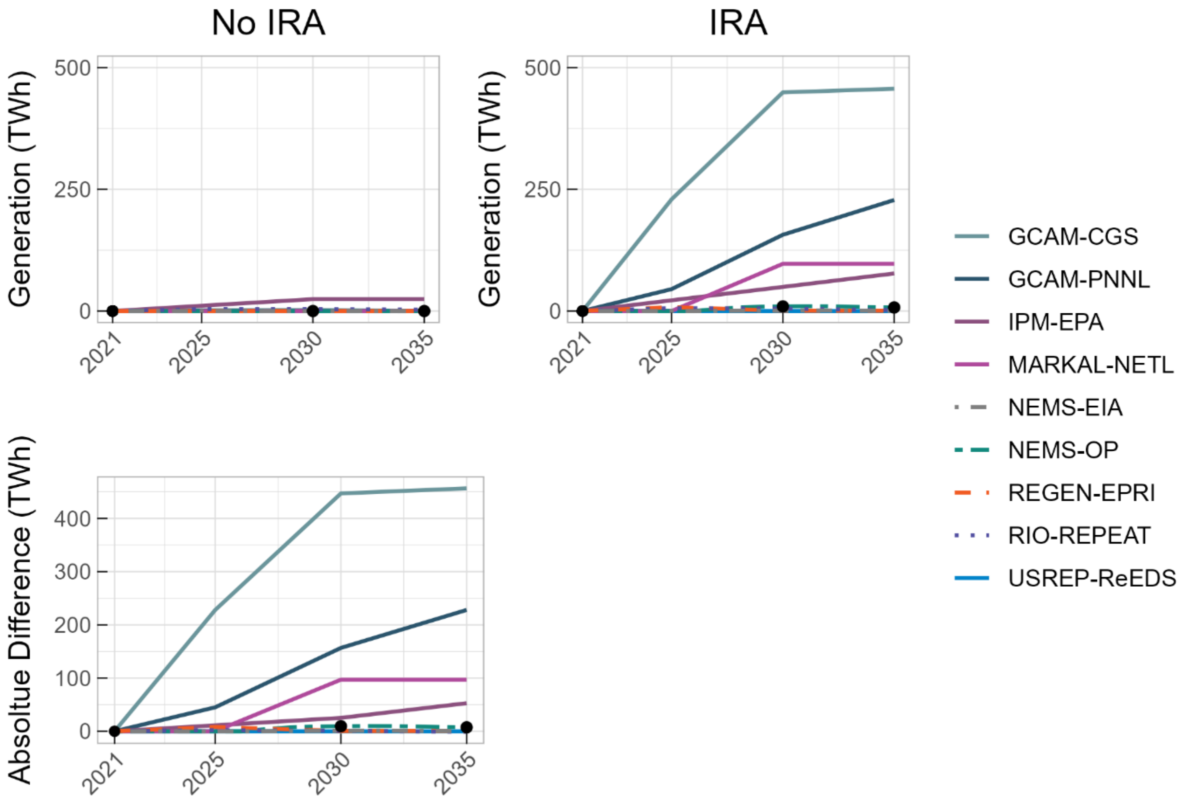


Figure E.14 Electricity generation from coal without CCS. Shown for the No IRA and IRA scenarios, along with the absolute and percent differences between the two scenarios. Black dots represent median values.

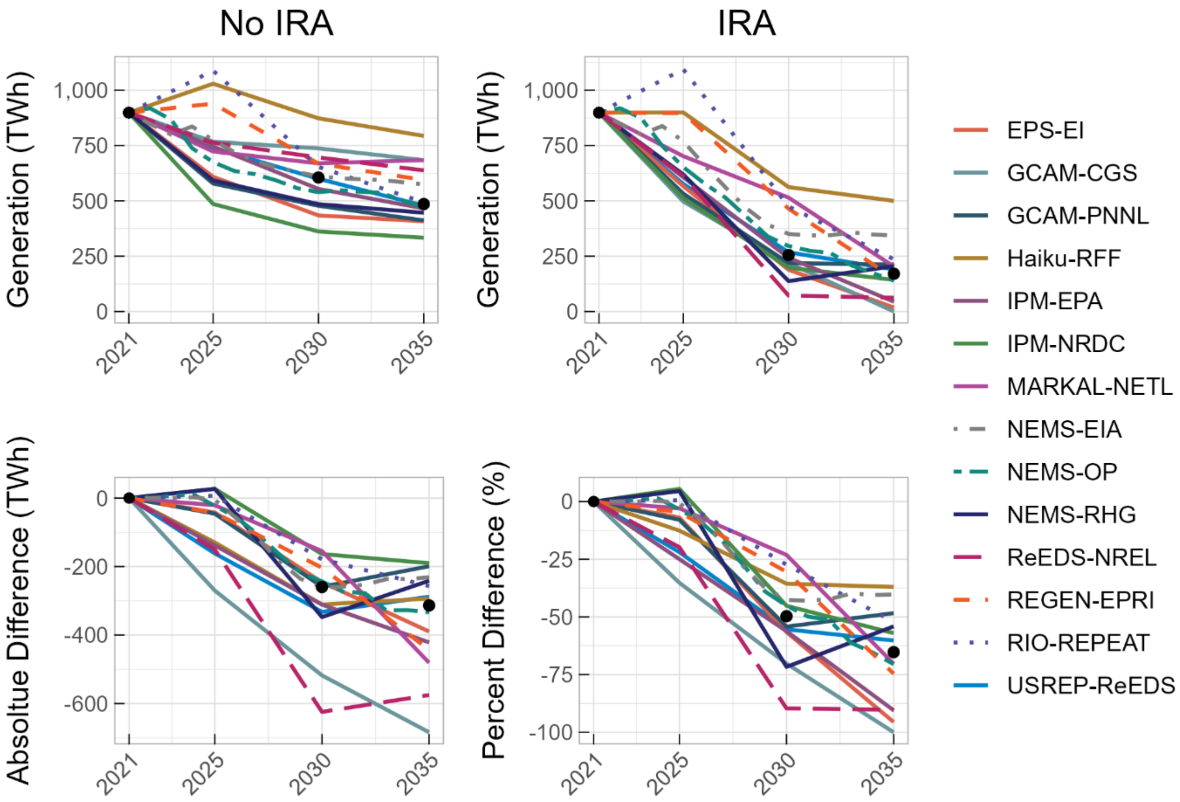


Figure E.15 Electricity generation from natural gas without CCS. Shown for the No IRA and IRA scenarios, along with the absolute and percent differences between the two scenarios. Black dots represent median values

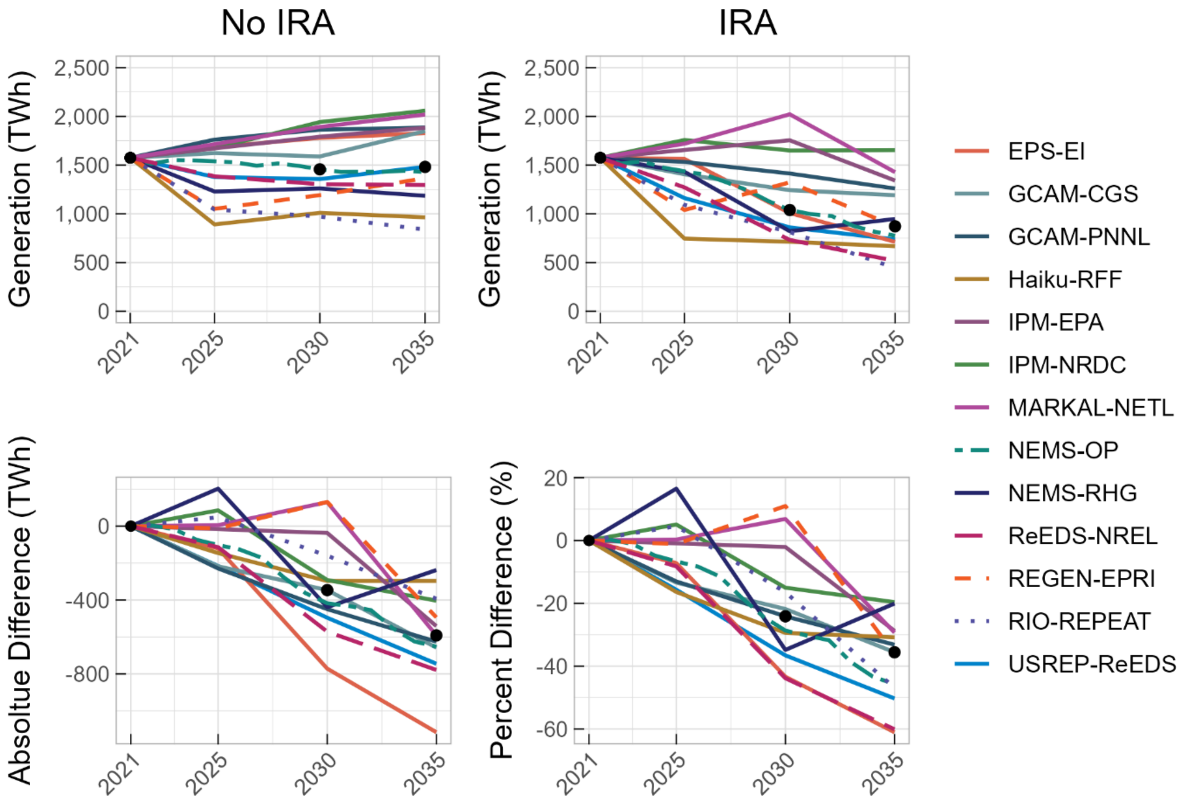


Figure E.16 Electricity generation from other energy sources. Shown for the No IRA and IRA scenarios, along with the absolute and percent differences between the two scenarios. Black dots represent median values. Other energy sources include geothermal, hydro, biomass, and oil. No model reported biomass or oil generation with CCS.

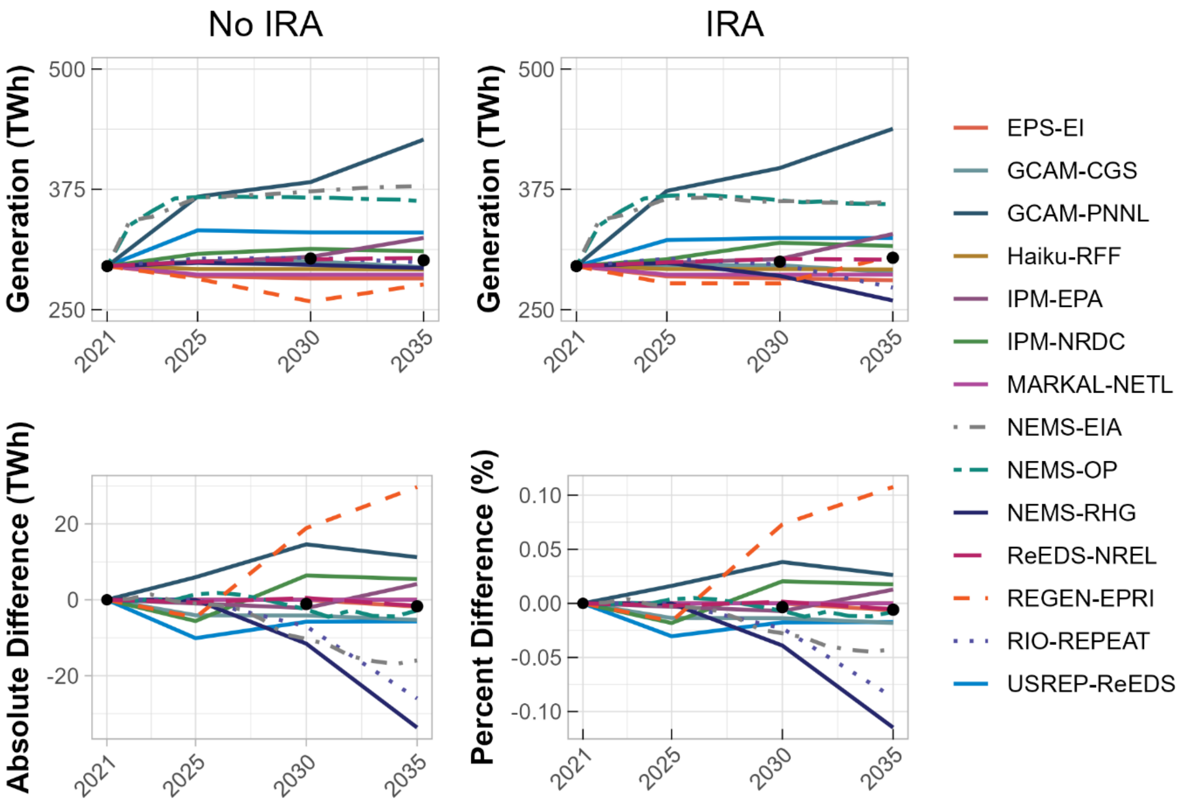


Figure E.17 Electric vehicle sales share. Shown for the No IRA and IRA scenarios along with the absolute percent point and percentage differences between the two scenarios. Black dots represent median values.

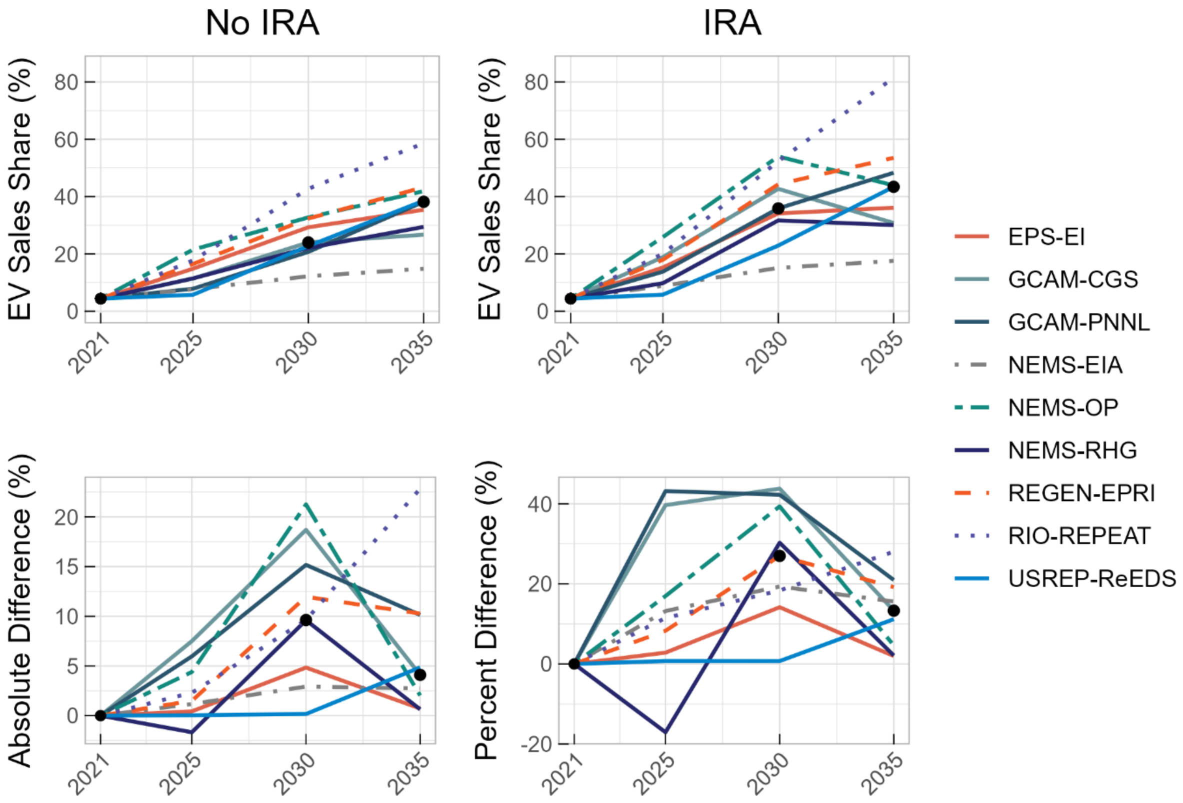


Figure E.18 Electricity generation by energy source in 2030 and 2035. Shown for the No IRA and IRA scenarios.

