Net-Zero America - north dakota state report v2

Larson et al. 2020

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Reading guide

IN DRAFT

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Table 1: *E- scenario - PILLAR 1: Efficiency/Electrification - Residential*

variable_name	2020	2025	2030	2035	2040	2045	2050
Residential HVAC investment in 2020s vs. REF - Cumulative 5-yr	0	0.501	0.505	0	0	0	0
Sale of space heating units by type - Electric Heat Pump	0.082	0.128	0.129	0.132	0.136	0.142	0.148
Sale of space heating units by type - Electric Resistance	0.285	0.338	0.336	0.334	0.328	0.324	0.319
Sale of space heating units by type - Fossil	0.138	0.183	0.171	0.162	0.159	0.156	0.158
Sale of space heating units by type - Gas	0.496	0.351	0.363	0.372	0.377	0.378	0.376
Sales of cooking units - Electric Resistance	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Sales of cooking units - Gas	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Sales of water heating units by type - Electric Heat Pump	0	0	0	0	0	0	0
Sales of water heating units by type - Electric Resistance	0.524	0.669	0.669	0.667	0.667	0.666	0.665
Sales of water heating units by type - Gas Furnace	0.476	0.331	0.331	0.333	0.333	0.334	0.334
Sales of water heating units by type - Other	0	0	0	0	0	0	0

Table 2: *E- scenario - PILLAR 1: Efficiency/Electrification - Transportation*

variable_name	2020	2025	2030	2035	2040	2045	2050
End-use technology sales by technology - HDV - diesel	0.981	0.982	0.979	0.97	0.956	0.935	0.916
End-use technology sales by technology - HDV - EV	0	0	0	0	0	0	0
End-use technology sales by technology - HDV - gasoline	0.002	0.002	0.003	0.003	0.003	0.003	0.003
End-use technology sales by technology - HDV - hybrid	0.001	0.001	0.001	0.001	0.002	0.002	0.002
End-use technology sales by technology - HDV - hydrogen FC	0.001	0.001	0.002	0.002	0.002	0.002	0.003
End-use technology sales by technology - HDV - other	0.015	0.013	0.016	0.024	0.037	0.057	0.076
End-use technology sales by technology - LDV - diesel	0.02	0.023	0.023	0.021	0.019	0.018	0.017
End-use technology sales by technology - LDV - EV	0.022	0.039	0.045	0.054	0.066	0.079	0.09
End-use technology sales by technology - LDV - gasoline	0.925	0.893	0.878	0.865	0.848	0.829	0.812
End-use technology sales by technology - LDV - hybrid	0.031	0.04	0.05	0.055	0.062	0.069	0.077
End-use technology sales by technology - LDV - hydrogen FC	0.001	0.004	0.004	0.003	0.003	0.003	0.004
End-use technology sales by technology - LDV - other	0.001	0.001	0.001	0.001	0.001	0.001	0.001
End-use technology sales by technology - MDV - diesel	0.652	0.635	0.616	0.596	0.58	0.565	0.552
End-use technology sales by technology - MDV - EV	0	0.001	0.003	0.007	0.009	0.01	0.01
End-use technology sales by technology - MDV - gasoline	0.34	0.355	0.37	0.385	0.397	0.408	0.417
End-use technology sales by technology - MDV - hybrid	0.004	0.004	0.005	0.006	0.007	0.008	0.009
End-use technology sales by technology - MDV - hydrogen FC	0.002	0.002	0.002	0.003	0.003	0.004	0.005
End-use technology sales by technology - MDV - other	0.003	0.003	0.003	0.003	0.004	0.005	0.007

Table 3: *E- scenario - PILLAR 6: Land carbon sinks - Agriculture*

variable_name	2020	2030	2050
Carbon sink enhancement potential - Accelerate regeneration	0	0	67.405
Carbon sink enhancement potential - All (not counting overlap)	0	0	39624.4
Carbon sink enhancement potential - Avoid deforestation	0	0	1300.599
Carbon sink enhancement potential - Extend rotation length	0	0	699.924
Carbon sink enhancement potential - Improve plantations	0	0	35.946
Carbon sink enhancement potential - Increase retention of HWP	0	0	69.105
Carbon sink enhancement potential - Increase trees outside forests	0	0	5597.7
Carbon sink enhancement potential - Reforest cropland	0	0	23425.1
Carbon sink enhancement potential - Reforest pasture	0	0	8110.5
Carbon sink enhancement potential - Restore productivity	0	0	318.074
Land impacted for carbon sink enhancement - Accelerate regeneration	0	0	27.167
Land impacted for carbon sink enhancement - All (not counting overlap)	0	0	8665.7
Land impacted for carbon sink enhancement - Avoid deforestation	0	0	349.128
Land impacted for carbon sink enhancement - Extend rotation length	0	0	385.575
Land impacted for carbon sink enhancement - Improve plantations	0	0	19.978
Land impacted for carbon sink enhancement - Increase retention of HWP	0	0	13.821
Land impacted for carbon sink enhancement - Increase trees outside forests	0	0	1579.088
Land impacted for carbon sink enhancement - Natural uptake	-1.19	0.158	0.045
Land impacted for carbon sink enhancement - Reforest cropland	0	0	7799.161
Land impacted for carbon sink enhancement - Reforest pasture	0	0	613.276
Land impacted for carbon sink enhancement - Restore productivity	0	0	179.492
Land impacted for carbon sink enhancement - Retained in Hardwood Products	-0.011	-0.023	-0.025
Land impacted for carbon sink enhancement - Total	-1.201	0.135	0.021
Land impacted for carbon sink enhancement - Total impacted (over 30 years)	0	0	2300.87

Table 4: *E- scenario - PILLAR 6: Land carbon sinks - Forests*

variable_name	2050
Business-as-usual carbon sink - Accelerate regeneration	6.299
Business-as-usual carbon sink - Avoid deforestation	111.216
Business-as-usual carbon sink - Extend rotation length	210.936
Business-as-usual carbon sink - Improve plantations	7.586

