Net-Zero America - minnesota state report v2

Larson et al. 2020

February 2021

Reading guide

IN DRAFT

List of Tables

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	4.025	4.154	0	0	0	0
Sale of space heating units by type - Electric Heat Pump	0.027	0.093	0.096	0.1	0.104	0.108	0.114
Sale of space heating units by type - Electric Resistance	0.099	0.136	0.134	0.133	0.132	0.127	0.124
Sale of space heating units by type - Fossil	0.092	0.15	0.142	0.135	0.132	0.13	0.131
Sale of space heating units by type - Gas	0.782	0.621	0.629	0.632	0.632	0.634	0.632
Sales of cooking units - Electric Resistance	0.583	0.583	0.583	0.583	0.583	0.583	0.583
Sales of cooking units - Gas	0.417	0.417	0.417	0.417	0.417	0.417	0.417
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	0.207	0.349	0.348	0.348	0.348	0.348	0.347
Sales of water heating units by type - Gas Furnace	0.792	0.651	0.652	0.652	0.652	0.652	0.652
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	0.016	0.02	0.022	0.02	0.018	0.017	0.016
End-use technology sales by technology - LDV - EV	0.034	0.054	0.062	0.076	0.093	0.108	0.119
End-use technology sales by technology - LDV - gasoline	0.905	0.869	0.848	0.83	0.81	0.79	0.775
End-use technology sales by technology - LDV - hybrid	0.043	0.052	0.063	0.069	0.075	0.081	0.085
End-use technology sales by technology - LDV - hydrogen FC	0.001	0.004	0.003	0.003	0.003	0.003	0.003
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	837.679
Carbon sink enhancement potential - All (not counting overlap)	0	0	66512.6
Carbon sink enhancement potential - Avoid deforestation	0	0	2961.8
Carbon sink enhancement potential - Extend rotation length	0	0	14393.6
Carbon sink enhancement potential - Improve plantations	0	0	1384.593
Carbon sink enhancement potential - Increase retention of HWP	0	0	7779.1
Carbon sink enhancement potential - Increase trees outside forests	0	0	5045.8
Carbon sink enhancement potential - Reforest cropland	0	0	14120.3
Carbon sink enhancement potential - Reforest pasture	0	0	12785.1
Carbon sink enhancement potential - Restore productivity	0	0	7204.7
Land impacted for carbon sink enhancement - Accelerate regeneration	0	0	337.616
Land impacted for carbon sink enhancement - All (not counting overlap)	0	0	12952.3
Land impacted for carbon sink enhancement - Avoid deforestation	0	0	795.042
Land impacted for carbon sink enhancement - Extend rotation length	0	0	7929.1
Land impacted for carbon sink enhancement - Improve plantations	0	0	769.528
Land impacted for carbon sink enhancement - Increase retention of HWP	0	0	1555.8
Land impacted for carbon sink enhancement - Increase trees outside forests	0	0	1423.317
Land impacted for carbon sink enhancement - Natural uptake	-33.26	-15.154	-13.55
Land impacted for carbon sink enhancement - Reforest cropland	0	0	4701.238
Land impacted for carbon sink enhancement - Reforest pasture	0	0	966.756
Land impacted for carbon sink enhancement - Restore productivity	0	0	4065.719
Land impacted for carbon sink enhancement - Retained in Hardwood Products	-1.27	-2.285	-2.375
Land impacted for carbon sink enhancement - Total	-34.53	-17.438	-15.925
Land impacted for carbon sink enhancement - Total impacted (over 30 years)	0	0	9591.8

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

variable_name	2050
Business-as-usual carbon sink - Accelerate regeneration	78.288
Business-as-usual carbon sink - Avoid deforestation	253.263
Business-as-usual carbon sink - Extend rotation length	4337.8
Business-as-usual carbon sink - Improve plantations	292.226

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	286.177
Business-as-usual carbon sink - Reforest cropland	533.47
Business-as-usual carbon sink - Reforest pasture	236.178
Business-as-usual carbon sink - Restore productivity	1431.2
Business-as-usual carbon sink - Total impacted (over 30 years)	533.47