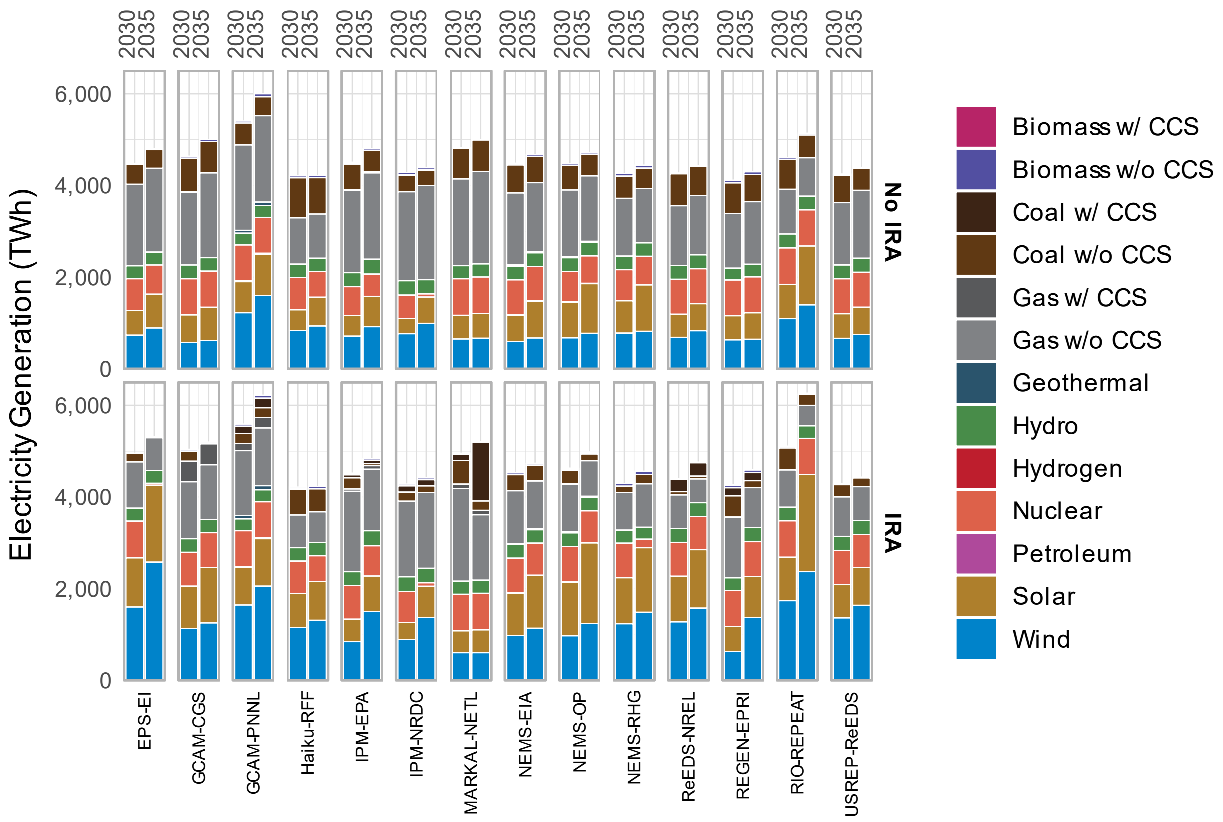


Figure E.19 Electricity capacity by energy source in 2030 and 2035. Shown for the No IRA and IRA scenarios.

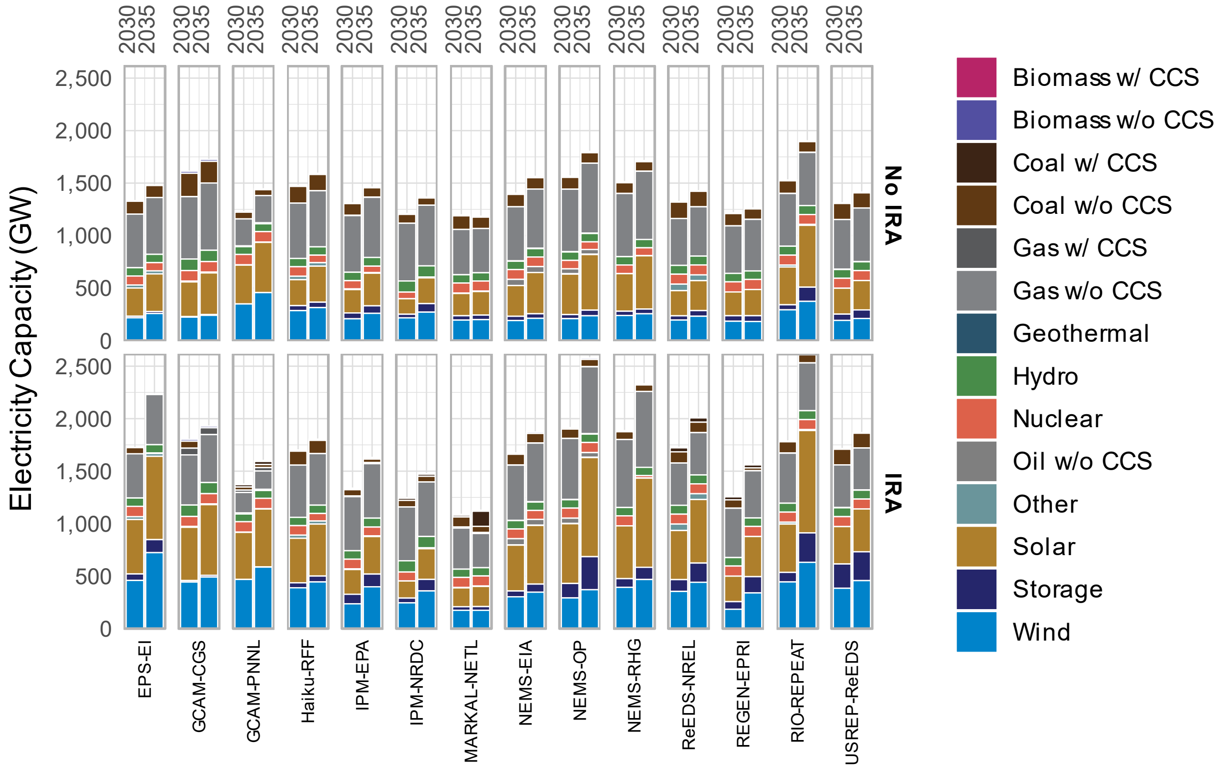


Figure E.20 Economy-wide electricity percent share of final energy. Shown for the No IRA and IRA scenarios along with the absolute percentage point (pp) and percentage differences between the two scenarios. Black dots represent median values.

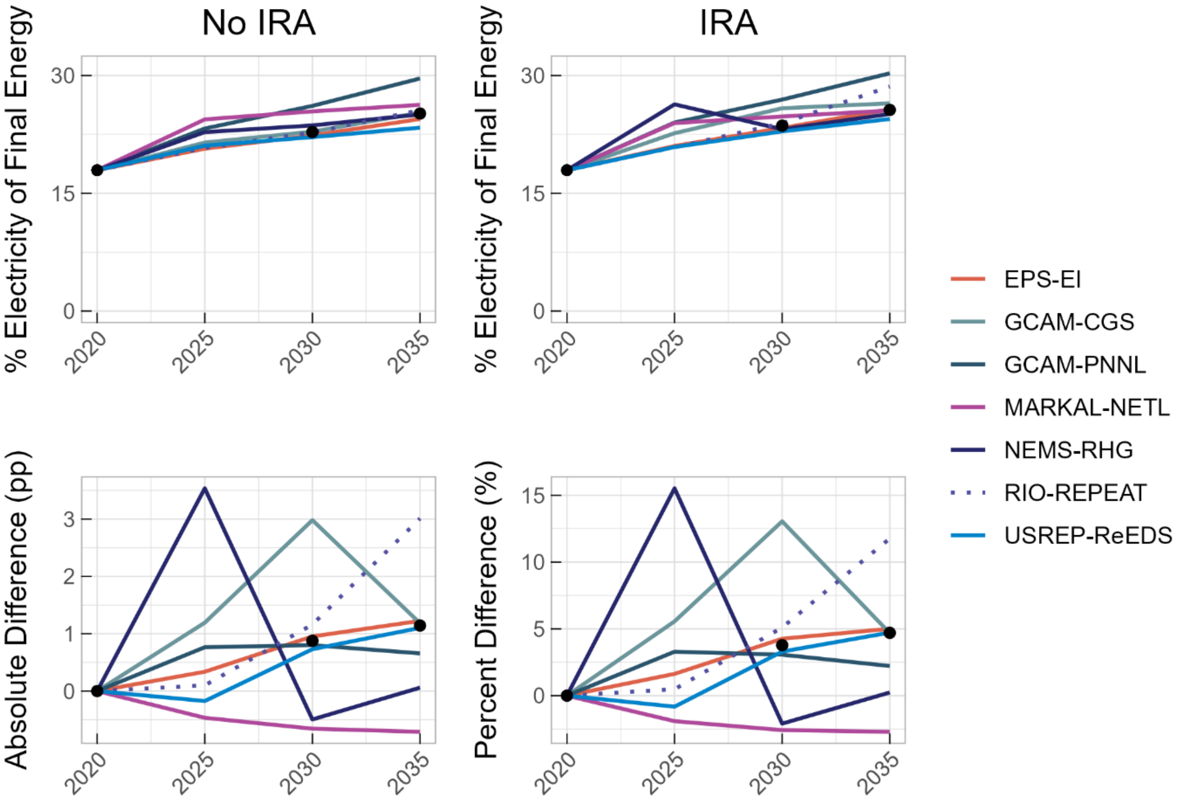


Figure E.21 Transportation sector electricity percent share of final energy. Shown for the No IRA and IRA scenarios along with the absolute percentage point (pp) and percentage differences between the two scenarios. Black dots represent median values.

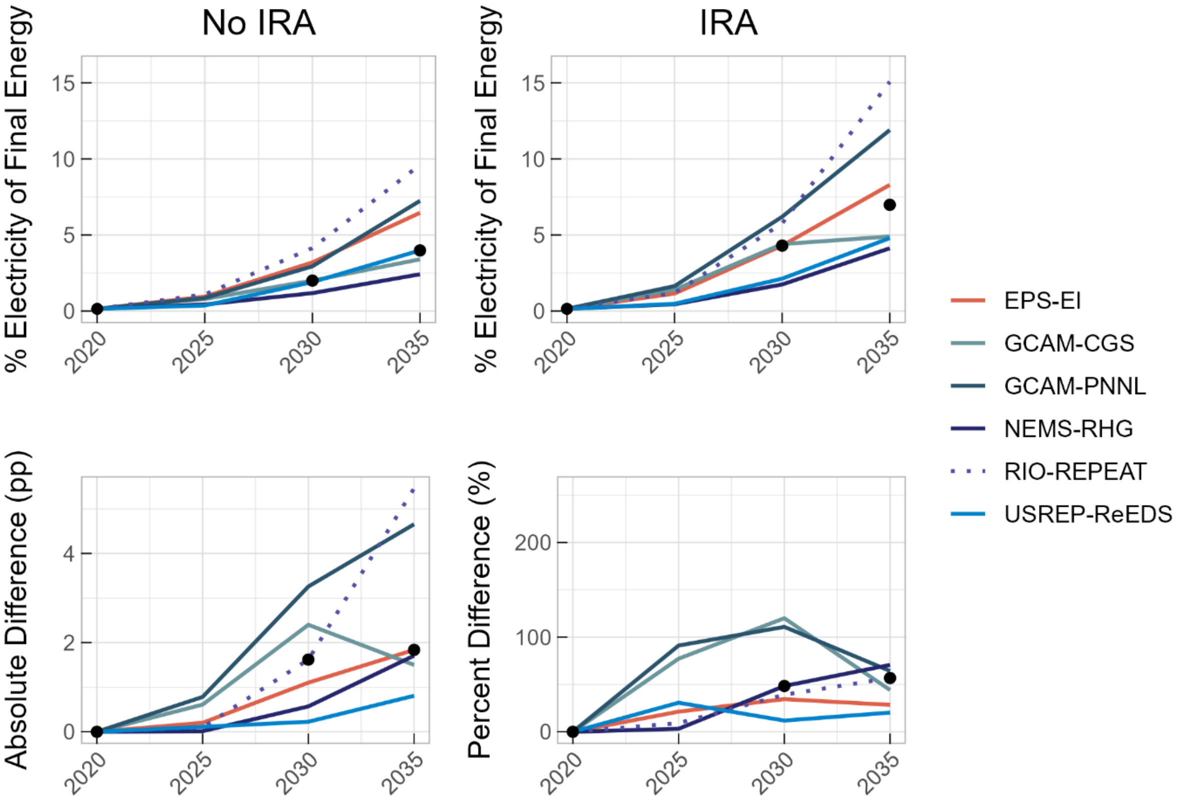


Figure E.22 Buildings sector electricity percent share of final energy. Shown for the No IRA and IRA scenarios along with the absolute percentage point (pp) and percentage differences between the two scenarios. Black dots represent median values.