Table 4: *E- scenario - PILLAR 6: Land carbon sinks - Forests (continued)*

variable_name	2050
Business-as-usual carbon sink - Increase retention of HWP	0
Business-as-usual carbon sink - Increase trees outside forests	317.485
Business-as-usual carbon sink - Reforest cropland	885.009
Business-as-usual carbon sink - Reforest pasture	149.823
Business-as-usual carbon sink - Restore productivity	63.186
Business-as-usual carbon sink - Total impacted (over 30 years)	885.009

Table 5: *E- scenario - PILLAR 1: Efficiency/Electrification - Overview*

variable_name	2020	2025	2030	2035	2040	2045	2050
Final energy demand by sector - commercial	0.025	0.025	0.025	0.025	0.025	0.025	0.026
Final energy demand by sector - industry	0.124	0.133	0.138	0.143	0.148	0.154	0.16
Final energy demand by sector - residential	0.038	0.037	0.036	0.035	0.035	0.034	0.034
Final energy demand by sector - transportation	0.104	0.098	0.092	0.088	0.088	0.091	0.094

Table 6: *E- scenario - PILLAR 1: Efficiency/Electrification - Commercial*

variable_name	2020	2025	2030	2035	2040	2045	2050
Commercial HVAC investment in 2020s - Cumulative 5-yr	0	2141310371	2214865380	0	0	0	0
Sales of cooking units - Electric Resistance	0.448	0.478	0.479	0.478	0.479	0.479	0.48
Sales of cooking units - Gas	0.552	0.522	0.521	0.522	0.521	0.521	0.52
Sales of space heating units - Electric Heat Pump	0.061	0.092	0.325	0.593	0.676	0.691	0.694
Sales of space heating units - Electric Resistance	0.1	0.07	0.138	0.236	0.293	0.301	0.301
Sales of space heating units - Fossil	0.098	0.028	0.023	0.011	0.002	0	0
Sales of space heating units - Gas Furnace	0.741	0.81	0.514	0.16	0.029	0.008	0.005
Sales of water heating units - Electric Heat Pump	0.016	0.008	0.008	0.008	0.008	0.008	0.008
Sales of water heating units - Electric Resistance	0.136	0.072	0.072	0.071	0.071	0.071	0.071
Sales of water heating units - Gas Furnace	0.821	0.91	0.91	0.91	0.91	0.91	0.91
Sales of water heating units - Other	0.027	0.01	0.01	0.01	0.01	0.01	0.01

Table 7: *E- scenario - PILLAR 1: Efficiency/Electrification - Electricity demand*

variable_name	2025	2030	2035	2040	2045	2050
Electricity distribution peak load (capital invested) - Cumulative 5-yr	0.725	0.744	0.892	0.926	0.943	0.974

Table 8: *RE- scenario - PILLAR 1: Efficiency/Electrification - Residential*

variable_name	2020	2025	2030	2035	2040	2045	2050
Residential HVAC investment in 2020s vs. REF - Cumulative 5-yr	0	0.514	0.598	0	0	0	0
Sale of space heating units by type - Electric Heat Pump	0.084	0.129	0.259	0.585	0.84	0.88	0.879
Sale of space heating units by type - Electric Resistance	0.284	0.341	0.309	0.194	0.101	0.088	0.089
Sale of space heating units by type - Fossil	0.137	0.183	0.143	0.08	0.033	0.024	0.025
Sale of space heating units by type - Gas	0.495	0.346	0.289	0.141	0.026	0.009	0.007
Sales of cooking units - Electric Resistance	0.802	0.844	0.973	0.999	1	1	1
Sales of cooking units - Gas	0.198	0.156	0.027	0.001	0	0	0
Sales of water heating units by type - Electric Heat Pump	0	0.002	0.035	0.143	0.219	0.23	0.231
Sales of water heating units by type - Electric Resistance	0.524	0.669	0.677	0.716	0.761	0.768	0.768
Sales of water heating units by type - Gas Furnace	0.476	0.328	0.288	0.14	0.02	0.002	0
Sales of water heating units by type - Other	0	0	0	0	0	0	0

Table 9: *RE- scenario - PILLAR 1: Efficiency/Electrification - Transportation*

variable_name	2020	2025	2030	2035	2040	2045	2050
End-use technology sales by technology - HDV - diesel	0.972	0.921	0.67	0.233	0.042	0.006	0
End-use technology sales by technology - HDV - EV	0.006	0.038	0.19	0.456	0.574	0.596	0.6
End-use technology sales by technology - HDV - gasoline	0.002	0.002	0.002	0.001	0	0	0
End-use technology sales by technology - HDV - hybrid	0.001	0.001	0.001	0	0	0	0
End-use technology sales by technology - HDV - hydrogen FC	0.004	0.025	0.127	0.304	0.382	0.397	0.4
End-use technology sales by technology - HDV - other	0.015	0.012	0.011	0.006	0.002	0	0
End-use technology sales by technology - LDV - diesel	0.02	0.022	0.014	0.005	0.001	0	0
End-use technology sales by technology - LDV - EV	0.026	0.111	0.399	0.792	0.96	0.993	1
End-use technology sales by technology - LDV - gasoline	0.922	0.827	0.556	0.192	0.036	0.006	0
End-use technology sales by technology - LDV - hybrid	0.031	0.036	0.027	0.011	0.003	0.001	0
End-use technology sales by technology - LDV - hydrogen FC	0.001	0.004	0.002	0.001	0	0	0
End-use technology sales by technology - LDV - other	0.001	0.001	0.001	0	0	0	0
End-use technology sales by technology - MDV - diesel	0.647	0.597	0.423	0.144	0.026	0.004	0
End-use technology sales by technology - MDV - EV	0.008	0.051	0.253	0.608	0.765	0.795	0.8
End-use technology sales by technology - MDV - gasoline	0.337	0.333	0.255	0.093	0.018	0.003	0
End-use technology sales by technology - MDV - hybrid	0.004	0.004	0.003	0.001	0	0	0
End-use technology sales by technology - MDV - hydrogen FC	0.002	0.013	0.063	0.152	0.191	0.199	0.2
End-use technology sales by technology - MDV - other	0.003	0.003	0.002	0.001	0	0	0
Light-duty vehicle capital costs - Cumulative 5-yr	0	173140424	442253240	719123902	1088354036	1185593102	1129819150
Number of public EV charging plugs - DC Fast Charging	24	0	352.646	0	1570.6	0	2543.8
Number of public EV charging plugs - L2 Charging	43	0	8487.2	0	37798.7	0	61221.7