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

variable_name	2020	2025	2030	2035	2040	2045	2050
Final energy demand by sector - commercial	0.221	0.221	0.221	0.218	0.216	0.217	0.223
Final energy demand by sector - industry	0.391	0.416	0.428	0.441	0.456	0.472	0.491
Final energy demand by sector - residential	0.296	0.281	0.273	0.268	0.265	0.264	0.263
Final energy demand by sector - transportation	0.552	0.526	0.489	0.468	0.472	0.488	0.508

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	15688074692	16188023292	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	0.018	0.121	0.416	0.677	0.729	0.737	0.737
Sales of space heating units - Electric Resistance	0.031	0.064	0.115	0.197	0.249	0.258	0.258
Sales of space heating units - Fossil	0.048	0.024	0.019	0.008	0.001	0	0
Sales of space heating units - Gas Furnace	0.903	0.791	0.451	0.118	0.02	0.006	0.005
Sales of water heating units - Electric Heat Pump	0.005	0.008	0.008	0.008	0.008	0.008	0.008
Sales of water heating units - Electric Resistance	0.043	0.069	0.07	0.069	0.069	0.069	0.069
Sales of water heating units - Gas Furnace	0.941	0.913	0.912	0.913	0.913	0.913	0.913
Sales of water heating units - Other	0.01	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	3.782	3.886	5.191	5.438	4.769	4.907

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	4.142	4.855	0	0	0	0
Sale of space heating units by type - Electric Heat Pump	0.034	0.08	0.309	0.767	0.903	0.919	0.917
Sale of space heating units by type - Electric Resistance	0.098	0.139	0.113	0.055	0.038	0.036	0.038
Sale of space heating units by type - Fossil	0.09	0.155	0.114	0.053	0.035	0.031	0.032
Sale of space heating units by type - Gas	0.778	0.626	0.463	0.124	0.025	0.014	0.013
Sales of cooking units - Electric Resistance	0.589	0.676	0.945	0.997	1	1	1
Sales of cooking units - Gas	0.411	0.324	0.055	0.003	0	0	0
Sales of water heating units by type - Electric Heat Pump	0	0.007	0.099	0.317	0.379	0.386	0.386
Sales of water heating units by type - Electric Resistance	0.207	0.353	0.413	0.56	0.608	0.613	0.613
Sales of water heating units by type - Gas Furnace	0.792	0.64	0.487	0.123	0.013	0.001	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	0.016	0.018	0.013	0.004	0.001	0	0
End-use technology sales by technology - LDV - EV	0.038	0.148	0.458	0.816	0.963	0.993	1
End-use technology sales by technology - LDV - gasoline	0.901	0.785	0.495	0.168	0.033	0.006	0
End-use technology sales by technology - LDV - hybrid	0.043	0.044	0.032	0.012	0.003	0.001	0
End-use technology sales by technology - LDV - hydrogen FC	0.001	0.003	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	1035203424	2658948952	4299628632	6516717158	7088639433	6760751654
Number of public EV charging plugs - DC Fast Charging	168	0	1921.3	0	8362.1	0	13509
Number of public EV charging plugs - L2 Charging	739	0	46231.1	0	201210.8	0	325056.2

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	0.049	0.493	0	0	0	0
Power generation capital investment - biomass w/ccu allam power plant	0	0	0	0	0	0	0
Power generation capital investment - biomass w/ccu power plant	0	0	0	0	0	0	0
Power generation capital investment - Solar PV - Base	0	0	0	0	0	0	0
Power generation capital investment - Solar PV - Constrained	0	0.395	0	0	0	0	0
Power generation capital investment - Wind - Base	0	11.318	7.505	14.512	14.484	18.684	27.24
Power generation capital investment - Wind - Constrained	0	2.201	2.945	6.208	4.375	4.584	5.58