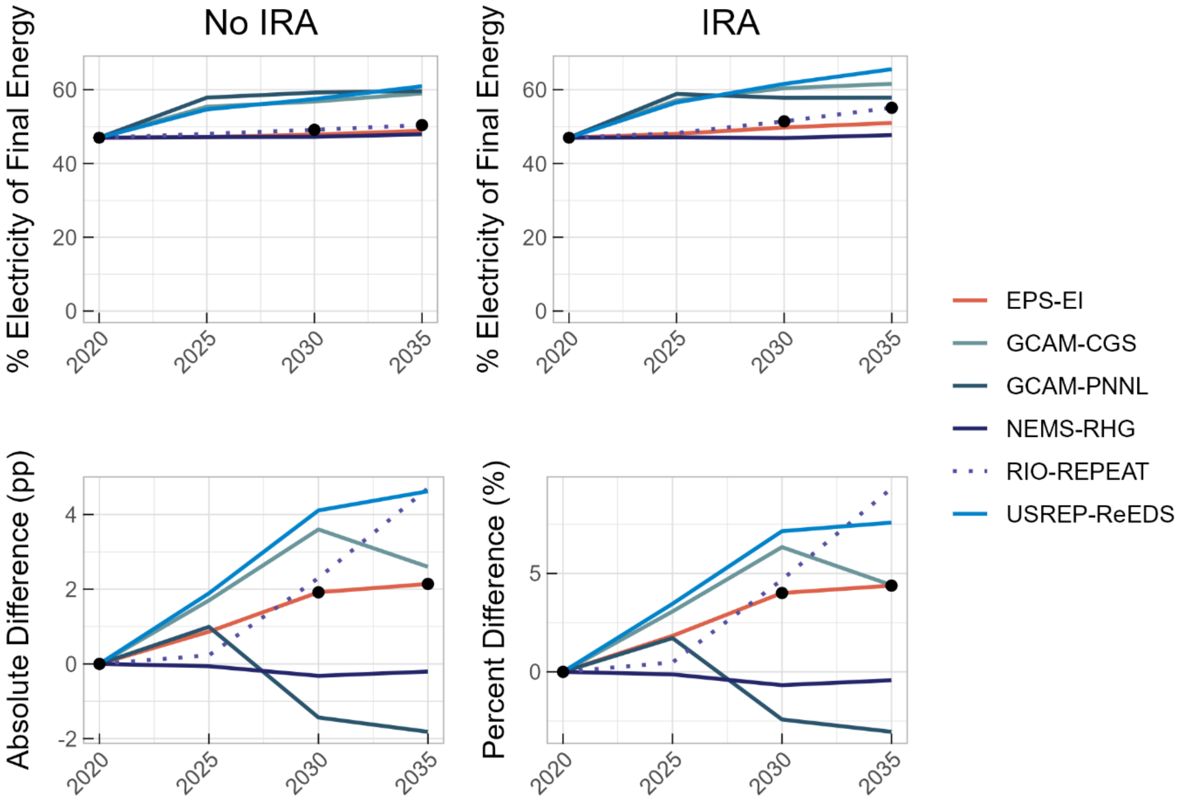


Figure E.23 Industrial sector electricity percent share of final energy. Shown for the No IRA and IRA scenarios along with the absolute percentage point (pp) and percentage differences between the two scenarios. Black dots represent median values.

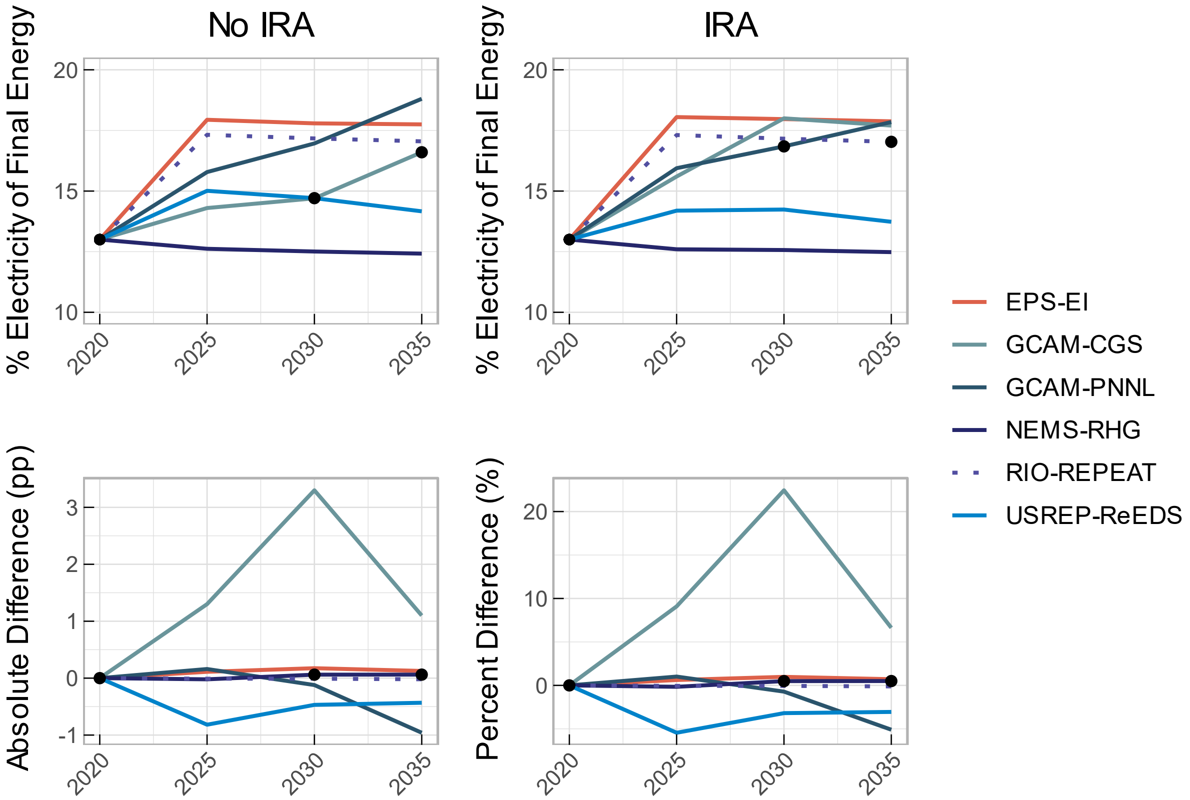


Figure E.24 Economy-wide CO_2 combustion emissions. Shown for the No IRA and IRA scenarios, along with the absolute and percent differences between the two scenarios. Black dots represent median values.

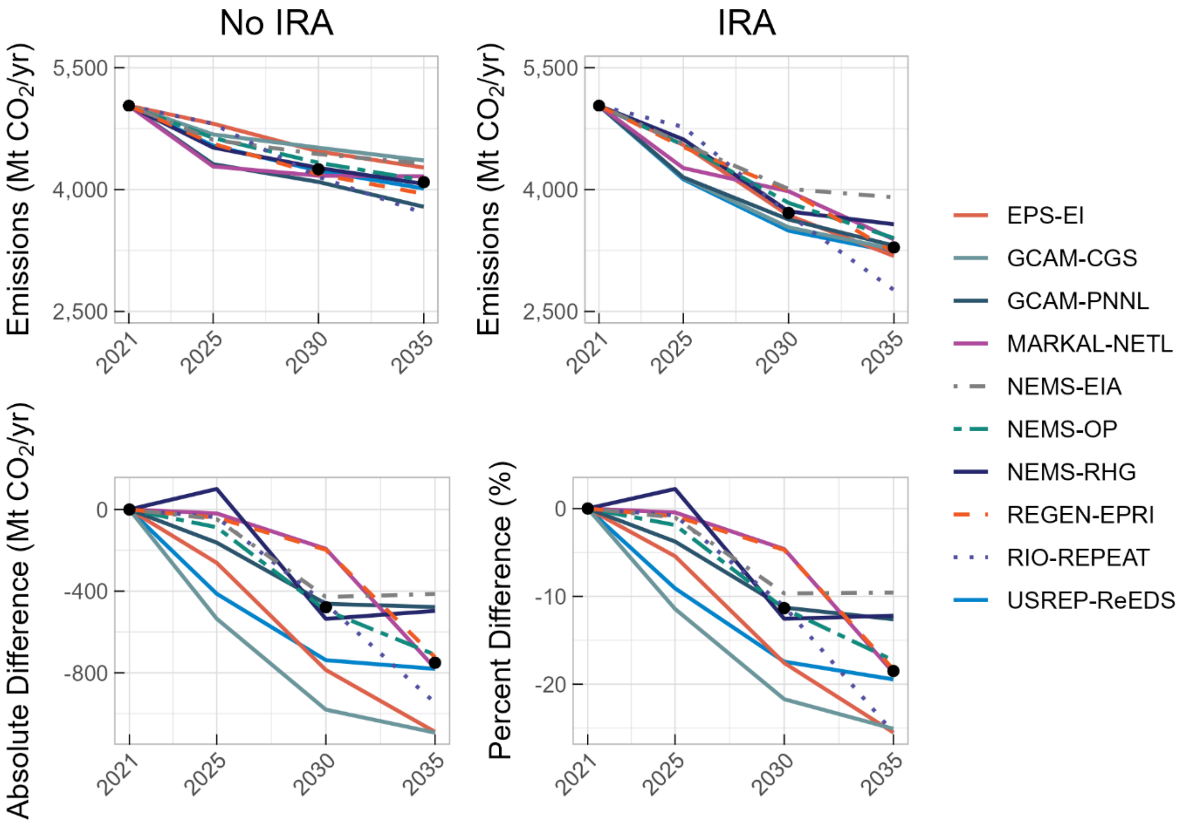


Figure E.25 Transportation sector CO₂ combustion emissions. Shown for the No IRA and IRA scenarios, along with the absolute and percent differences between the two scenarios. Black dots represent median values.

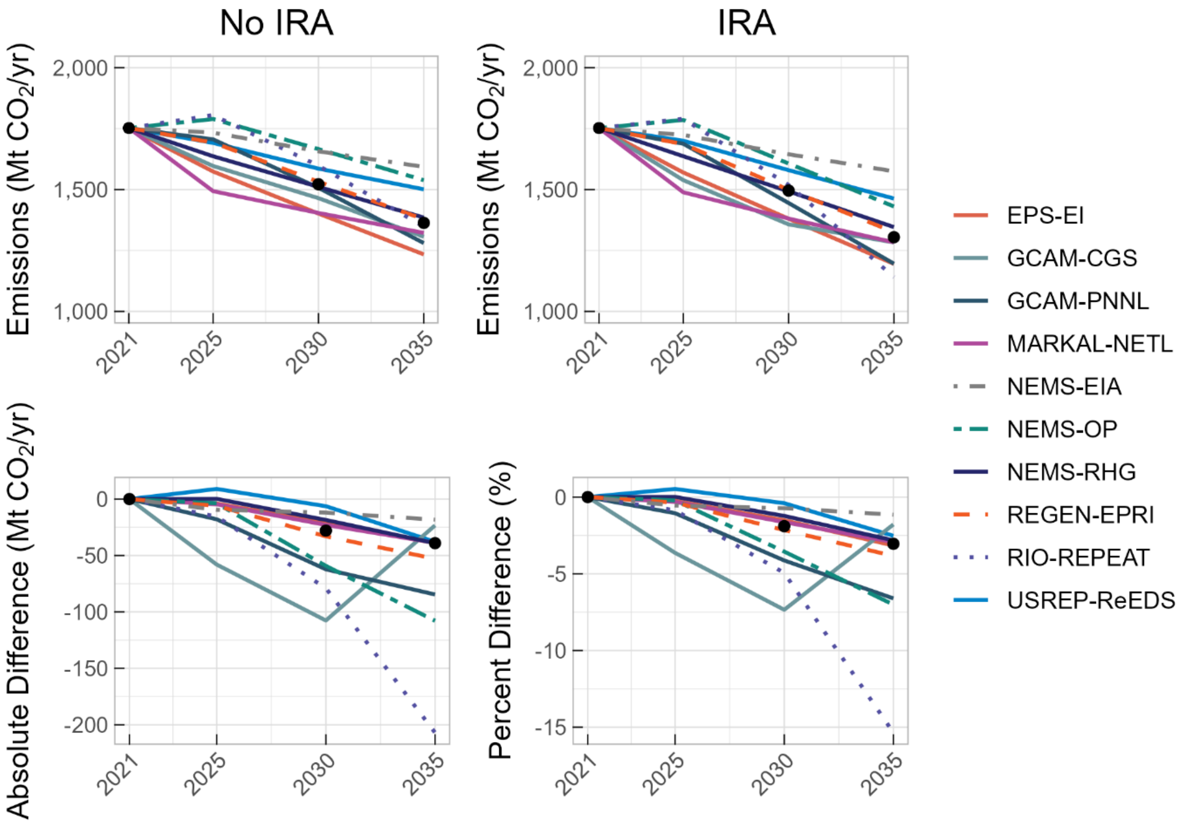


Figure E.26 Buildings sector CO_2 combustion emissions. Shown for the No IRA and IRA scenarios, along with the absolute and percent differences between the two scenarios. Black dots represent median values.

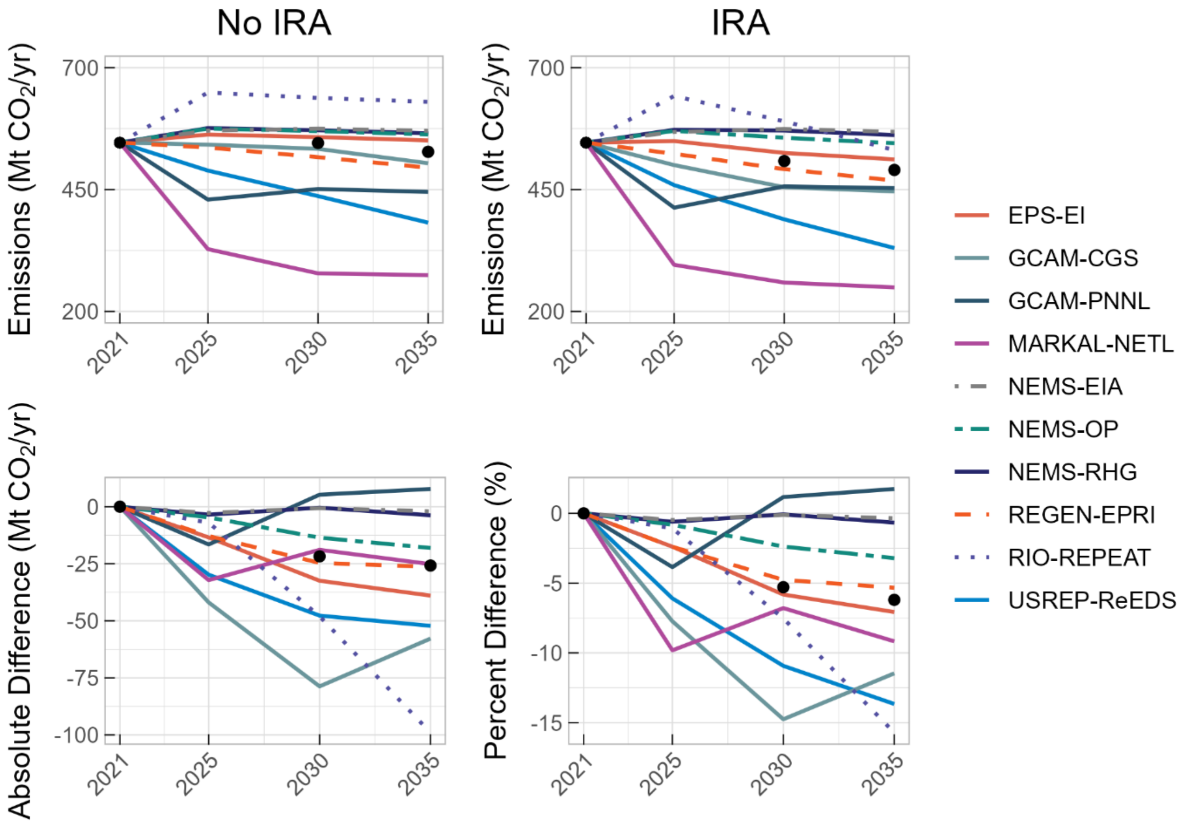


Figure E.27 Buildings sector CO_2 combustion emissions. Shown for the No IRA and IRA scenarios, along with the absolute and percent differences between the two scenarios. Black dots represent median values.