Table 10: *RE- scenario - PILLAR 2: Clean Electricity - Generating capacity*

variable_name	2020	2025	2030	2035	2040	2045	2050
Power generation capital investment - biomass power plant	0	0	0	0	0	0	0
Power generation capital investment - biomass w/ccu allam power plant	0	0	0	0.024	0	0.007	0
Power generation capital investment - biomass w/ccu power plant	0	0	0.081	0	0	0.013	0
Power generation capital investment - Wind - Base	0	0	0	0.287	0.603	3.222	9.019
Power generation capital investment - Wind - Constrained	0	0.092	1.877	4.94	9.394	26.798	72.792

Table 11: *RE- scenario - PILLAR 2: Clean Electricity - Generation*

variable_name	2020	2025	2030	2035	2040	2045	2050
Power generation by technology - biomass power plant	0	0	0	0	0	0	0
Power generation by technology - biomass w/ccu allam power plant	0	0	0	23.917	23.917	30.806	30.806
Power generation by technology - biomass w/ccu power plant	0	0	90.714	90.714	90.714	104.903	104.903

Table 12: *RE- scenario - PILLAR 2: Clean Electricity - Transmission*

variable_name	2020	2025	2030	2035	2040	2045	2050
HV transmission for wind and solar - base all	0	113.253	113.253	261.426	699.139	2631.8	5686.8
HV transmission for wind and solar - base other intra-state	0	0	0	0	0	0	0
HV transmission for wind and solar - base spur intra-state	0	20.541	20.541	42.646	92.823	229.03	831.93
HV transmission for wind and solar - constrained all	0	678.083	1438.2	5399.7	8613.8	19841.5	53453.7
HV transmission for wind and solar - constrained other intra-state	0	0	0	0	0	0	0
HV transmission for wind and solar - constrained spur intra-state	0	153.003	201.936	458.266	1128.6	3959.5	12594.2

Table 13: *RE- scenario - PILLAR 3: Bioenergy and Hydrogen - Bioconversion*

variable_name	2020	2025	2030	2035	2040	2045	2050
Biomass purchases	0	0	0.005	0.386	0.499	0.574	0.964
Capital investment	0	0	0.07	0	6.682	0	6.284
Number of facilities - allam power w ccu	0	0	0	1	1	2	2
Number of facilities - beccs hydrogen	0	0	0	7	10	13	17
Number of facilities - diesel	0	0	0	0	0	0	0
Number of facilities - diesel ccu	0	0	0	1	2	3	3
Number of facilities - power	0	0	0	0	0	0	0
Number of facilities - power ccu	0	0	1	1	1	2	2
Number of facilities - pyrolysis	0	0	0	0	0	0	0
Number of facilities - pyrolysis ccu	0	0	0	1	2	3	3
Number of facilities - sng	0	0	0	0	0	0	0
Number of facilities - sng ccu	0	0	1	1	1	2	2

Table 14: *RE- scenario - PILLAR 4: CO2 capture, use, storage - CO2 capture*

variable_name	2025	2030	2035	2040	2045	2050
Annual - All	0	0.09	7.12	9.17	10.54	17.7
Annual - BECCS	0	0.09	7.08	9.15	10.52	17.69
Annual - Cement	0	0	0	0	0	0
Annual - NGCC	0	0	0.03	0.03	0.02	0.01
Cumulative - All	0	0.09	7.21	16.38	26.92	44.62
Cumulative - BECCS	0	0.09	7.17	16.32	26.84	44.53
Cumulative - Cement	0	0	0	0	0	0
Cumulative - NGCC	0	0	0.03	0.06	0.08	0.09

Table 15: *RE- scenario - PILLAR 4: CO2 capture, use, storage - CO2 storage*

variable_name	2025	2030	2035	2040	2045	2050
Annual	0	2.19	6.17	11.74	18.94	25.16
Injection wells	0	4	15	26	44	54
Resource characterization, appraisal and permitting costs cumulative	135.4	406.22	541.62	541.62	541.62	541.62
Wells and facilities construction costs cumulative	0	112.7	439.21	782.71	1308.8	1624.9

Table 16: *RE- scenario - PILLAR 4: CO2 capture, use, storage - CO2 transportation*

variable_name	2025	2030	2035	2040	2045	2050
CO2 pipelines - All	0	416610.12	2906950	3055767.2	3388361.1	4472970.5
CO2 pipelines - Spur	0	217030.006	1180072.1	1328889.3	1661483.2	2746092.6
CO2 pipelines - Trunk	0	199580.014	1726877.9	1726877.9	1726877.9	1726877.9

Table 17: *RE- scenario - IMPACTS - Jobs*

variable_name	2020	2025	2030	2035	2040	2045	2050
Jobs by economic sector - agriculture	818.602	819.006	825.069	1384	1095.1	695.567	882.528
Jobs by economic sector - construction	8009.1	8513.4	7967.9	9267	7706.2	8665.9	11179.3
Jobs by economic sector - manufacturing	7532.7	10548.9	11439.2	13535.6	12081.4	9891.2	11264.6
Jobs by economic sector - mining	13001.4	11230.2	8983.6	7221.8	4831.1	3347.6	2008.2
Jobs by economic sector - other	246.453	266.73	229.602	261.512	270.139	395.876	686.023
Jobs by economic sector - pipeline	1375.4	1477.2	1486.3	1775.4	1313	1210.3	1181.3