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	93.417	1062.5	1062.5	1062.5	1062.5	1062.5
Power generation by technology - biomass w/ccu allam power plant	0	0	0	0	0	0	0
Power generation by technology - biomass w/ccu power plant	0	0	0	0	0	0	0

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	1968.6	3449	7389.5	16767.4	27863.7	39947
HV transmission for wind and solar - base other intra-state	0	668.997	1133.2	2149.3	3189.7	4773.7	6840.8
HV transmission for wind and solar - base spur intra-state	0	648.168	1116.1	1975.7	2855.6	4203.8	6458.1
HV transmission for wind and solar - constrained all	0	1377.7	5147.5	12792	20352.9	34058.3	63244.3
HV transmission for wind and solar - constrained other intra-state	0	157.02	338.857	792.926	1135.7	1494.8	2649.5
HV transmission for wind and solar - constrained spur intra-state	0	177.446	341.76	847.742	1448.6	2010.1	2591.4

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

variable_name	2020	2025	2030	2035	2040	2045	2050
Biomass purchases	0	0.026	0.152	0.376	0.455	1.251	4.641
Capital investment	0	0	0.569	0	4.182	0	84.887
Number of facilities - allam power w ccu	0	0	0	0	0	0	0
Number of facilities - beccs hydrogen	0	0	0	3	5	20	24
Number of facilities - diesel	0	0	0	1	1	1	2
Number of facilities - diesel ccu	0	0	0	0	0	0	1
Number of facilities - power	0	1	1	1	1	1	1
Number of facilities - power ccu	0	0	0	0	0	0	0
Number of facilities - pyrolysis	0	0	0	1	1	1	7
Number of facilities - pyrolysis ccu	0	0	0	0	0	0	45
Number of facilities - sng	0	1	1	1	1	1	2
Number of facilities - sng ccu	0	0	0	0	0	0	1

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

variable_name	2025	2030	2035	2040	2045	2050
Annual - All	0	0	4.17	5.67	20.63	58.89
Annual - BECCS	0	0	4.17	5.67	20.63	58.89
Annual - Cement	0	0	0	0	0	0
Annual - NGCC	0	0	0	0	0	0
Cumulative - All	0	0	4.17	9.84	30.47	89.36
Cumulative - BECCS	0	0	4.17	9.84	30.47	89.36
Cumulative - Cement	0	0	0	0	0	0
Cumulative - NGCC	0	0	0	0	0	0

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

variable_name	2025	2030	2035	2040	2045	2050
Annual	0	0	0	0	0	0
Injection wells	0	0	0	0	0	0
Resource characterization, appraisal and permitting costs cumulative	0	0	0	0	0	0
Wells and facilities construction costs cumulative	0	0	0	0	0	0

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

variable_name	2025	2030	2035	2040	2045	2050
CO2 pipelines - All	0	0	459504.229	564545.629	712955.643	3735140
CO2 pipelines - Spur	0	0	22277.575	127318.975	275728.989	3297912.9
CO2 pipelines - Trunk	0	0	437226.654	437226.654	437226.654	437226.654

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

variable_name	2020	2025	2030	2035	2040	2045	2050
Jobs by economic sector - agriculture	2150.2	2171.6	2428.6	2657.3	1770.4	1635.8	4380.3
Jobs by economic sector - construction	6327.4	10123.5	10808.6	15599.5	19028.4	23443.3	33116.2
Jobs by economic sector - manufacturing	4761	8752.3	10321.3	13567.3	13227.9	11761	17131.1