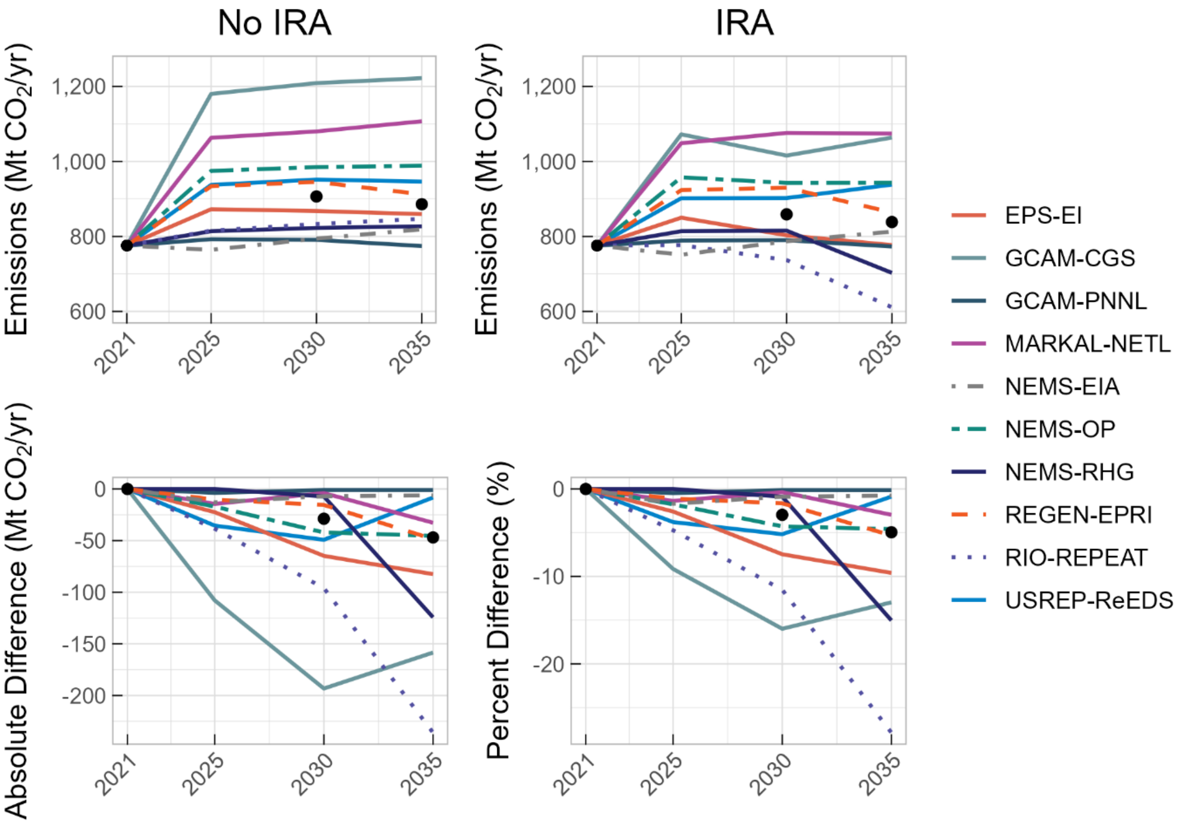


Figure E.28 Economy-wide CO_2 emissions from electricity production. Shown for the No IRA and IRA scenarios, along with the absolute and percent differences between the two scenarios. Black dots represent median values.

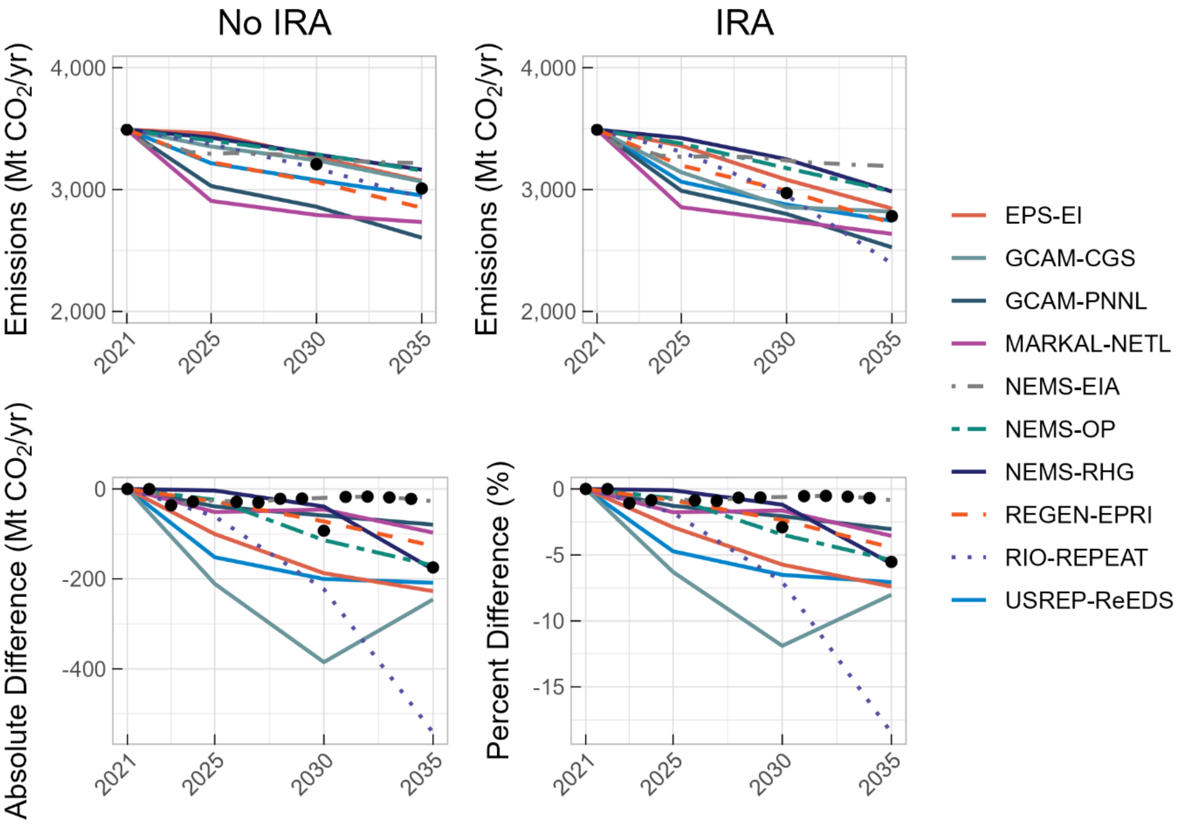


Figure E.29 Transportation sector CO_2 indirect emissions from electricity consumed. Shown for the No IRA and IRA scenarios, along with the absolute and percent differences between the two scenarios. Black dots represent median values.

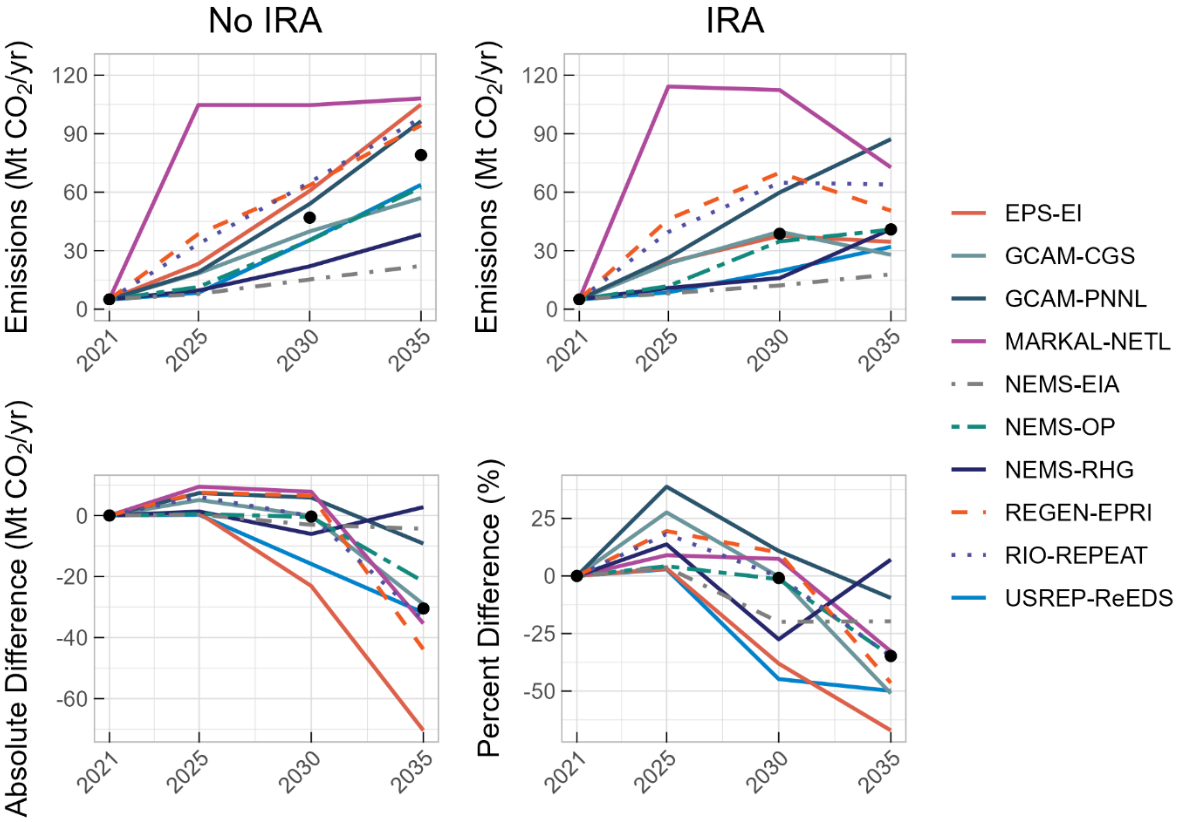


Figure E.30 Buildings sector CO_2 indirect emissions from electricity consumed. Shown for the No IRA and IRA scenarios, along with the absolute and percent differences between the two scenarios. Black dots represent median values.

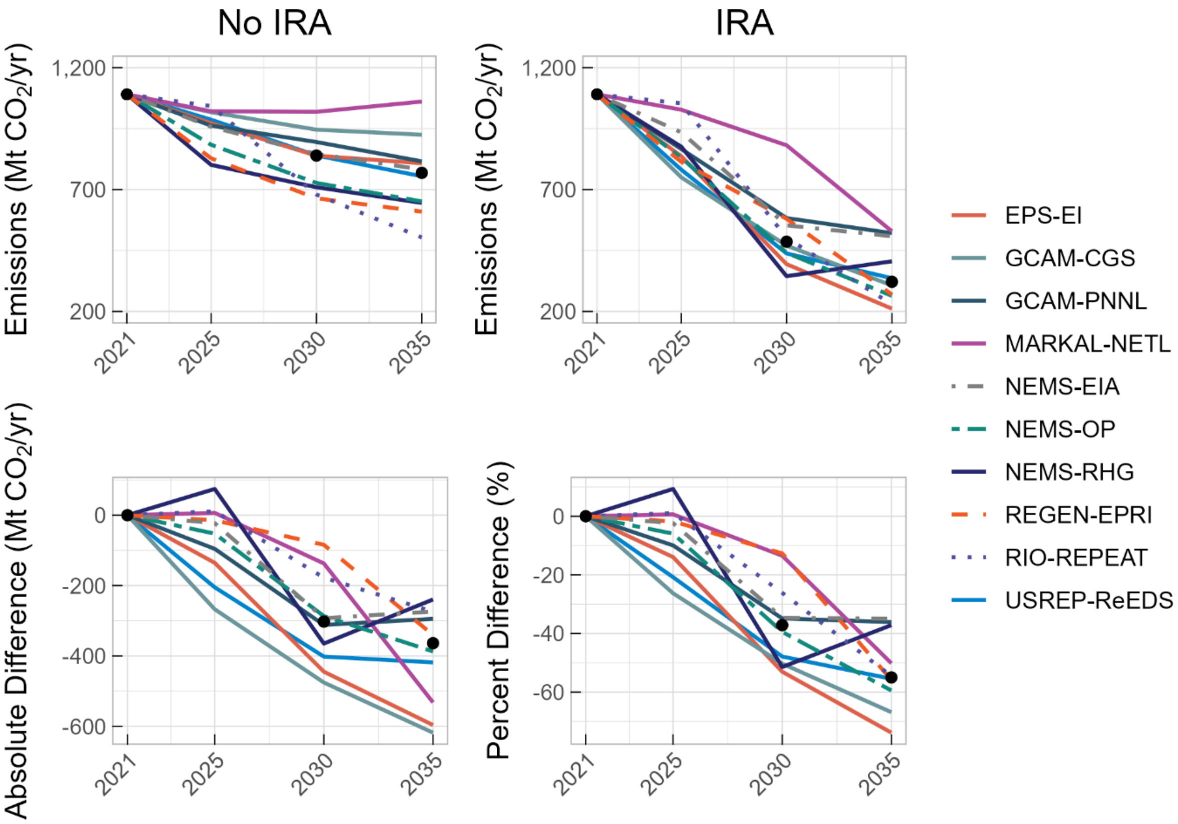


Figure E.31 Industrial sector CO_2 indirect emissions from electricity consumed. Shown for the No IRA and IRA scenarios, along with the absolute and percent differences between the two scenarios. Black dots represent median values.

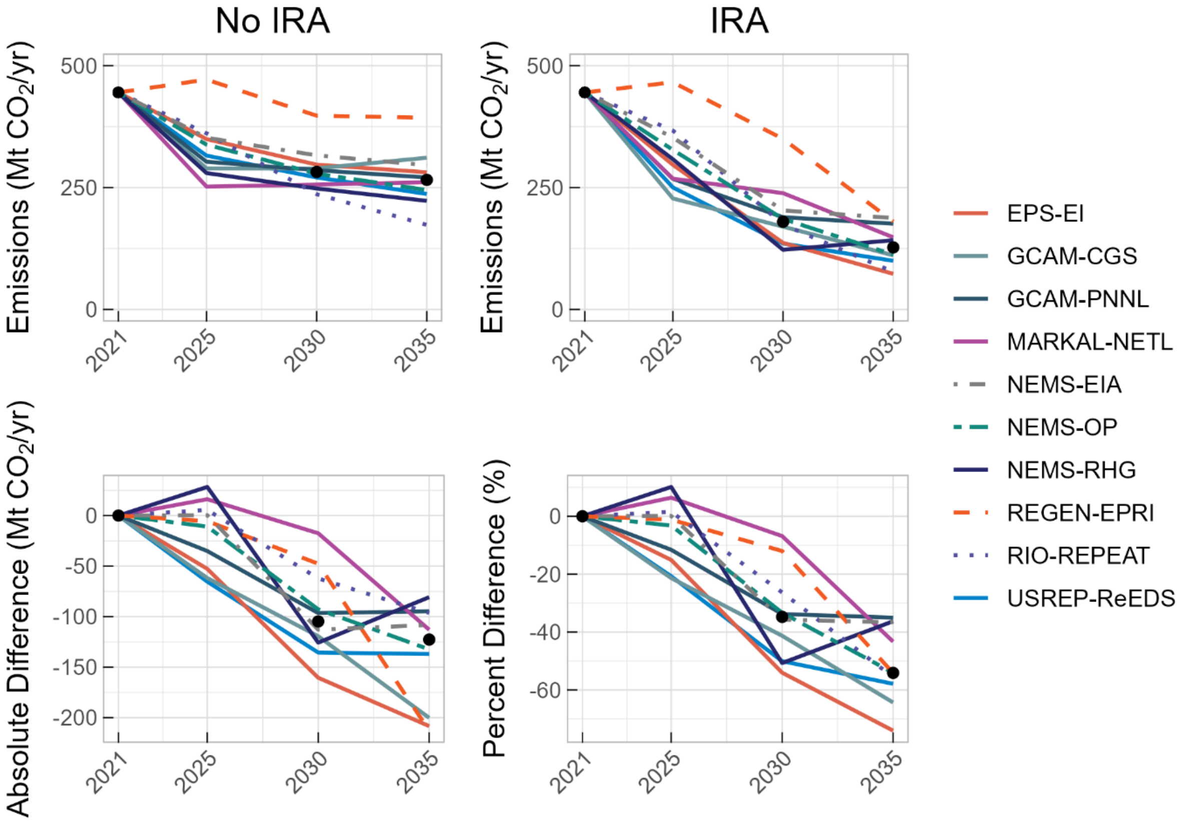


Table E.1 Electricity generation from coal and gas technologies without carbon capture. Shown for the No IRA and IRA scenarios for years 2030 and 2035.