Table 17: *RE- scenario - IMPACTS - Jobs (continued)*

variable_name	2020	2025	2030	2035	2040	2045	2050
Jobs by economic sector - professional	4674.3	4757.9	4147.3	4633.7	4202.1	4756.1	6844.1
Jobs by economic sector - trade	9667.5	8804.4	7514.1	6824	5154.9	4501.1	4597.9
Jobs by economic sector - utilities	3658.2	3426.1	2545.4	4159.5	3638.6	5793.5	9513.8
Jobs by resource sector - Biomass	1979.7	1922.7	1881.7	3450.1	3008	2574.9	3902.4
Jobs by resource sector - CO2	0	72.027	432.04	3217	1823.9	3001.8	5307.4
Jobs by resource sector - Coal	2773.7	1397.8	306.139	18.391	13.573	10.519	8.795
Jobs by resource sector - Grid	4196.8	3938.1	2787.1	4098.9	4716.9	8046.2	13276.7
Jobs by resource sector - Natural Gas	6791.1	6389.6	5138.8	3905.7	2817.9	2149.5	1561
Jobs by resource sector - Nuclear	0	0	0	0	0	0	0
Jobs by resource sector - Oil	29165.2	28669.4	26332.8	24125.6	17858.8	13626	8671.7
Jobs by resource sector - Solar	828.708	2034.2	2405.6	3518.5	3642.6	3208.1	4483.9
Jobs by resource sector - Wind	3248.5	5419.9	5854.2	6728.4	6410.8	6640.2	10945.8
Median wages - All	60187.1	60554.7	60861.8	61280	61935.9	63658.3	64906.6
Required Level of Education - Associates degree or some college	13419.5	13835.3	12551.3	13935.3	11576	11697.9	14875.1
Required Level of Education - Bachelors degree	11629.1	11621.5	10352.5	10761.6	8734.8	8340.7	9983
Required Level of Education - Doctoral degree	370.235	365.844	319.75	328.227	271.991	272.667	344.349
Required Level of Education - High school diploma or less	20950.8	21431.4	19639.4	21671.4	17777.8	17039.3	20584.7
Required Level of Education - Masters or professional degree	2614	2589.8	2275.5	2366.1	1932	1906.6	2370.7
Wage income - All	2948263211	3018357537	2747274734	3006636588	2495631396	2499150029	3125924655

Table 18: *RE- scenario - PILLAR 6: Land carbon sinks - Agriculture*

variable_name	2050
Carbon sink enhancement potential - Accelerate regeneration	67.405
Carbon sink enhancement potential - All (not counting overlap)	39624.4
Carbon sink enhancement potential - Avoid deforestation	1300.599
Carbon sink enhancement potential - corn-ethanol to energy grasses	-1101.46
Carbon sink enhancement potential - cropland measures	-15437.869
Carbon sink enhancement potential - Extend rotation length	699.924
Carbon sink enhancement potential - Improve plantations	35.946
Carbon sink enhancement potential - Increase retention of HWP	69.105
Carbon sink enhancement potential - Increase trees outside forests	5597.7
Carbon sink enhancement potential - permanent conservation cover	-990.211
Carbon sink enhancement potential - Reforest cropland	23425.1
Carbon sink enhancement potential - Reforest pasture	8110.5
Carbon sink enhancement potential - Restore productivity	318.074
Carbon sink enhancement potential - total	-17529.541
Land impacted for carbon sink enhancement - Accelerate regeneration	27.167
Land impacted for carbon sink enhancement - All (not counting overlap)	8665.7
Land impacted for carbon sink enhancement - Avoid deforestation	349.128
Land impacted for carbon sink enhancement - corn-ethanol to energy grasses	600.65
Land impacted for carbon sink enhancement - cropland measures	15164.6
Land impacted for carbon sink enhancement - Extend rotation length	385.575
Land impacted for carbon sink enhancement - Improve plantations	19.978
Land impacted for carbon sink enhancement - Increase retention of HWP	13.821
Land impacted for carbon sink enhancement - Increase trees outside forests	1579.088
Land impacted for carbon sink enhancement - permanent conservation cover	1638.62
Land impacted for carbon sink enhancement - Reforest cropland	7799.161
Land impacted for carbon sink enhancement - Reforest pasture	613.276
Land impacted for carbon sink enhancement - Restore productivity	179.492
Land impacted for carbon sink enhancement - total	17403.9
Land impacted for carbon sink enhancement - Total impacted (over 30 years)	2300.87

Table 19: *RE- scenario - PILLAR 6: Land carbon sinks - Forests*

variable_name	2050
Business-as-usual carbon sink - Accelerate regeneration	6.299
Business-as-usual carbon sink - Avoid deforestation	111.216
Business-as-usual carbon sink - Extend rotation length	210.936
Business-as-usual carbon sink - Improve plantations	7.586
Business-as-usual carbon sink - Increase retention of HWP	0
Business-as-usual carbon sink - Increase trees outside forests	317.485
Business-as-usual carbon sink - Reforest cropland	885.009
Business-as-usual carbon sink - Reforest pasture	149.823
Business-as-usual carbon sink - Restore productivity	63.186
Business-as-usual carbon sink - Total impacted (over 30 years)	885.009

Table 20: *RE- scenario - IMPACTS - Fossil fuel industries*

variable_name	2020	2025	2030	2035	2040	2045	2050
Natural gas consumption	96649	98084.4	82679.6	66312.4	49919	31407.4	21783.3
Oil consumption	45911.6	45953	42812	37093.1	31086.2	26352	21830.7

Table 21: *RE- scenario - PILLAR 1: Efficiency/Electrification - Overview*

variable_name	2020	2025	2030	2035	2040	2045	2050
Final energy demand by sector - commercial	0.025	0.025	0.024	0.023	0.022	0.02	0.019
Final energy demand by sector - industry	0.124	0.13	0.131	0.13	0.129	0.129	0.13
Final energy demand by sector - residential	0.038	0.036	0.035	0.032	0.028	0.025	0.022
Final energy demand by sector - transportation	0.104	0.098	0.088	0.077	0.066	0.06	0.057