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

variable_name	2020	2025	2030	2035	2040	2045	2050
Jobs by economic sector - mining	2728.7	2120.7	1497.3	1015.9	662.546	416.682	270.597
Jobs by economic sector - other	446.97	751.421	857.931	1349.7	1779.9	2340.3	3371.1
Jobs by economic sector - pipeline	489.266	485.859	417.009	391.266	258.538	180.844	533.643
Jobs by economic sector - professional	4065.2	6639.8	7484.1	10911.7	13467.1	18109	28926.4
Jobs by economic sector - trade	3638.7	4469.1	4542.5	5997.8	7141.6	9205.4	13772.2
Jobs by economic sector - utilities	7171.9	9755.8	10126.1	14669.9	18329.9	23000.5	32691.7
Jobs by resource sector - Biomass	5430.1	5396.6	5727.3	6356.8	4618.5	6060	19035.1
Jobs by resource sector - CO2	0	0	0	457.037	14.28	21.815	3367.5
Jobs by resource sector - Coal	1636.4	885.733	203.939	0	0	0	0
Jobs by resource sector - Grid	8203.8	13435.3	14667.7	24240.2	32875.5	41812.1	57452.6
Jobs by resource sector - Natural Gas	4449.8	4133.2	3754.4	3165.6	2912.4	2868.5	2726.3
Jobs by resource sector - Nuclear	959.926	944.449	929.367	539.07	0	0	0
Jobs by resource sector - Oil	5381.1	4752.4	3902.5	2946.1	2165.8	1601.1	1201.8
Jobs by resource sector - Solar	2190	3438.1	3702.7	5325.3	5610.3	5111.9	7366.8
Jobs by resource sector - Wind	3528.2	12284.5	15595.4	23130.3	27469.5	32617.5	43043.2
Median wages - All	63416.5	64389.8	65102.7	66419.5	68260.8	70124.5	70957.2
Required Level of Education - Associates degree or some college	9232.9	13638.2	14675.9	20444.5	23898.7	28614.8	41887.4
Required Level of Education - Bachelors degree	6547.1	9291.2	9907.5	13442.7	15504.8	18796.9	28215.9
Required Level of Education - Doctoral degree	227.109	335.135	363.785	502.783	596.301	771.543	1208.7
Required Level of Education - High school diploma or less	14178.4	19727.4	21093.6	28417.6	31737.5	37020.3	55458.6
Required Level of Education - Masters or professional degree	1593.8	2278.2	2442.7	3352.7	3928.9	4889.2	7422.6
Wage income - All	2015427667	2915109546	3156595522	4394642735	5165443898	6318272337	9522816844

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

variable_name	2050
Carbon sink enhancement potential - Accelerate regeneration	837.679
Carbon sink enhancement potential - All (not counting overlap)	66512.6
Carbon sink enhancement potential - Avoid deforestation	2961.8
Carbon sink enhancement potential - corn-ethanol to energy grasses	-4846.658
Carbon sink enhancement potential - cropland measures	-21104.579
Carbon sink enhancement potential - Extend rotation length	14393.6
Carbon sink enhancement potential - Improve plantations	1384.593
Carbon sink enhancement potential - Increase retention of HWP	7779.1
Carbon sink enhancement potential - Increase trees outside forests	5045.8
Carbon sink enhancement potential - permanent conservation cover	-620.655
Carbon sink enhancement potential - Reforest cropland	14120.3
Carbon sink enhancement potential - Reforest pasture	12785.1
Carbon sink enhancement potential - Restore productivity	7204.7
Carbon sink enhancement potential - total	-26571.892
Land impacted for carbon sink enhancement - Accelerate regeneration	337.616
Land impacted for carbon sink enhancement - All (not counting overlap)	12952.3
Land impacted for carbon sink enhancement - Avoid deforestation	795.042
Land impacted for carbon sink enhancement - corn-ethanol to energy grasses	2194.6
Land impacted for carbon sink enhancement - cropland measures	10648.8
Land impacted for carbon sink enhancement - Extend rotation length	7929.1
Land impacted for carbon sink enhancement - Improve plantations	769.528
Land impacted for carbon sink enhancement - Increase retention of HWP	1555.8
Land impacted for carbon sink enhancement - Increase trees outside forests	1423.317
Land impacted for carbon sink enhancement - permanent conservation cover	1128.86
Land impacted for carbon sink enhancement - Reforest cropland	4701.238
Land impacted for carbon sink enhancement - Reforest pasture	966.756
Land impacted for carbon sink enhancement - Restore productivity	4065.719
Land impacted for carbon sink enhancement - total	13972.2
Land impacted for carbon sink enhancement - Total impacted (over 30 years)	9591.8