	Coal				Gas			
	No IRA		IRA		No IRA		IRA	
Model	2030	2035	2030	2035	2030	2035	2030	2035
EPS-EI	434	408	189	18	1,779	1,828	1,008	712
GCAM-CGS	737	684	219	0	1,589	1,849	1,242	1,191
GCAM-PNNL	478	412	376	423	1,863	1,885	1,570	1,488
Haiku-RFF	873	794	562	500	1,010	964	713	667
IPM-EPA	554	466	243	44	1,791	1,883	1,754	1,341
IPM-NRDC	362	334	198	143	1,942	2,058	1,650	1,654
MARKAL-NETL	670	684	515	203	1,892	2,018	2,021	1,427
NEMS-EIA	611	575	353	347	1,571	1,500	1,154	1,039
NEMS-OP	539	473	300	143	1,456	1,427	1,048	782
NEMS-RHG	485	446	138	205	1,260	1,185	821	947
REGEN-EPRI	668	594	465	151	1,192	1,366	1,323	872
RIO-REPEAT	654	493	475	236	972	838	812	445
ReEDS-NREL	696	-	334	-	1,303	-	695	-
USREP-ReEDS	600	478	268	190	1,356	1,481	861	737

Table E.2 Electricity generation capacity from coal and gas technologies without carbon capture. Shown for the No IRA and IRA scenarios for years 2030 and 2035.

	Coal				Gas			
	No IRA		IRA		No IRA		IRA	
Model	2030	2035	2030	2035	2030	2035	2030	2035
EPS-EI	123	114	58	7	510	541	421	478
GCAM-CGS	223	206	66	0	594	641	478	457
GCAM-PNNL	64	55	52	59	257	260	218	207
Haiku-RFF	159	155	133	126	527	534	497	491
IPM-EPA	111	88	60	33	539	572	515	519
IPM-NRDC	85	68	63	54	550	578	512	520
MARKAL-NETL	129	108	96	58	432	422	391	326
NEMS-EIA	118	108	105	93	515	563	525	558
NEMS-OP	112	100	90	70	595	666	581	638
NEMS-RHG	102	91	74	61	602	650	648	723
REGEN-EPRI	117	99	80	27	453	491	470	449
RIO-REPEAT	120	102	108	77	502	506	476	455
ReEDS-NREL	156	-	136	-	447	-	402	-
USREP-ReEDS	152	144	149	141	473	510	406	399

Table E.3 Electricity generation capacity factors for coal and gas technologies without carbon capture. Shown for the No IRA and IRA scenarios for years 2030 and 2035. Capacity factor is the ratio of electrical energy produced by a generating technology over a year to the electrical energy that could have been produced at continuous full power operation during the year expressed as a percentage.

	Coal				Gas			
	No IRA		IRA		No IRA		IRA	
Model	2030	2035	2030	2035	2030	2035	2030	2035
EPS-EI	40%	41%	37%	30%	40%	39%	27%	17%
GCAM-CGS	38%	38%	38%	0%[7]	31%	33%	30%	30%
GCAM-PNNL	85%	85%	83%	82%	83%	83%	82%	82%
Haiku-RFF	63%	58%	48%	45%	22%	21%	16%	16%
IPM-EPA	57%	61%	46%	15%	38%	38%	39%	30%
IPM-NRDC	49%	56%	36%	30%	40%	41%	37%	36%
MARKAL-NETL	59%	72%	61%	40%	50%	55%	59%	50%
NEMS-EIA	59%	61%	38%	42%	35%	30%	25%	21%
NEMS-OP	55%	54%	38%	23%	28%	24%	21%	14%
NEMS-RHG	54%	56%	21%	38%	24%	21%	14%	15%
REGEN-EPRI	65%	68%	66%	64%	30%	32%	32%	22%
RIO-REPEAT	62%	55%	50%	35%	22%	19%	19%	11%
ReEDS-NREL	51%	-	28%	-	33%	-	20%	-
USREP-ReEDS	45%	38%	20%	15%	33%	33%	24%	21%

[1] GCAM-CGS coal generation and capacity are beneath rounding tolerance, so CF has been set to 0%.

Appendix F: Supplemental Results

F.1 Electrification

Appendix F.1 summarizes electrification changes, both economy-wide and by sector. Electrification is presented as the electricity share of final energy. Electrification and energy efficiency are not broken out.

Figure F.1.1 Electricity share of final energy. Economy-wide (total), transportation, buildings, and industry share electricity of final energy over time for the IRA (blue line and circles) and No IRA scenarios (orange dashed line and triangles). Horizontal bars to the right of each panel represent the median of model results.

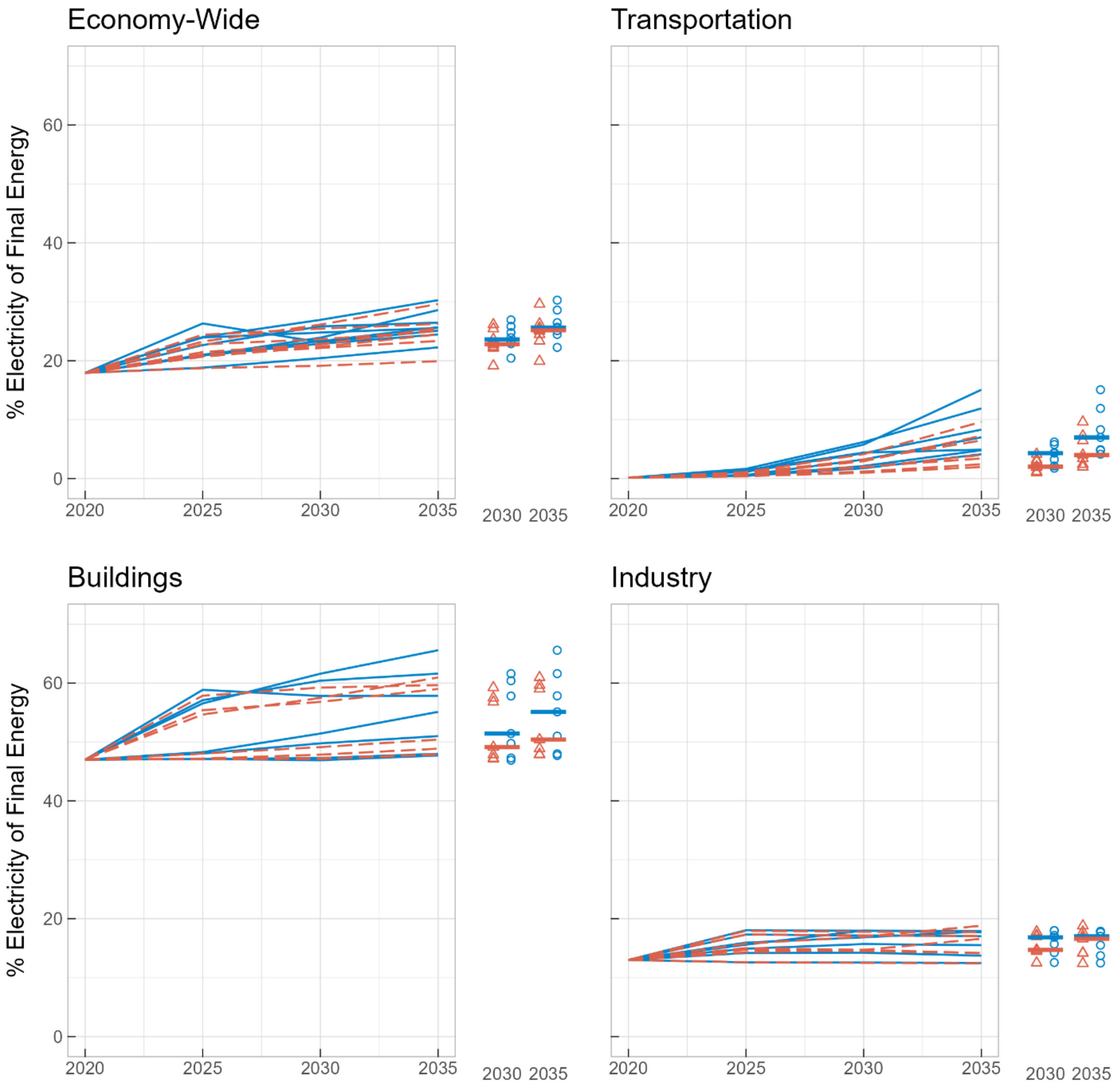


Table F.1.1 Summary of electricity share of final energy.

Sector	Year	No IRA			IRA		
		Min	Median	Max	Min	Median	Max
Economy-Wide	2025	19%	21%	24%	19%	22%	26%
	2030	19%	23%	26%	20%	24%	27%
	2035	20%	25%	30%	22%	26%	30%
Transportation	2025	0%	1%	1%	0%	1%	2%
	2030	1%	2%	4%	2%	4%	6%
	2035	2%	4%	10%	4%	7%	15%
Buildings	2025	47%	48%	58%	47%	48%	59%
	2030	47%	49%	59%	47%	51%	62%
	2035	48%	50%	61%	48%	55%	66%
Industry	2025	13%	15%	18%	13%	16%	18%
	2030	13%	15%	18%	13%	17%	18%
	2035	12%	17%	19%	12%	17%	18%

Table F.1.2 Differences in electricity share of final energy between IRA and No IRA scenarios.

Sector	Year	Percent Difference			Percentage Point Difference		
		Min	Median	Max	Min	Median	Max
Economy-Wide	2025	−2%	1%	16%	-0.47 pp	0.22 pp	3.54 pp
	2030	−3%	4%	13%	-0.66 pp	0.875 pp	2.98 pp
	2035	−3%	5%	12%	-0.71 pp	1.14 pp	3.01 pp
Transportation	2025	2%	30%	91%	0.01 pp	0.19 pp	0.78 pp
	2030	12%	48%	233%	0.23 pp	1.62 pp	3.26 pp
	2035	20%	57%	257%	0.81 pp	1.84 pp	5.46 pp
Buildings	2025	−0%	2%	3%	-0.06 pp	0.86 pp	1.89 pp
	2030	−2%	4%	7%	-1.43 pp	1.92 pp	4.11 pp
	2035	−3%	4%	9%	-1.82 pp	2.14 pp	4.7 pp
Industry	2025	−5%	1%	9%	-0.82 pp	0.11 pp	1.3 pp
	2030	−3%	0%	22%	-0.47 pp	0.06 pp	3.3 pp
	2035	−5%	0%	9%	-0.96 pp	0.06 pp	1.31 pp

F.2 Direct vs Indirect CO_2 Emissions

Appendix F.2 shows CO_2 emissions presented in Figures 1.2, 2.3, 3.3, 4.2, and 5.3, broken out into emissions from electricity and emissions from non-electricity. Blue lines show model results for the IRA scenario and dashed orange lines show results for the No IRA scenario. For each of the figures, individual model results are represented to the right of each panel—blue circles are model results for 2030 and 2035 for the IRA scenario, orange triangles are for the No IRA scenario, and the horizontal bars represent the median of model results.

Figure F.2.1 Economy-wide CO_2 emissions. Left panel for non-electricity includes emissions from fuel combustion and industrial processes in every sector—except for the electricity sector, on the right panel.

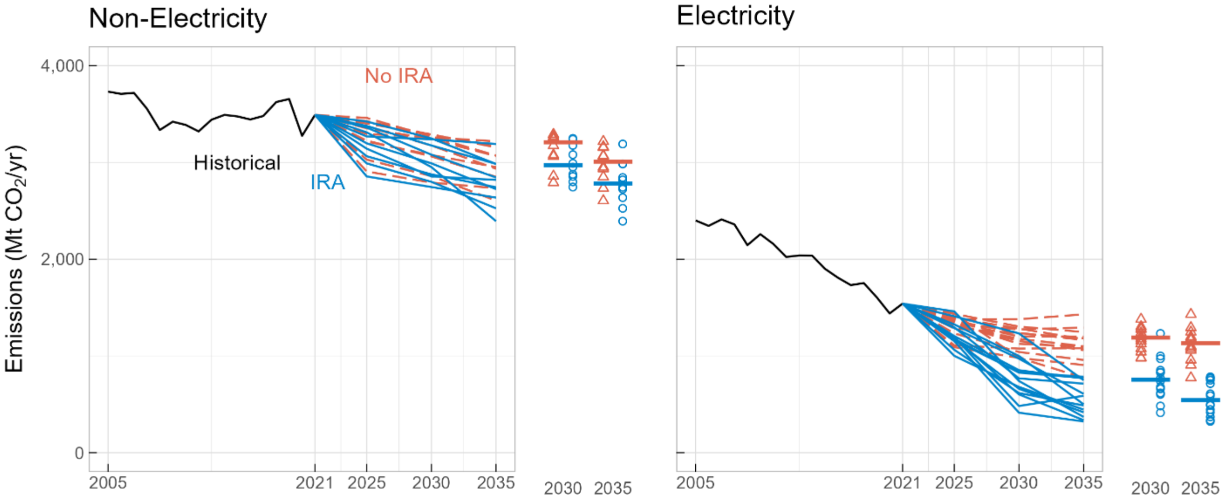


Figure F.2.2 Transportation direct combustion and indirect CO_2 emissions. Horizontal bars to the right of each panel represent the median of model results.