Table 22: *RE- scenario - PILLAR 1: Efficiency/Electrification - Commercial*

variable_name	2020	2025	2030	2035	2040	2045	2050
Commercial HVAC investment in 2020s - Cumulative 5-yr	0	2164953299	2360818924	0	0	0	0
Sales of cooking units - Electric Resistance	0.448	0.571	0.84	0.893	0.896	0.896	0.896
Sales of cooking units - Gas	0.552	0.429	0.16	0.107	0.104	0.104	0.104
Sales of space heating units - Electric Heat Pump	0.061	0.045	0.155	0.53	0.818	0.863	0.867
Sales of space heating units - Electric Resistance	0.1	0.058	0.08	0.12	0.129	0.129	0.129
Sales of space heating units - Fossil	0.098	0.024	0.005	0	0	0	0
Sales of space heating units - Gas Furnace	0.741	0.873	0.76	0.35	0.053	0.008	0.005
Sales of water heating units - Electric Heat Pump	0.016	0.012	0.069	0.275	0.44	0.465	0.467
Sales of water heating units - Electric Resistance	0.136	0.075	0.131	0.334	0.498	0.524	0.526
Sales of water heating units - Gas Furnace	0.821	0.904	0.793	0.384	0.055	0.004	0
Sales of water heating units - Other	0.027	0.01	0.007	0.007	0.007	0.007	0.007

Table 23: *RE- scenario - PILLAR 1: Efficiency/Electrification - Electricity demand*

variable_name	2025	2030	2035	2040	2045	2050
Electricity distribution peak load (capital invested) - Cumulative 5-yr	0.777	0.801	1.503	1.608	1.569	1.657

Table 24: *REF scenario - PILLAR 1: Efficiency/Electrification - Residential*

variable_name	2020	2025	2030	2035	2040	2045	2050
Residential HVAC investment in 2020s vs. REF - Cumulative 5-yr	0	0.511	0.578	0	0	0	0
Sale of space heating units by type - Electric Heat Pump	0.084	0.116	0.127	0.156	0.229	0.338	0.43
Sale of space heating units by type - Electric Resistance	0.284	0.343	0.338	0.33	0.305	0.269	0.239
Sale of space heating units by type - Fossil	0.137	0.19	0.189	0.18	0.161	0.136	0.12
Sale of space heating units by type - Gas	0.495	0.351	0.346	0.334	0.305	0.256	0.212
Sales of cooking units - Electric Resistance	0.802	0.807	0.825	0.873	0.939	0.98	0.995
Sales of cooking units - Gas	0.198	0.193	0.175	0.127	0.061	0.02	0.005
Sales of water heating units by type - Electric Heat Pump	0	0.001	0.003	0.011	0.032	0.066	0.095
Sales of water heating units by type - Electric Resistance	0.524	0.669	0.67	0.671	0.678	0.692	0.705
Sales of water heating units by type - Gas Furnace	0.476	0.33	0.326	0.318	0.29	0.242	0.199
Sales of water heating units by type - Other	0	0	0	0	0	0	0

Table 25: *REF scenario - PILLAR 1: Efficiency/Electrification - Transportation*

variable_name	2020	2025	2030	2035	2040	2045	2050
End-use technology sales by technology - HDV - diesel	0.974	0.96	0.913	0.798	0.582	0.321	0.137
End-use technology sales by technology - HDV - EV	0.005	0.015	0.041	0.108	0.236	0.394	0.51
End-use technology sales by technology - HDV - gasoline	0.002	0.002	0.002	0.002	0.002	0.001	0.001
End-use technology sales by technology - HDV - hybrid	0.001	0.001	0.001	0.001	0.001	0.001	0
End-use technology sales by technology - HDV - hydrogen FC	0.003	0.01	0.027	0.072	0.157	0.263	0.34
End-use technology sales by technology - HDV - other	0.015	0.013	0.015	0.019	0.022	0.02	0.011
End-use technology sales by technology - LDV - diesel	0.02	0.023	0.021	0.017	0.011	0.006	0.003
End-use technology sales by technology - LDV - EV	0.014	0.036	0.096	0.223	0.444	0.694	0.865
End-use technology sales by technology - LDV - gasoline	0.932	0.894	0.831	0.712	0.507	0.277	0.121
End-use technology sales by technology - LDV - hybrid	0.032	0.041	0.047	0.044	0.035	0.022	0.011
End-use technology sales by technology - LDV - hydrogen FC	0.001	0.004	0.004	0.003	0.002	0.001	0.001
End-use technology sales by technology - LDV - other	0.001	0.001	0.001	0.001	0.001	0	0
End-use technology sales by technology - MDV - diesel	0.648	0.622	0.577	0.494	0.356	0.196	0.084
End-use technology sales by technology - MDV - EV	0.007	0.019	0.055	0.143	0.314	0.526	0.68
End-use technology sales by technology - MDV - gasoline	0.338	0.347	0.347	0.319	0.244	0.142	0.063
End-use technology sales by technology - MDV - hybrid	0.004	0.004	0.005	0.005	0.004	0.003	0.001
End-use technology sales by technology - MDV - hydrogen FC	0.002	0.005	0.014	0.036	0.079	0.132	0.17
End-use technology sales by technology - MDV - other	0.003	0.003	0.003	0.003	0.003	0.002	0.001
Light-duty vehicle capital costs - Cumulative 5-yr	0	0	27740037	58885523	198280295	625760807	911039965
Number of public EV charging plugs - DC Fast Charging	24	0	105.957	0	580.048	0	1629.3
Number of public EV charging plugs - L2 Charging	43	0	2550.1	0	13960.1	0	39212.5

Table 26: *REF scenario - PILLAR 6: Land carbon sinks - Agriculture*

variable_name	2050
Carbon sink enhancement potential - Accelerate regeneration	67.405
Carbon sink enhancement potential - All (not counting overlap)	39624.4
Carbon sink enhancement potential - Avoid deforestation	1300.599
Carbon sink enhancement potential - corn-ethanol to energy grasses	-1101.46