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

variable_name	2050
Business-as-usual carbon sink - Accelerate regeneration	78.288
Business-as-usual carbon sink - Avoid deforestation	253.263
Business-as-usual carbon sink - Extend rotation length	4337.8
Business-as-usual carbon sink - Improve plantations	292.226
Business-as-usual carbon sink - Increase retention of HWP	0
Business-as-usual carbon sink - Increase trees outside forests	286.177
Business-as-usual carbon sink - Reforest cropland	533.47
Business-as-usual carbon sink - Reforest pasture	236.178
Business-as-usual carbon sink - Restore productivity	1431.2
Business-as-usual carbon sink - Total impacted (over 30 years)	533.47

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

variable_name	2020	2025	2030	2035	2040	2045	2050
Natural gas consumption	374082.3	379637.9	320013.3	256663.9	193212.7	121563	84312.9
Oil consumption	110390.6	106900	95662	78222.6	61913.9	48996.5	39151.6

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

variable_name	2020	2025	2030	2035	2040	2045	2050
Final energy demand by sector - commercial	0.221	0.216	0.207	0.194	0.179	0.168	0.16
Final energy demand by sector - industry	0.391	0.405	0.406	0.401	0.4	0.399	0.401
Final energy demand by sector - residential	0.296	0.28	0.265	0.236	0.202	0.173	0.153
Final energy demand by sector - transportation	0.552	0.519	0.46	0.389	0.325	0.285	0.269

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	15866448433	17271455745	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	0.018	0.068	0.265	0.718	0.853	0.868	0.869
Sales of space heating units - Electric Resistance	0.031	0.057	0.082	0.119	0.126	0.126	0.126
Sales of space heating units - Fossil	0.048	0.021	0.004	0	0	0	0
Sales of space heating units - Gas Furnace	0.903	0.854	0.649	0.163	0.021	0.005	0.005
Sales of water heating units - Electric Heat Pump	0.005	0.017	0.126	0.385	0.463	0.471	0.472
Sales of water heating units - Electric Resistance	0.043	0.078	0.185	0.436	0.512	0.521	0.522
Sales of water heating units - Gas Furnace	0.941	0.896	0.682	0.172	0.018	0.001	0
Sales of water heating units - Other	0.01	0.009	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	3.874	3.989	7.914	8.482	7.131	7.471

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	4.122	4.74	0	0	0	0
Sale of space heating units by type - Electric Heat Pump	0.034	0.061	0.075	0.119	0.223	0.356	0.44
Sale of space heating units by type - Electric Resistance	0.098	0.141	0.138	0.133	0.121	0.104	0.096
Sale of space heating units by type - Fossil	0.09	0.161	0.159	0.151	0.133	0.113	0.102
Sale of space heating units by type - Gas	0.778	0.638	0.628	0.596	0.523	0.427	0.362
Sales of cooking units - Electric Resistance	0.587	0.598	0.636	0.735	0.874	0.959	0.989
Sales of cooking units - Gas	0.413	0.402	0.364	0.265	0.126	0.041	0.011
Sales of water heating units by type - Electric Heat Pump	0	0.002	0.008	0.026	0.072	0.132	0.171
Sales of water heating units by type - Electric Resistance	0.207	0.35	0.353	0.365	0.396	0.437	0.465
Sales of water heating units by type - Gas Furnace	0.792	0.648	0.639	0.609	0.533	0.431	0.364
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	0.016	0.02	0.021	0.016	0.011	0.005	0.002
End-use technology sales by technology - LDV - EV	0.018	0.046	0.116	0.255	0.48	0.718	0.875
End-use technology sales by technology - LDV - gasoline	0.919	0.877	0.799	0.671	0.466	0.251	0.111
End-use technology sales by technology - LDV - hybrid	0.044	0.053	0.059	0.054	0.041	0.024	0.012
End-use technology sales by technology - LDV - hydrogen FC	0.001	0.004	0.003	0.003	0.002	0.001	0
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	168437233	351766015	1189991268	3738123958	5448299295
Number of public EV charging plugs - DC Fast Charging	168	0	603.519	0	3108.5	0	8652.5
Number of public EV charging plugs - L2 Charging	739	0	14522	0	74797.7	0	208198.3