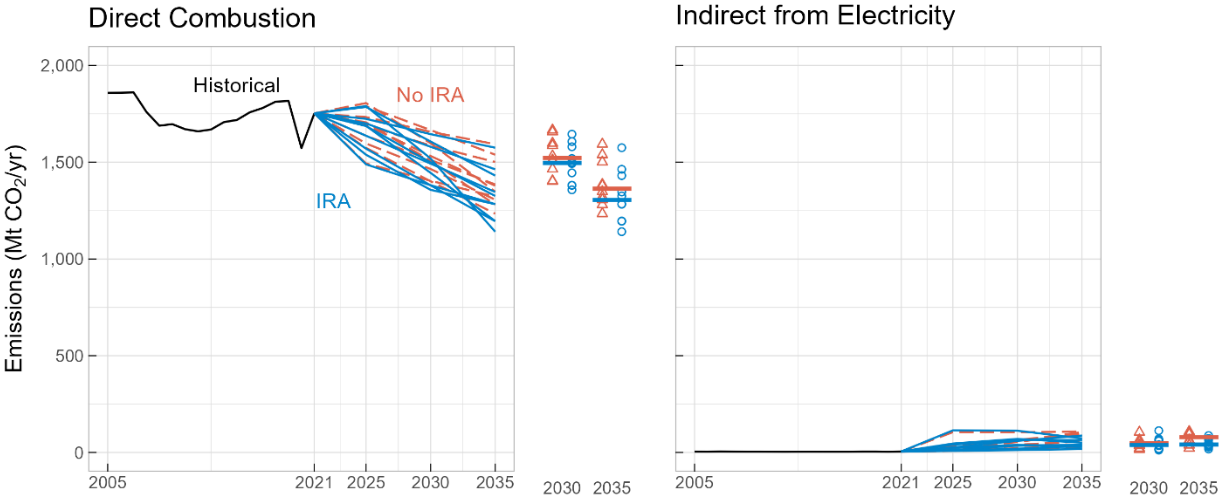


Figure F.2.3 Buildings direct combustion and indirect CO₂ emissions.

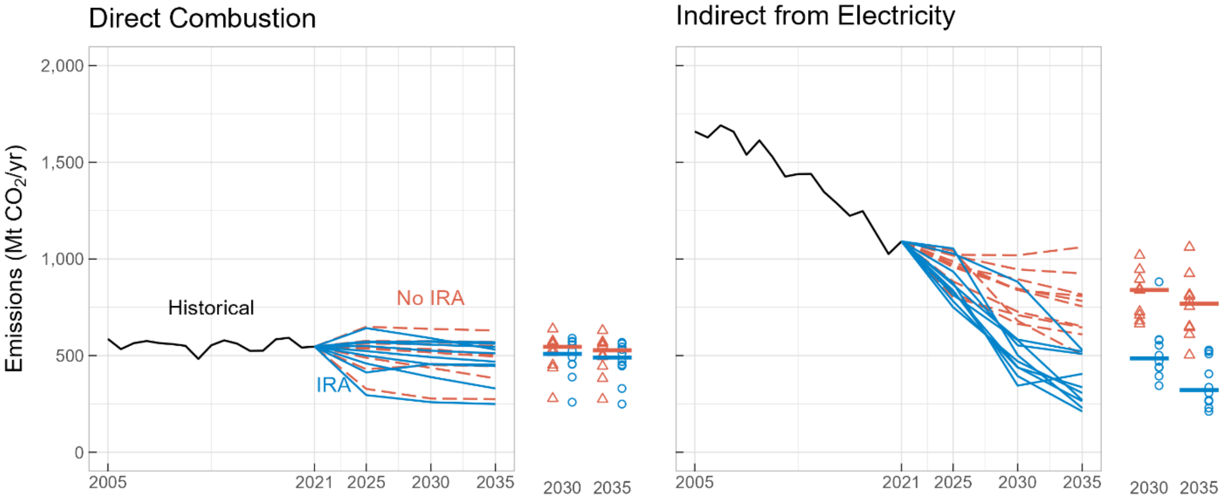
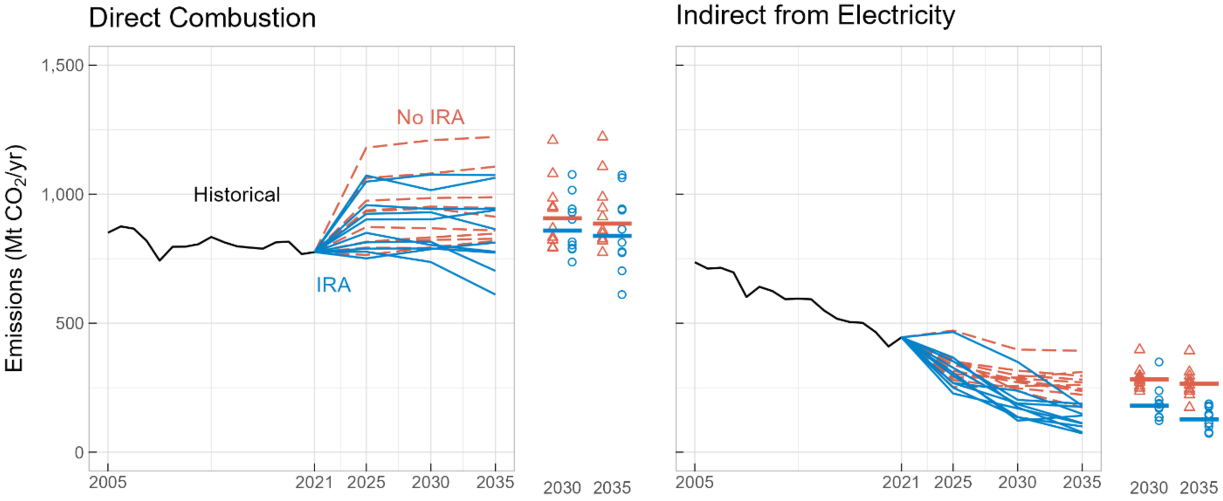


Figure F.2.4 Industry direct combustion and indirect CO₂ emissions.



F.3 Trends in Electricity Generation

Figure F.3.1 Electricity generation (in TWh) by technology and technology type. The horizontal line in each panel represents generation in 2021, the orange dots represent the range of modeled results in the No IRA scenario. The orange and blue dashes represent the mean generation in the No IRA and IRA scenarios, respectively. In the top panel, low or zero-emission generation includes solar, wind, nuclear, biomass, hydro, geothermal, and fossil with CCS, and high emitting generation includes unabated natural gas, coal, and petroleum. In the middle panel, CCS includes all fossil (coal, gas, petroleum) with CCS. In the third panel, other includes hydro, geothermal, and biomass (with and without CCS), and coal and natural gas are unabated.

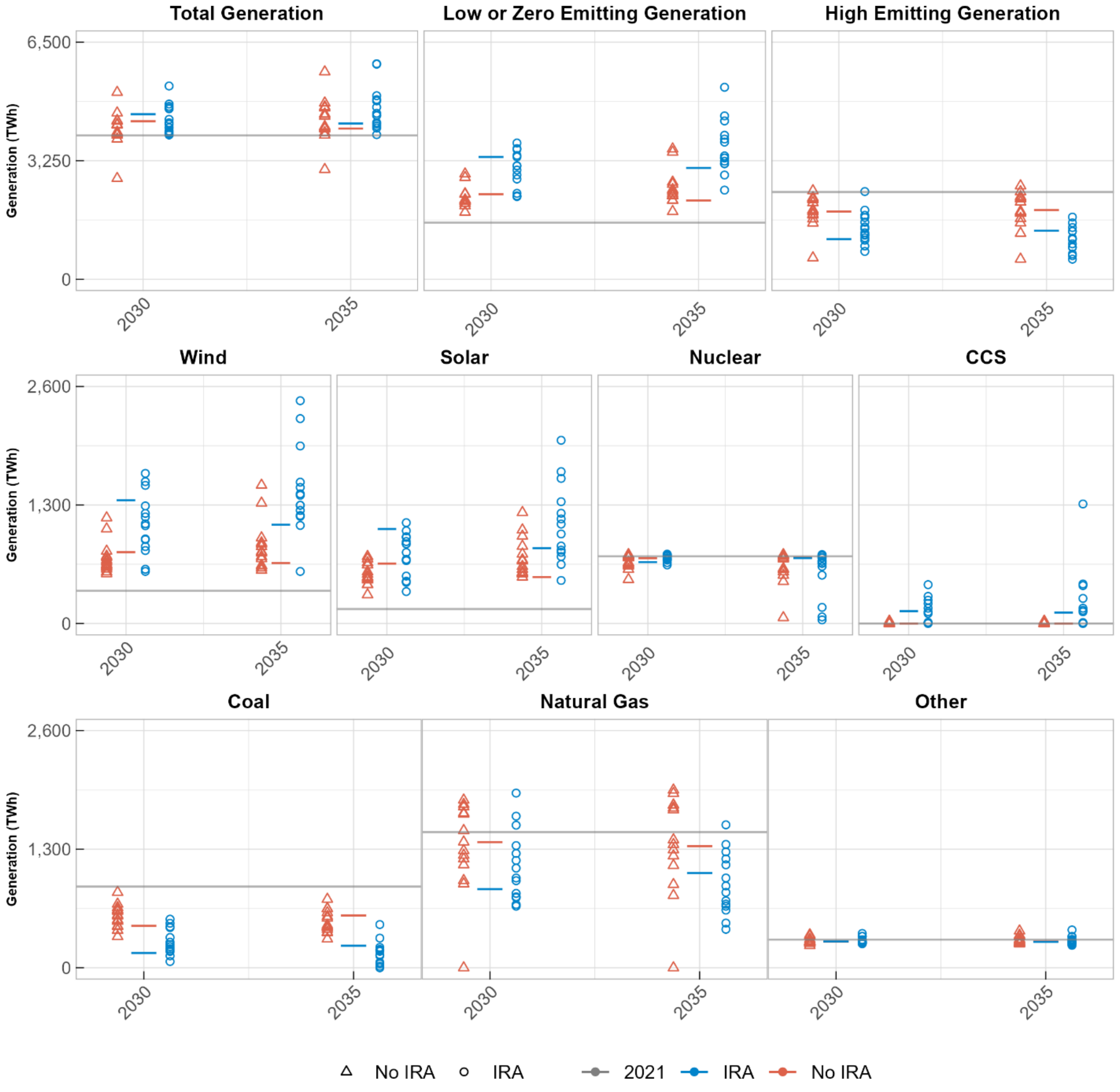
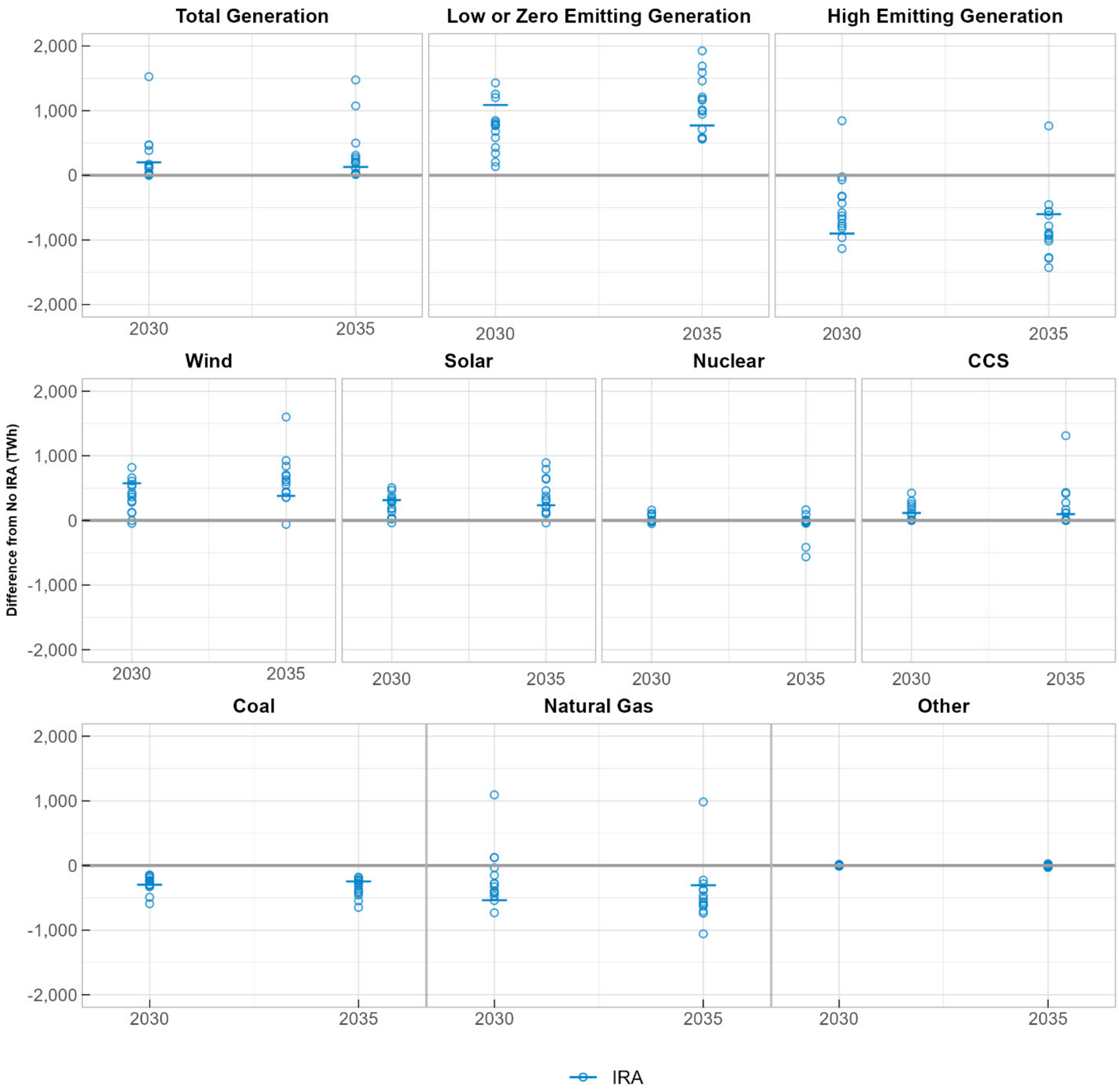


Figure F.3.2 Difference in electricity generation by technology and technology type between the IRA and No IRA scenarios. The blue dots represent the difference between electricity generation in the IRA scenario and No IRA scenario for each model. The blue dashes represent the median difference for the results. In the top panel, low or zero-emission generation includes solar, wind, nuclear, biomass, hydro, geothermal, and fossil with CCS, and high emitting generation includes unabated natural gas, coal, and petroleum. In the middle panel, CCS includes all fossil (coal, gas, petroleum) with CCS. In the third panel, other includes hydro, geothermal, and biomass (with and without CCS), and coal and natural gas are unabated.