Table 26: *REF scenario - PILLAR 6: Land carbon sinks - Agriculture (continued)*

variable_name	2050
Carbon sink enhancement potential - cropland measures	-15437.869
Carbon sink enhancement potential - Extend rotation length	699.924
Carbon sink enhancement potential - Improve plantations	35.946
Carbon sink enhancement potential - Increase retention of HWP	69.105
Carbon sink enhancement potential - Increase trees outside forests	5597.7
Carbon sink enhancement potential - permanent conservation cover	-990.211
Carbon sink enhancement potential - Reforest cropland	23425.1
Carbon sink enhancement potential - Reforest pasture	8110.5
Carbon sink enhancement potential - Restore productivity	318.074
Carbon sink enhancement potential - total	-17529.541
Land impacted for carbon sink enhancement - Accelerate regeneration	27.167
Land impacted for carbon sink enhancement - All (not counting overlap)	8665.7
Land impacted for carbon sink enhancement - Avoid deforestation	349.128
Land impacted for carbon sink enhancement - corn-ethanol to energy grasses	600.65
Land impacted for carbon sink enhancement - cropland measures	15164.6
Land impacted for carbon sink enhancement - Extend rotation length	385.575
Land impacted for carbon sink enhancement - Improve plantations	19.978
Land impacted for carbon sink enhancement - Increase retention of HWP	13.821
Land impacted for carbon sink enhancement - Increase trees outside forests	1579.088
Land impacted for carbon sink enhancement - permanent conservation cover	1638.62
Land impacted for carbon sink enhancement - Reforest cropland	7799.161
Land impacted for carbon sink enhancement - Reforest pasture	613.276
Land impacted for carbon sink enhancement - Restore productivity	179.492
Land impacted for carbon sink enhancement - total	17403.9
Land impacted for carbon sink enhancement - Total impacted (over 30 years)	2300.87

Table 27: *REF scenario - PILLAR 6: Land carbon sinks - Forests*

variable_name	2050
Business-as-usual carbon sink - Accelerate regeneration	6.299
Business-as-usual carbon sink - Avoid deforestation	111.216
Business-as-usual carbon sink - Extend rotation length	210.936
Business-as-usual carbon sink - Improve plantations	7.586
Business-as-usual carbon sink - Increase retention of HWP	0
Business-as-usual carbon sink - Increase trees outside forests	317.485
Business-as-usual carbon sink - Reforest cropland	885.009
Business-as-usual carbon sink - Reforest pasture	149.823
Business-as-usual carbon sink - Restore productivity	63.186
Business-as-usual carbon sink - Total impacted (over 30 years)	885.009

Table 28: *REF scenario - PILLAR 1: Efficiency/Electrification - Overview*

variable_name	2020	2025	2030	2035	2040	2045	2050
Final energy demand by sector - commercial	0.025	0.025	0.024	0.024	0.023	0.023	0.022
Final energy demand by sector - industry	0.124	0.13	0.132	0.133	0.133	0.134	0.134
Final energy demand by sector - residential	0.038	0.036	0.035	0.034	0.032	0.031	0.03
Final energy demand by sector - transportation	0.104	0.098	0.091	0.086	0.082	0.077	0.071

Table 29: *REF scenario - PILLAR 1: Efficiency/Electrification - Commercial*

variable_name	2020	2025	2030	2035	2040	2045	2050
Commercial HVAC investment in 2020s - Cumulative 5-yr	0	2164904913	2362943480	0	0	0	0
Sales of cooking units - Electric Resistance	0.448	0.493	0.531	0.63	0.769	0.855	0.885
Sales of cooking units - Gas	0.552	0.507	0.469	0.37	0.231	0.145	0.115
Sales of space heating units - Electric Heat Pump	0.061	0.039	0.049	0.076	0.147	0.265	0.37
Sales of space heating units - Electric Resistance	0.1	0.055	0.056	0.061	0.07	0.082	0.088
Sales of space heating units - Fossil	0.098	0.028	0.028	0.026	0.021	0.017	0.016
Sales of space heating units - Gas Furnace	0.741	0.878	0.866	0.838	0.761	0.636	0.526
Sales of water heating units - Electric Heat Pump	0.016	0.009	0.014	0.029	0.069	0.134	0.194
Sales of water heating units - Electric Resistance	0.136	0.072	0.078	0.092	0.131	0.196	0.255
Sales of water heating units - Gas Furnace	0.821	0.908	0.898	0.869	0.792	0.661	0.543
Sales of water heating units - Other	0.027	0.01	0.01	0.01	0.009	0.009	0.009

Table 30: *REF scenario - PILLAR 1: Efficiency/Electrification - Electricity demand*

variable_name	2025	2030	2035	2040	2045	2050
Electricity distribution peak load (capital invested) - Cumulative 5-yr	0.635	0.643	0.813	0.84	1.284	1.361

Table 31: *E+ scenario - PILLAR 2: Clean Electricity - Generating capacity*

variable_name	2025	2030	2035	2040	2045	2050
Power generation capital investment - Wind - Base	0	0	0.709	3.368	14.531	34.171

Table 32: *E+ scenario - PILLAR 2: Clean Electricity - Transmission*

variable_name	2020	2025	2030	2035	2040	2045	2050
HV transmission for wind and solar - base all	0	313.065	313.065	758.747	4726.8	11249.1	26310.3
HV transmission for wind and solar - base other intra-state	0	0	0	0	0	0	0
HV transmission for wind and solar - base spur intra-state	0	78.727	78.727	139.556	299.209	1304.2	4662.5