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

variable_name	2050
Carbon sink enhancement potential - Accelerate regeneration	837.679
Carbon sink enhancement potential - All (not counting overlap)	66512.6
Carbon sink enhancement potential - Avoid deforestation	2961.8
Carbon sink enhancement potential - corn-ethanol to energy grasses	-4846.658

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

variable_name	2050
Carbon sink enhancement potential - cropland measures	-21104.579
Carbon sink enhancement potential - Extend rotation length	14393.6
Carbon sink enhancement potential - Improve plantations	1384.593
Carbon sink enhancement potential - Increase retention of HWP	7779.1
Carbon sink enhancement potential - Increase trees outside forests	5045.8
Carbon sink enhancement potential - permanent conservation cover	-620.655
Carbon sink enhancement potential - Reforest cropland	14120.3
Carbon sink enhancement potential - Reforest pasture	12785.1
Carbon sink enhancement potential - Restore productivity	7204.7
Carbon sink enhancement potential - total	-26571.892
Land impacted for carbon sink enhancement - Accelerate regeneration	337.616
Land impacted for carbon sink enhancement - All (not counting overlap)	12952.3
Land impacted for carbon sink enhancement - Avoid deforestation	795.042
Land impacted for carbon sink enhancement - corn-ethanol to energy grasses	2194.6
Land impacted for carbon sink enhancement - cropland measures	10648.8
Land impacted for carbon sink enhancement - Extend rotation length	7929.1
Land impacted for carbon sink enhancement - Improve plantations	769.528
Land impacted for carbon sink enhancement - Increase retention of HWP	1555.8
Land impacted for carbon sink enhancement - Increase trees outside forests	1423.317
Land impacted for carbon sink enhancement - permanent conservation cover	1128.86
Land impacted for carbon sink enhancement - Reforest cropland	4701.238
Land impacted for carbon sink enhancement - Reforest pasture	966.756
Land impacted for carbon sink enhancement - Restore productivity	4065.719
Land impacted for carbon sink enhancement - total	13972.2
Land impacted for carbon sink enhancement - Total impacted (over 30 years)	9591.8

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

variable_name	2050
Business-as-usual carbon sink - Accelerate regeneration	78.288
Business-as-usual carbon sink - Avoid deforestation	253.263
Business-as-usual carbon sink - Extend rotation length	4337.8
Business-as-usual carbon sink - Improve plantations	292.226
Business-as-usual carbon sink - Increase retention of HWP	0
Business-as-usual carbon sink - Increase trees outside forests	286.177
Business-as-usual carbon sink - Reforest cropland	533.47
Business-as-usual carbon sink - Reforest pasture	236.178
Business-as-usual carbon sink - Restore productivity	1431.2
Business-as-usual carbon sink - Total impacted (over 30 years)	533.47

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

variable_name	2020	2025	2030	2035	2040	2045	2050
Final energy demand by sector - commercial	0.221	0.216	0.21	0.204	0.198	0.192	0.187
Final energy demand by sector - industry	0.391	0.406	0.408	0.408	0.409	0.409	0.41
Final energy demand by sector - residential	0.296	0.28	0.269	0.259	0.249	0.237	0.223
Final energy demand by sector - transportation	0.552	0.523	0.479	0.445	0.418	0.387	0.35

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	15865555191	17291045358	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	0.018	0.056	0.068	0.106	0.198	0.321	0.402
Sales of space heating units - Electric Resistance	0.031	0.054	0.056	0.06	0.07	0.081	0.087
Sales of space heating units - Fossil	0.048	0.025	0.024	0.022	0.018	0.015	0.014
Sales of space heating units - Gas Furnace	0.903	0.865	0.852	0.812	0.714	0.583	0.497
Sales of water heating units - Electric Heat Pump	0.005	0.01	0.017	0.039	0.093	0.166	0.213
Sales of water heating units - Electric Resistance	0.043	0.072	0.078	0.1	0.152	0.223	0.269
Sales of water heating units - Gas Furnace	0.941	0.908	0.895	0.852	0.746	0.603	0.509
Sales of water heating units - Other	0.01	0.01	0.01	0.009	0.009	0.008	0.008