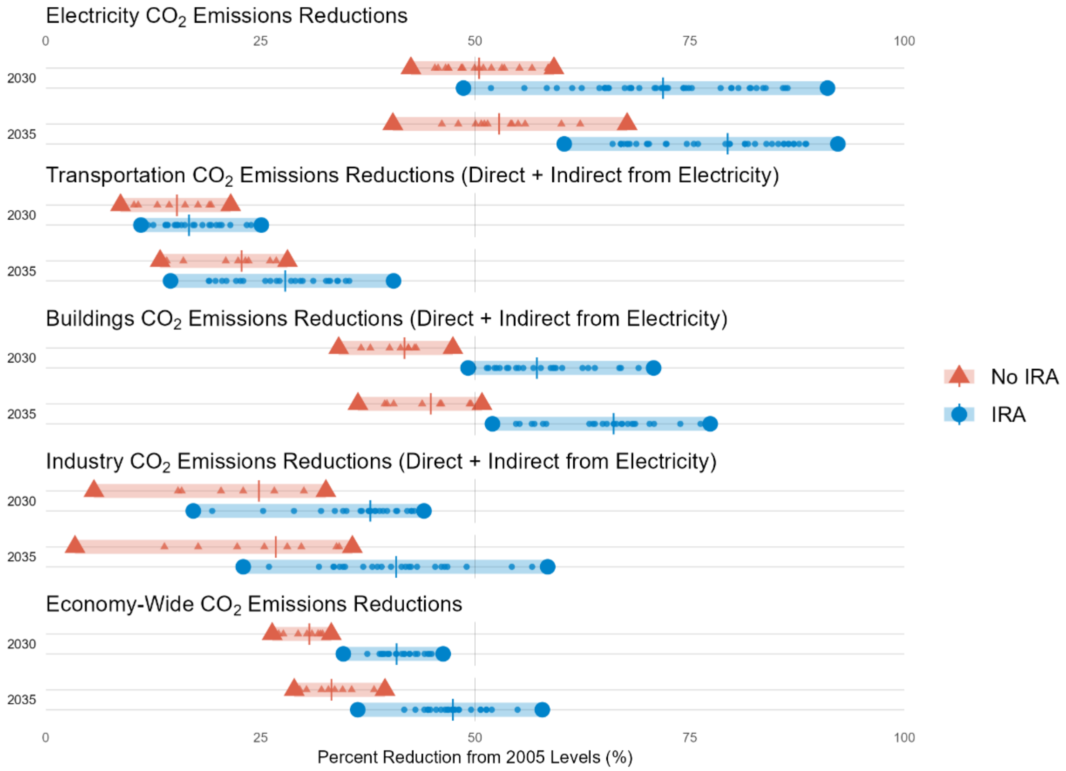
F.4 Sensitivity Analysis

Ranges for the “IRA Moderate Scenario” are those shown in Figure ES.2/1.3. Ranges for the “IRA All Sensitivities” are those shown in Figure F.4.1 and include the Moderate IRA scenario as well as all sensitivity scenarios presented in Figures 1.5 and 2.6. “Range change with inclusion of all sensitivities” presents the changes to the CO_2 emissions reductions from 2005 range when all sensitivity scenarios are included.

Table F.4.1 Summary of CO_2 emissions reductions below 2005 levels for the Moderate IRA scenario only and all IRA sensitivity scenarios.

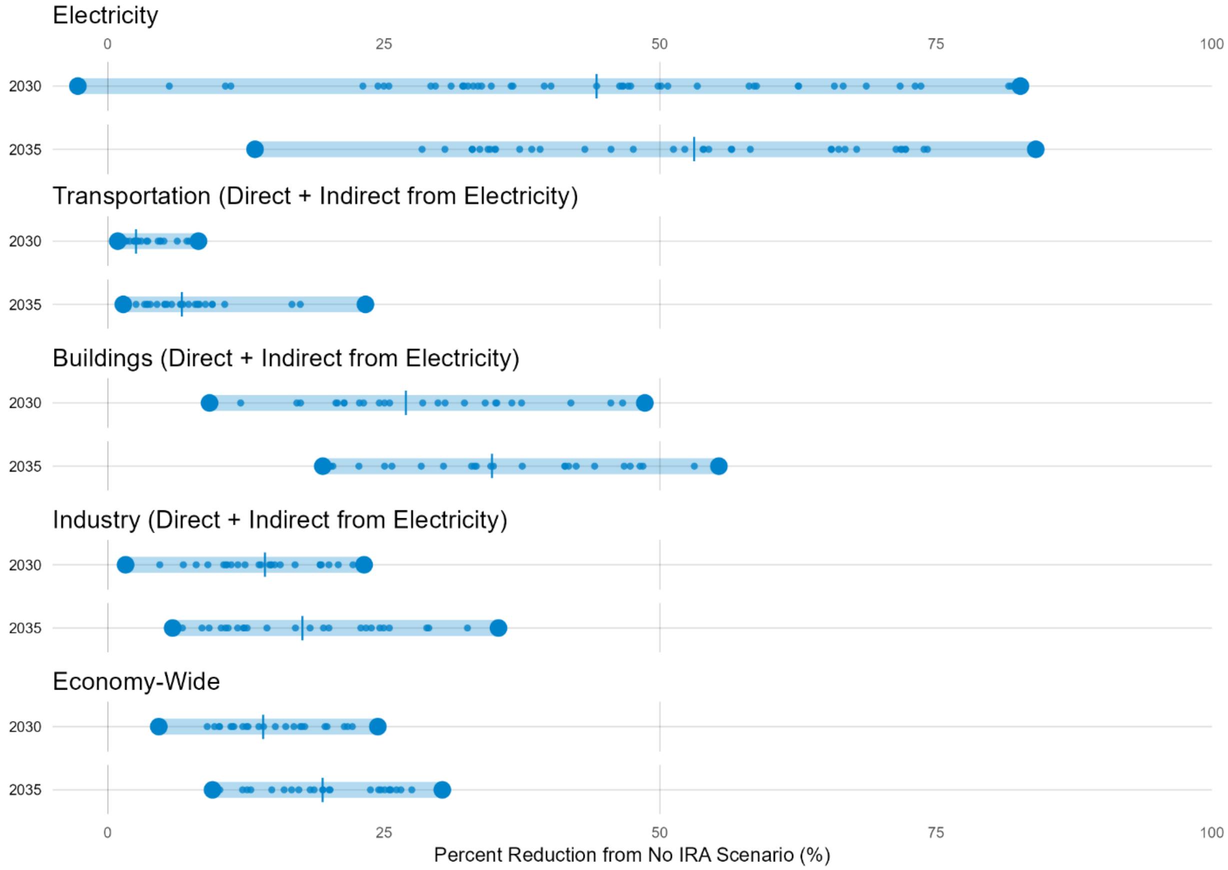
Sector	Year	IRA Moderate Scenario			IRA All Sensitivities			Range Change with Inclusion of Sensitivities		
		Min	Median	Max	Min	Median	Max	Min	Median	Max
Electricity	2030	49%	69%	83%	49%	72%	91%	0%	3%	8%
	2035	67%	77%	87%	60%	79%	92%	-7%	2%	6%
Transportation	2030	11%	17%	25%	11%	17%	25%	0%	-1%	0%
	2035	15%	27%	35%	15%	28%	41%		1%	5%
Buildings	2030	49%	55%	63%	49%	57%	71%	0%	3%	8%
	2035	52%	66%	70%	52%	66%	77%		0%	7%
Industry	2030	17%	36%	43%	17%	38%	44%	0%	2%	1%
	2035	23%	36%	57%	23%	41%	58%		5%	2%
Economy-Wide	2030	35%	39%	43%	35%	41%	46%	0%	1%	3%
	2035	36%	46%	55%	36%	47%	58%		1%	3%

Figure F.4.1 Range of CO_2 emissions reductions across all scenarios including sensitivity cases.



In 2030 under the full range of the IRA scenario economy-wide emissions fall to 35 to 46% (41% median) below 2005 levels; power-sector CO_2 emissions fall to 49 to 91% (72% median) below 2005 levels; transportation sector CO_2 emissions fall to 11 to 25% (17% median) below 2005 levels in 2030; buildings sector CO_2 emissions fall to 49 to 71% (57% median) below 2005 levels; and industry sector CO_2 emissions fall to 17 to 44% (38% median) below 2005 levels. Note that transportation, buildings, and industry emissions include reductions from changes in direct combustion as well as indirect emissions from electricity generation.

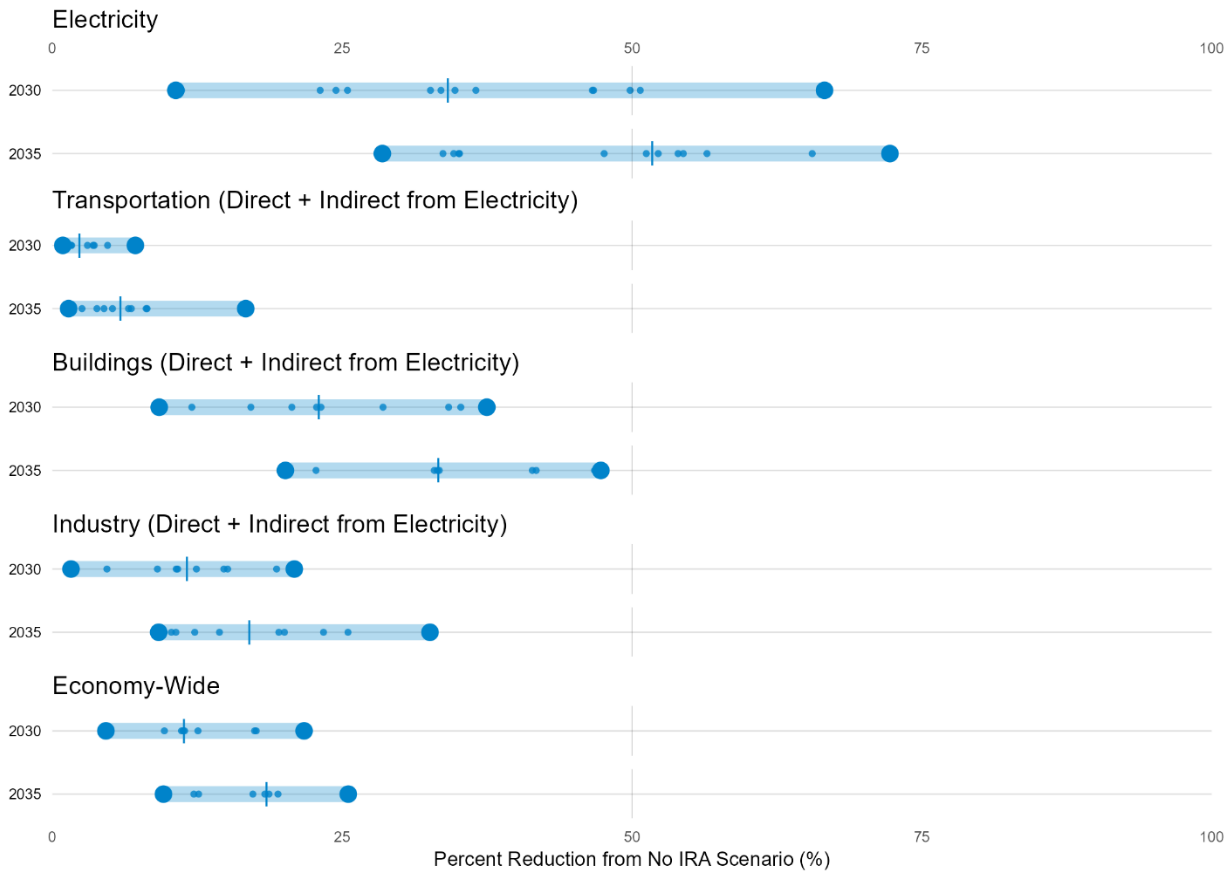
Figure F.4.2 Range of percent reduction of all IRA sensitivity scenarios from the No IRA scenario.



F.5 Summary of Emissions Reduction from No IRA

Appendix F.5 presents the range of percent reduction of the Moderate IRA scenario from the No IRA scenario, summarizing figures 1.2(b), 2.3(b), 3.3(b), 4.2(b), and 5.3(b). See Appendix F.4 for this range inclusive of all IRA sensitivity scenarios.

Figure F.5.1 Range of percent reduction of the Moderate IRA scenario from the No IRA scenario.



Appendix G: Supplemental EPA Analyses

G.1 Buildings Measures

This appendix details the assumptions for and results from the Scout technical scenarios completed by NREL and LBNL for EPA, quantifying the emission impacts of heat pump and building envelope measures. This is discussed in the Chapter 4 text box “Building Sector Measures Incented by IRA.”

Notes on Assumptions:

1. Technical experts across NREL, LBNL, and EPA developed the scenarios to reflect feasible deployment of building envelope measures and heat pumps under IRA, informed by market research. Deployment under the IRA is uncertain and could encompass a wide variety of scenarios.
2. The scenarios analyzed for EPA draw significantly on assumptions developed for Langevin et al. 2022[12].
3. Building efficiency improvements follow the moderate scenario in Table 1 of Langevin et al.:
    - Building technologies with breakthrough performance/cost enter the market by 2035. The Scout assumptions represent emerging heat pump, envelope, and control technologies drawn from DOE roadmaps where available, see Langevin et al. Table 6.
    - Elevated building codes and standards to latest ENERGYSTAR/IECC/90.1 levels take effect in 2030
    - Additional near-term deployment of building envelope/control efficiency measures
4. Assumptions for technology performance improvement over time are shown in Table G.2.
5. Heat pump sales are exogenously specified based on a separate analysis conducted by Guidehouse. Heat pump sales follow the definition provided for Table 7 in Langevin et al.: “Sales shares are relative to total sales of unitary AC equipment plus heat pumps; rates for comparable studies are typically relative to total heating equipment sales. Sales shares are exclusive to heat pumps and do not include electric resistance technologies." The sales assumptions are shown below in Table G.1.
6. For reference, Air-Conditioning, Heating, and Refrigeration Institute (AHRI) reported 42% for residential space heating heat pump sales in 2022. ENERGY STAR reported 2% for residential heat pump water heat sales in 2021. Using a combination of Commercial Buildings Energy Consumption Survey (CBECS) data and AHRI data, commercial space heating sales for 2022 are estimated to be 14%. Using a combination of CBECS and ENERGY STAR data, commercial heat pump water heating sales for 2021 are estimated to be 0.4%.
7. The high scenario is the only scenario that includes accelerated heat pump retrofits before the end of useful life. Early retrofits assumptions are the same as those provided in for Table 8 in Langevin et al. Specifically, it is assumed that the residential HVAC and water heating annual early retrofit rates increase from 0.5% up to 2% by 2035. For commercial, the annual early retrofit rates for HVAC and water heating increase from 0.9% to 3.6% in 2035.
8. The scenarios assume an 80% reduction in grid carbon dioxide emissions vs. 2005 levels by 2050.