Table 33: *E+ scenario - PILLAR 6: Land carbon sinks - Agriculture*

variable_name	2050
Carbon sink enhancement potential - Accelerate regeneration	67.405
Carbon sink enhancement potential - All (not counting overlap)	39624.4
Carbon sink enhancement potential - Avoid deforestation	1300.599
Carbon sink enhancement potential - corn-ethanol to energy grasses	-1101.46
Carbon sink enhancement potential - cropland measures	-15437.869
Carbon sink enhancement potential - Extend rotation length	699.924
Carbon sink enhancement potential - Improve plantations	35.946
Carbon sink enhancement potential - Increase retention of HWP	69.105
Carbon sink enhancement potential - Increase trees outside forests	5597.7
Carbon sink enhancement potential - permanent conservation cover	-990.211
Carbon sink enhancement potential - Reforest cropland	23425.1
Carbon sink enhancement potential - Reforest pasture	8110.5
Carbon sink enhancement potential - Restore productivity	318.074
Carbon sink enhancement potential - total	-17529.541
Land impacted for carbon sink enhancement - Accelerate regeneration	27.167
Land impacted for carbon sink enhancement - All (not counting overlap)	8665.7
Land impacted for carbon sink enhancement - Avoid deforestation	349.128
Land impacted for carbon sink enhancement - corn-ethanol to energy grasses	600.65
Land impacted for carbon sink enhancement - cropland measures	15164.6
Land impacted for carbon sink enhancement - Extend rotation length	385.575
Land impacted for carbon sink enhancement - Improve plantations	19.978
Land impacted for carbon sink enhancement - Increase retention of HWP	13.821
Land impacted for carbon sink enhancement - Increase trees outside forests	1579.088
Land impacted for carbon sink enhancement - permanent conservation cover	1638.62
Land impacted for carbon sink enhancement - Reforest cropland	7799.161
Land impacted for carbon sink enhancement - Reforest pasture	613.276
Land impacted for carbon sink enhancement - Restore productivity	179.492
Land impacted for carbon sink enhancement - total	17403.9
Land impacted for carbon sink enhancement - Total impacted (over 30 years)	2300.87

Table 34: *E+ scenario - PILLAR 6: Land carbon sinks - Forests*

variable_name	2050
Business-as-usual carbon sink - Accelerate regeneration	6.299
Business-as-usual carbon sink - Avoid deforestation	111.216
Business-as-usual carbon sink - Extend rotation length	210.936
Business-as-usual carbon sink - Improve plantations	7.586
Business-as-usual carbon sink - Increase retention of HWP	0
Business-as-usual carbon sink - Increase trees outside forests	317.485
Business-as-usual carbon sink - Reforest cropland	885.009
Business-as-usual carbon sink - Reforest pasture	149.823
Business-as-usual carbon sink - Restore productivity	63.186
Business-as-usual carbon sink - Total impacted (over 30 years)	885.009

Table 35: *RE+ scenario - PILLAR 2: Clean Electricity - Generating capacity*

variable_name	2020	2025	2030	2035	2040	2045	2050
Power generation capital investment - biomass power plant	0	0	0	0	0	0	0
Power generation capital investment - biomass w/ccu allam power plant	0	0	0	0.025	0	0	0
Power generation capital investment - biomass w/ccu power plant	0	0	0.093	0	0	0	0

Table 36: *RE+ scenario - PILLAR 2: Clean Electricity - Generation*

variable_name	2020	2025	2030	2035	2040	2045	2050
Power generation by technology - biomass power plant	0	0	0	0	0	0	0
Power generation by technology - biomass w/ccu allam power plant	0	0	0	25.394	25.394	25.394	25.394
Power generation by technology - biomass w/ccu power plant	0	0	103.997	103.997	103.997	103.997	103.997

Table 37: *RE+ scenario - PILLAR 3: Bioenergy and Hydrogen - Bioconversion*

variable_name	2020	2025	2030	2035	2040	2045	2050
Biomass purchases	0	0	0.007	1.19	1.621	2.571	2.571
Capital investment	0	0	0.081	0	17.977	0	10.562
Number of facilities - allam power w ccu	0	0	0	1	1	1	1
Number of facilities - beccs hydrogen	0	0	0	15	19	32	32
Number of facilities - diesel	0	0	0	0	0	0	0
Number of facilities - diesel ccu	0	0	0	1	1	1	1
Number of facilities - power	0	0	0	0	0	0	0
Number of facilities - power ccu	0	0	1	1	1	1	1
Number of facilities - pyrolysis	0	0	0	0	0	0	0
Number of facilities - pyrolysis ccu	0	0	0	1	1	1	1
Number of facilities - sng	0	0	0	0	0	0	0
Number of facilities - sng ccu	0	0	1	1	1	1	1

Table 38: *RE+ scenario - PILLAR 4: CO2 capture, use, storage - CO2 capture*

variable_name	2025	2030	2035	2040	2045	2050
Annual - All	0	0.11	18.06	24.59	38.99	38.98
Annual - BECCS	0	0.11	18.04	24.57	38.97	38.97
Annual - Cement	0	0	0	0	0	0
Annual - NGCC	0	0	0.02	0.02	0.01	0.01
Cumulative - All	0	0.11	18.17	42.76	81.75	120.73
Cumulative - BECCS	0	0.11	18.15	42.72	81.69	120.66
Cumulative - Cement	0	0	0	0	0	0
Cumulative - NGCC	0	0	0.02	0.04	0.05	0.06

Table 39: *RE+ scenario - PILLAR 4: CO2 capture, use, storage - CO2 storage*

variable_name	2025	2030	2035	2040	2045	2050
Annual	0	4.62	20.34	40.4	56.13	58.52
Injection wells	0	10	38	68	113	141
Resource characterization, appraisal and permitting costs cumulative	135.4	622.86	974.92	974.92	974.92	974.92
Wells and facilities construction costs cumulative	0	293.02	1142	2035	3402.8	4224.6

Table 40: *RE+ scenario - PILLAR 4: CO2 capture, use, storage - CO2 transportation*

variable_name	2025	2030	2035	2040	2045	2050
CO2 pipelines - All	0	366017.137	3446972	3932455	5016531.9	5035502.1
CO2 pipelines - Spur	0	166437.122	1624558.1	2110041.1	3194118	3213088.2
CO2 pipelines - Trunk	0	199580.014	1822413.9	1822413.9	1822413.9	1822413.9