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	3.063	3.081	4.068	4.202	6.249	6.61

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

variable_name	2025	2030	2035	2040	2045	2050
Power generation capital investment - Solar PV - Base	0	0	0	0.529	0	2.403
Power generation capital investment - Wind - Base	12.753	8.51	17.639	27.49	39.737	39.079

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	2083.7	3575.2	12703	28949.7	53276.1	87583.5
HV transmission for wind and solar - base other intra-state	0	746.023	1291.7	2527.4	4672.6	7457.9	10072.2
HV transmission for wind and solar - base spur intra-state	0	728.817	1244.7	2281.3	4109.8	7427.3	11379.6

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

variable_name	2050
Carbon sink enhancement potential - Accelerate regeneration	837.679
Carbon sink enhancement potential - All (not counting overlap)	66512.6
Carbon sink enhancement potential - Avoid deforestation	2961.8
Carbon sink enhancement potential - corn-ethanol to energy grasses	-4846.658
Carbon sink enhancement potential - cropland measures	-21104.579
Carbon sink enhancement potential - Extend rotation length	14393.6
Carbon sink enhancement potential - Improve plantations	1384.593
Carbon sink enhancement potential - Increase retention of HWP	7779.1
Carbon sink enhancement potential - Increase trees outside forests	5045.8
Carbon sink enhancement potential - permanent conservation cover	-620.655
Carbon sink enhancement potential - Reforest cropland	14120.3
Carbon sink enhancement potential - Reforest pasture	12785.1
Carbon sink enhancement potential - Restore productivity	7204.7
Carbon sink enhancement potential - total	-26571.892
Land impacted for carbon sink enhancement - Accelerate regeneration	337.616
Land impacted for carbon sink enhancement - All (not counting overlap)	12952.3
Land impacted for carbon sink enhancement - Avoid deforestation	795.042
Land impacted for carbon sink enhancement - corn-ethanol to energy grasses	2194.6
Land impacted for carbon sink enhancement - cropland measures	10648.8
Land impacted for carbon sink enhancement - Extend rotation length	7929.1
Land impacted for carbon sink enhancement - Improve plantations	769.528
Land impacted for carbon sink enhancement - Increase retention of HWP	1555.8
Land impacted for carbon sink enhancement - Increase trees outside forests	1423.317
Land impacted for carbon sink enhancement - permanent conservation cover	1128.86
Land impacted for carbon sink enhancement - Reforest cropland	4701.238
Land impacted for carbon sink enhancement - Reforest pasture	966.756
Land impacted for carbon sink enhancement - Restore productivity	4065.719
Land impacted for carbon sink enhancement - total	13972.2
Land impacted for carbon sink enhancement - Total impacted (over 30 years)	9591.8

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

variable_name	2050
Business-as-usual carbon sink - Accelerate regeneration	78.288
Business-as-usual carbon sink - Avoid deforestation	253.263
Business-as-usual carbon sink - Extend rotation length	4337.8
Business-as-usual carbon sink - Improve plantations	292.226
Business-as-usual carbon sink - Increase retention of HWP	0
Business-as-usual carbon sink - Increase trees outside forests	286.177
Business-as-usual carbon sink - Reforest cropland	533.47
Business-as-usual carbon sink - Reforest pasture	236.178
Business-as-usual carbon sink - Restore productivity	1431.2
Business-as-usual carbon sink - Total impacted (over 30 years)	533.47