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[12] https://escholarship.org/uc/item/6507p161

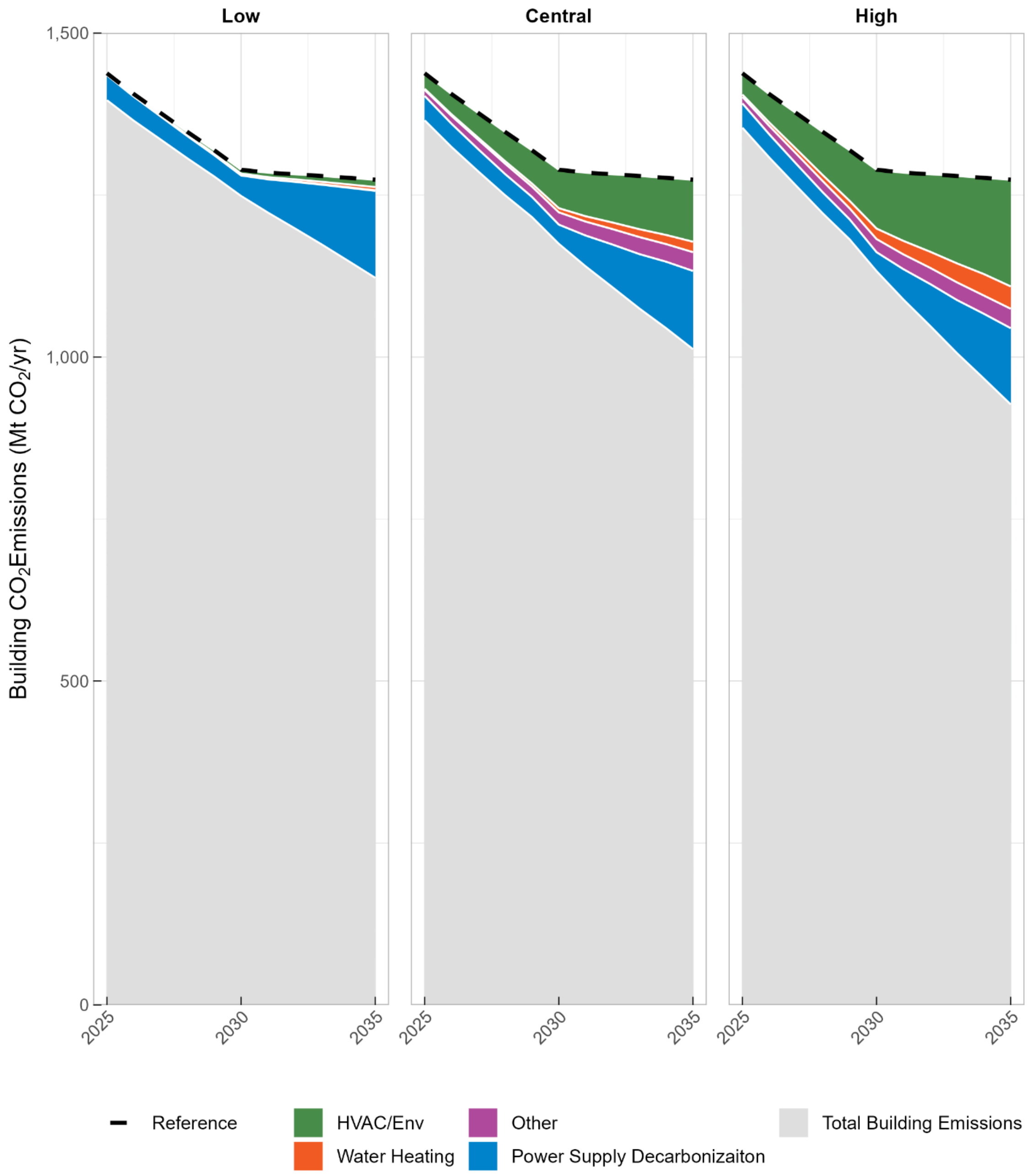
Table G.1.1 Scout analysis efficiency and heat pump assumptions.

Scenario	Building Efficiency Improvements	2030 Heat Pump Sales			
		Residential Space Heating	Residential Water Heating	Commercial Space Heating	Commercial Water Heating
Low	EIA AEO 2022 Reference Case	45%	10%	15%	3%
Central	Moderate Increases from AEO 2022	50%	20%	20%	5%
High	Moderate Increases from AEO 2022	63%	40%	25%	7%

Table G.1.2 Scout analysis technology performance assumptions.

Scenario	Market-Available Technology Performance Range	
	Raise Floor (via building codes and standards)	Raise Ceiling (via market entry of emerging technology)
Low	BAU (AEO 2022 Reference Case)	BAU (AEO 2022 Reference Case)
Central	Moderate Improvement (take effect in 2030)	Moderate Improvement (market entry in 2035)
High	Moderate Improvement (take effect in 2030)	Moderate Improvement (market entry in 2035)

Figure G.1.1 Emissions reductions by end use type from Scout technical scenarios for heat pump and building efficiency deployment. This graph shows the initial trajectory of reductions in the EPA Scout scenarios. Energy efficiency and electrification both contribute to an 50% decrease in emissions from 2005 in the Low Scenario, 52% in the Central Scenario, and 60% in the High scenario by 2035.



G.2 Industrial Measures

In addition to the LEEP Assessment economy-wide modeling of the industrial sector as whole, this appendix discusses supplemental analyses by EPA or researchers working with EPA that specify emissions reduction measures and their impacts in industrial subsectors. This work does not specifically analyze IRA policies but can provide insights to inform IRA implementation.

A key strategy for reducing emissions in the industrial sector involves finding the unique opportunities within the different industrial sectors. As part of an EPA analysis, Worrell and Boyd analyzed industry by sector, and projected significant potential reductions, reducing industrial emissions 86% by 2050. The emission reductions come from a wide range of sources including energy efficiency, material efficiency, and efficient electrification combined with grid decarbonization, and in some cases, technologies like hydrogen and carbon capture applied to specific industries. [13] While Worrell and Boyd did not estimate potential reductions by 2035, they do offer near-term recommendations.

In contrast to the situation in heavy industry, there are many near-term lower-cost reduction opportunities in light industry. Light industry emissions tend to resemble building sector emissions. This resemblance is primarily due to similar levels of combustion of natural gas and electricity consumption, and often heating, cooling, and water heating play significant roles.[14] Similar to buildings, energy efficiency and efficient electrification can deliver significant reductions in the near term. A list of light industry NAICS codes and corresponding energy use can be found below in Table G.2.1.

EPA analysis estimates energy efficiency could deliver 34% of the GHG emission reductions from industry overall. However, many manufacturing companies have not taken important first steps to efficiency savings, such as employing energy managers and conducting energy assessments of their facilities. [15] Projections suggest that these two actions could lower energy intensity of manufacturing plants by 14%, across heavy and light industry. [16] To illustrate, the ENERGY STAR Program saw the cement industry improve energy intensity by 13% between 1997 and 2008, representing 60 trillion Btu in source energy saved, while U.S.-based automobile producers reduced the fossil fuel consumption of their assembly plants by 12% between 2000 and 2005.[17,18] EPA analysis shows that emissions from the energy-intensive industrial sectors fell 26% between 2007-2017, while emissions from manufacturing as a whole fell 5%.[19] Further analysis from Duke University examines CO_2 emissions per dollar of product shipped, using data from the Census of Manufactures by NAICS code. It shows that there are many industries with widely distributed carbon

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[13] Ernst Worrell and Gale Boyd. Bottom-up estimates of deep decarbonization of U.S. manufacturing in 2050. Journal of Cleaner Productions, 2021. https://doi.org/10.1016/j.jclepro.2021.129758.

[14] Ernst Worrell and Gale Boyd. Bottom-up estimates of deep decarbonization of U.S. manufacturing in 2050. Journal of Cleaner Productions, 2021. https://doi.org/10.1016/j.jclepro.2021.129758.

[15] Gale Boyd, E. M. C., Su Zhang (2021). Impact of Strategic Energy Management Practices on Energy Efficiency: Evidence from Plant-Level Data. Summer Study on Energy Efficiency in Industry 2021, Virtual, ACEEE.

[16] Gale Boyd, E. M. C., Su Zhang (2021). Impact of Strategic Energy Management Practices on Energy Efficiency: Evidence from Plant-Level Data. Summer Study on Energy Efficiency in Industry 2021, Virtual, ACEEE.

[17] https://www.energystar.gov/industrial_plants/measure-track-and-benchmark/energy-star-energy-1

[18] https://www.energystar.gov/buildings/tools-and-resources/assessing-improvement-energy-efficiency-us-auto-assembly-plants

[19] Creason, Jared, Jameel Alsalam, Kong Chiu, and Allen A. Fawcett, 2021. Energy Intensive Manufacturing Industries and GHG Emissions. Climate Change Economics, 12(3) DOI: 10.1142/S201000782150010X

intensities across different plants, implying that some plants in these industries have been able to significantly reduce emissions while others in the sector can do the same.[20]

The ENERGY STAR Program has also found specific near-term opportunities for improvement in light industry energy efficiency through benchmarking and basic energy management. Light manufacturing plants that participated in the ENERGY STAR Program's Challenge for Industry, on average, achieved a 20% reduction in energy intensity within two years.[21] Light industry has significant efficient electrification opportunities, including process and building heating requirements. Burners and fired heaters can be replaced with electrically supplied equipment, including heat pumps.

EPA analysis also shows opportunity for electrification, particularly for light industry. Decarbonization of electricity used within the sector has a meaningful effect on indirect emissions, again with light industry playing a significant role. Light industry only uses 12% of total manufacturing energy, but 44% of manufacturing electricity. Some companies, particularly those that are consumer facing (which many light industrial companies are), may have incentives to actively pursue renewable energy power purchases over and above reductions in emissions from grid power.[22]

EPA analysis shows light industry and bulk chemical manufacturing are the sectors with the greatest potential for significant reductions from energy efficiency and electrification. Substantial efficiency reductions can also be found in refining, paper, and iron and steel. Aluminum and glass, iron and steel, and paper have potential for substantial reductions from electrification. While refining and cement have more limited electrification potential, they have substantial potential for emissions reductions through material efficiency and carbon capture, use, and storage (CCUS).[23]

Possible constraints to such electrification in the near term include necessary infrastructure upgrades and capital turnover. The infrastructure issues reflect the fact that complete electrification would double light industry electricity use; the ability to reliably deliver that additional power to manufacturing plants would be a significant concern to industry. Capital turnover would also impact the speed of any electrification since businesses are unlikely to retire equipment early. In addition, policy needs to be nimble to offer incentives when that turnover window opens for equipment to be replaced. If that window closes, then the opportunity may not present itself again for many years.

The key barriers to energy efficiency and efficient electrification in industry include technology costs, lack of equipment supply, incompatibility of new equipment with existing plants, insufficient electrical supply to meet industry's needs, and lack of sufficient grid infrastructure to deliver the needed power supply. In concert with IRA incentives, IRA programs can help address these industry-specific barriers.

Overall, to achieve substantial goals in the long-term, efficiency and electrification will need to be complemented with other technologies to reduce the carbon impact of fossil fuel use and the emissions impact of other industrial processes. Combined heat and power has been an important complementary technology in industries like chemicals, refining, food

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20 Boyd et al (2011) Preliminary Analysis of the Distributions of Carbon and Energy Intensity for 27 Energy Intensive Trade Exposed Industrial Sectors, Duke University Working Paper EE 11-03, https://sites.nicholasinstitute.duke.edu/environmentaleconomics/wp-content/uploads/sites/3/2016/03/WP-EE-11-03.pdf

[21] https://www.energystar.gov/industrial_plants/results_energy_star_challenge_industry_2010_through_2020

[22] Ernst Worrell and Gale Boyd. Bottom-up estimates of deep decarbonization of U.S. manufacturing in 2050. Journal of Cleaner Productions, 2021. https://doi.org/10.1016/j.jclepro.2021.129758.. Detailed table is provided in Appendix D.

[23] Ernst Worrell and Gale Boyd. Bottom-up estimates of deep decarbonization of U.S. manufacturing in 2050. Journal of Cleaner Productions, 2021. https://doi.org/10.1016/j.jclepro.2021.129758.. Detailed table is provided in Appendix D.

processing, metals, and paper—providing significant efficiencies in on-site heat and power production.[24] On-site renewables, including biomass and geothermal, can also provide electricity and replace fossil combustion needs in whole or in part. High-temperature processes will still need some type of on-side fuel combustion. CCUS is a potential solution to mitigate fossil combustion as well as the bulk of process emissions from cement production. Hydrogen is another potential low-GHG fuel under study for high-temperature industrial processes. Most of these technologies can benefit from near-term Research Development Demonstration & Deployment (RDD&D) to scale up to a level of deployment that delivers significant reductions.

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[24] https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/CHP_Technical_Potential_Study.pdf

Table G.2.1 Light Industry by NAICS with associated energy use (source: First Use of Energy for All Purposes (Fuel and Nonfuel), EIA Manufacturing Energy Consumption Survey 2018). Units are trillion Btu.

NAICS Code	Subsector and Industry	Total	Net Electricit y	Natural Gas	Other[25]
3115	Dairy Product	124	39	81	4
3116	Animal Slaughtering and Processing	278	108	151	19
312	Beverage and Tobacco Products	118	49	54	15
3121	Beverages	111	46	50	15
3122	Tobacco	7	3	4	0
313	Textile Mills	64	37	23	4
314	Textile Product Mills	22	10	11	1
315	Apparel	4	2	2	0
316	Leather and Allied Products	2	1	1	0
321	Wood Products	388	71	68	
323	Printing and Related Support	60	34	25	1
3254	Pharmaceuticals and Medicines	115	36	63	16
326	Plastics and Rubber Products	257	168	84	5
332	Fabricated Metal Products	257	124	126	7
333	Machinery	148	80	61	7
334	Computer and Electronic Products	110	76	33	1
335	Electrical Equip., Appliances, and Components	85	38	37	10
336	Transportation Equipment	348	172	159	17
337	Furniture and Related Products	37	16	15	6
339	Miscellaneous	61	33	26	2
	Total of non-energy intensive industry	2,347	1,143	1,074	130
	Share of total	12%	44%	15%	1%

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[25] Other includes HGL (excluding natural gasoline), Coke, Coal, Breeze, and waste-derived fuels.

Appendix H: Peer Review Process

Peer Review of the Report

Consistent with guidelines described in EPA's Peer Review Handbook,[26,27] this report was subject to an independent, external expert peer review that concluded in August 2023. The peer review documentation is available at EPA's Science Inventory.[28]

Expert Peer Review

The expert review was managed by a contractor (RTI International) under the direction of a designated independent EPA peer review leader, who prepared a peer review plan, the scope of work for the review contract, and the charge for the reviewers. Reviewers worked individually (i.e., without contact with other reviewers, colleagues, or EPA) to prepare written comments in response to the charge questions.

The contractor identified, screened, and selected six reviewers who had no conflict of interest in performing the review, and who collectively met the technical selection criteria provided by EPA. The peer review charge directed reviewers to provide responses to the following questions during the main review:

1. Are the writing level and graphics appropriate for an educated but general audience including stakeholders and decision-makers?
2. Do the text, figures, and tables in the sector specific chapters clearly communicate the modeling results? If not, please provide recommendations for improvement. Note that Appendices [E and F] contains additional figures and alternative figure styles.
3. Does the executive summary provide sufficient context to understand the synthesized results?
4. Does the introductory chapter clearly explain the purpose of the report and provide appropriate context for the sector chapter results?
5. Does the introductory chapter adequately explain the overall analytic framework of the project?
6. Are the inputs and scenarios clearly explained and documented in the introduction? If not, please provide recommendations for improvement.
7. Is the cited literature accurately represented?
8. Are there any additional relevant data sources that are not included but could be incorporated into this analysis?
9. The analysis presented in this report is multi-faceted, using results from several sophisticated multi-sector and single-sector energy-economy models. Is the use of a multi-model approach, incorporating multi-sector and power sector models, appropriate to estimate the potential

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[26] EPA, 2015: Peer Review Handbook, 4th Edition, 2015. United States Environmental Protection Agency, Programs of the Office of the Science Advisor. Available online at https://www.epa.gov/osa/peer-review-handbook-4th-edition-2015.

[27] EPA has determined that this report falls under the classification of "influential scientific information," as defined by OMB and further described in the EPA Peer Review Handbook. This product is for science dissemination and communication purposes only and does not reflect analysis of nor recommendations regarding any particular policy.

[28] https://cfpub.epa.gov/si/

effects of the energy- and climate-related provisions of the IRA? If not, please suggest other approaches.

10. Does the report provide an assessment of reductions in greenhouse gas emissions that result from changes in domestic electricity generation and use due to the Inflation Reduction Act of 2022 that are anticipated to occur on an annual basis through fiscal year 2031?
11. Is the draft report missing important findings or messages based on your review?
12. Do you have any recommendations for any key research that could be discussed but is not mentioned? Do you have recommendations for future updates to the report that EPA should consider?