Table 41: *RE+ scenario - PILLAR 6: Land carbon sinks - Agriculture*

variable_name	2050
Carbon sink enhancement potential - Accelerate regeneration	67.405
Carbon sink enhancement potential - All (not counting overlap)	39624.4
Carbon sink enhancement potential - Avoid deforestation	1300.599
Carbon sink enhancement potential - corn-ethanol to energy grasses	-2529.272
Carbon sink enhancement potential - cropland measures	-14426.287
Carbon sink enhancement potential - Cropland to woody energy crops	0
Carbon sink enhancement potential - Extend rotation length	699.924
Carbon sink enhancement potential - Improve plantations	35.946
Carbon sink enhancement potential - Increase retention of HWP	69.105
Carbon sink enhancement potential - Increase trees outside forests	5597.7
Carbon sink enhancement potential - pasture to energy crops	0
Carbon sink enhancement potential - permanent conservation cover	-928.376
Carbon sink enhancement potential - Reforest cropland	23425.1
Carbon sink enhancement potential - Reforest pasture	8110.5
Carbon sink enhancement potential - Restore productivity	318.074
Carbon sink enhancement potential - total	-17883.935
Land impacted for carbon sink enhancement - Accelerate regeneration	27.167
Land impacted for carbon sink enhancement - All (not counting overlap)	8665.7
Land impacted for carbon sink enhancement - Avoid deforestation	349.128
Land impacted for carbon sink enhancement - corn-ethanol to energy grasses	1850.854
Land impacted for carbon sink enhancement - cropland measures	27892.5

Table 41: *RE+ scenario - PILLAR 6: Land carbon sinks - Agriculture (continued)*

variable_name	2050
Land impacted for carbon sink enhancement - Cropland to woody energy crops	126.914
Land impacted for carbon sink enhancement - Extend rotation length	385.575
Land impacted for carbon sink enhancement - Improve plantations	19.978
Land impacted for carbon sink enhancement - Increase retention of HWP	13.821
Land impacted for carbon sink enhancement - Increase trees outside forests	1579.088
Land impacted for carbon sink enhancement - pasture to energy crops	0
Land impacted for carbon sink enhancement - permanent conservation cover	1535.392
Land impacted for carbon sink enhancement - Reforest cropland	7799.161
Land impacted for carbon sink enhancement - Reforest pasture	613.276
Land impacted for carbon sink enhancement - Restore productivity	179.492
Land impacted for carbon sink enhancement - total	31405.7
Land impacted for carbon sink enhancement - Total impacted (over 30 years)	2300.87

Table 42: *RE+ scenario - PILLAR 6: Land carbon sinks - Forests*

variable_name	2050
Business-as-usual carbon sink - Accelerate regeneration	6.299
Business-as-usual carbon sink - Avoid deforestation	111.216
Business-as-usual carbon sink - Extend rotation length	210.936
Business-as-usual carbon sink - Improve plantations	7.586
Business-as-usual carbon sink - Increase retention of HWP	0
Business-as-usual carbon sink - Increase trees outside forests	317.485
Business-as-usual carbon sink - Reforest cropland	885.009
Business-as-usual carbon sink - Reforest pasture	149.823
Business-as-usual carbon sink - Restore productivity	63.186
Business-as-usual carbon sink - Total impacted (over 30 years)	885.009

Table 43: *B+ scenario - PILLAR 6: Land carbon sinks - Agriculture*

variable_name	2050
Carbon sink enhancement potential - Accelerate regeneration	67.405
Carbon sink enhancement potential - All (not counting overlap)	39624.4
Carbon sink enhancement potential - Avoid deforestation	1300.599
Carbon sink enhancement potential - corn-ethanol to energy grasses	-1101.46
Carbon sink enhancement potential - cropland measures	-15437.869
Carbon sink enhancement potential - Extend rotation length	699.924
Carbon sink enhancement potential - Improve plantations	35.946
Carbon sink enhancement potential - Increase retention of HWP	69.105
Carbon sink enhancement potential - Increase trees outside forests	5597.7
Carbon sink enhancement potential - permanent conservation cover	-990.211
Carbon sink enhancement potential - Reforest cropland	23425.1
Carbon sink enhancement potential - Reforest pasture	8110.5
Carbon sink enhancement potential - Restore productivity	318.074
Carbon sink enhancement potential - total	-17529.541
Land impacted for carbon sink enhancement - Accelerate regeneration	27.167
Land impacted for carbon sink enhancement - All (not counting overlap)	8665.7
Land impacted for carbon sink enhancement - Avoid deforestation	349.128
Land impacted for carbon sink enhancement - corn-ethanol to energy grasses	600.65
Land impacted for carbon sink enhancement - cropland measures	15164.6
Land impacted for carbon sink enhancement - Extend rotation length	385.575
Land impacted for carbon sink enhancement - Improve plantations	19.978
Land impacted for carbon sink enhancement - Increase retention of HWP	13.821
Land impacted for carbon sink enhancement - Increase trees outside forests	1579.088
Land impacted for carbon sink enhancement - permanent conservation cover	1638.62
Land impacted for carbon sink enhancement - Reforest cropland	7799.161
Land impacted for carbon sink enhancement - Reforest pasture	613.276
Land impacted for carbon sink enhancement - Restore productivity	179.492
Land impacted for carbon sink enhancement - total	17403.9
Land impacted for carbon sink enhancement - Total impacted (over 30 years)	2300.87

Table 44: *B+ scenario - PILLAR 6: Land carbon sinks - Forests*

variable_name	2050
Business-as-usual carbon sink - Accelerate regeneration	6.299
Business-as-usual carbon sink - Avoid deforestation	111.216
Business-as-usual carbon sink - Extend rotation length	210.936
Business-as-usual carbon sink - Improve plantations	7.586
Business-as-usual carbon sink - Increase retention of HWP	0
Business-as-usual carbon sink - Increase trees outside forests	317.485
Business-as-usual carbon sink - Reforest cropland	885.009
Business-as-usual carbon sink - Reforest pasture	149.823
Business-as-usual carbon sink - Restore productivity	63.186
Business-as-usual carbon sink - Total impacted (over 30 years)	885.009