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	0.046	0.387	0	0	0	0
Power generation capital investment - biomass w/ccu allam power plant	0	0	0	0	0	0	0
Power generation capital investment - biomass w/ccu power plant	0	0	0	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	88.092	849.003	849.003	849.003	849.003	849.003
Power generation by technology - biomass w/ccu allam power plant	0	0	0	0	0	0	0
Power generation by technology - biomass w/ccu power plant	0	0	0	0	0	0	0

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

variable_name	2020	2025	2030	2035	2040	2045	2050
Biomass purchases	0	0.03	0.18	0.896	2.262	3.144	7.957
Capital investment	0	0	0.455	0	22.17	0	72.737
Number of facilities - allam power w ccu	0	0	0	0	0	0	0
Number of facilities - beccs hydrogen	0	0	0	9	30	42	42
Number of facilities - diesel	0	0	0	1	1	1	1
Number of facilities - diesel ccu	0	0	0	0	0	0	0
Number of facilities - power	0	1	1	1	1	1	1
Number of facilities - power ccu	0	0	0	0	0	0	0
Number of facilities - pyrolysis	0	0	0	1	1	1	47
Number of facilities - pyrolysis ccu	0	0	0	0	0	0	18
Number of facilities - sng	0	1	1	1	1	1	1
Number of facilities - sng ccu	0	0	0	0	0	0	0

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

variable_name	2025	2030	2035	2040	2045	2050
Annual - All	0	0	10.36	30.2	43.01	55.11
Annual - BECCS	0	0	10.36	30.2	43.01	55.11
Annual - Cement	0	0	0	0	0	0
Annual - NGCC	0	0	0	0	0	0
Cumulative - All	0	0	10.36	40.56	83.57	138.68
Cumulative - BECCS	0	0	10.36	40.56	83.57	138.68
Cumulative - Cement	0	0	0	0	0	0
Cumulative - NGCC	0	0	0	0	0	0

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

variable_name	2025	2030	2035	2040	2045	2050
Annual	0	0	0	0	0	0
Injection wells	0	0	0	0	0	0
Resource characterization, appraisal and permitting costs cumulative	0	0	0	0	0	0
Wells and facilities construction costs cumulative	0	0	0	0	0	0

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

variable_name	2025	2030	2035	2040	2045	2050
CO2 pipelines - All	0	0	715345.829	1224268.6	1917671.4	2314464.4
CO2 pipelines - Spur	0	0	250769.575	759692.189	1453095.4	1849888.3
CO2 pipelines - Trunk	0	0	464576.154	464576.154	464576.154	464576.154

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

variable_name	2050
Carbon sink enhancement potential - Accelerate regeneration	837.679
Carbon sink enhancement potential - All (not counting overlap)	66512.6
Carbon sink enhancement potential - Avoid deforestation	2961.8
Carbon sink enhancement potential - corn-ethanol to energy grasses	-5828.32
Carbon sink enhancement potential - cropland measures	-19777.534
Carbon sink enhancement potential - Cropland to woody energy crops	0
Carbon sink enhancement potential - Extend rotation length	14393.6
Carbon sink enhancement potential - Improve plantations	1384.593
Carbon sink enhancement potential - Increase retention of HWP	7779.1
Carbon sink enhancement potential - Increase trees outside forests	5045.8
Carbon sink enhancement potential - pasture to energy crops	0
Carbon sink enhancement potential - permanent conservation cover	-578.634
Carbon sink enhancement potential - Reforest cropland	14120.3
Carbon sink enhancement potential - Reforest pasture	12785.1
Carbon sink enhancement potential - Restore productivity	7204.7
Carbon sink enhancement potential - total	-26184.487
Land impacted for carbon sink enhancement - Accelerate regeneration	337.616
Land impacted for carbon sink enhancement - All (not counting overlap)	12952.3
Land impacted for carbon sink enhancement - Avoid deforestation	795.042
Land impacted for carbon sink enhancement - corn-ethanol to energy grasses	3177.2
Land impacted for carbon sink enhancement - cropland measures	19520

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	58.37
Land impacted for carbon sink enhancement - Extend rotation length	7929.1
Land impacted for carbon sink enhancement - Improve plantations	769.528
Land impacted for carbon sink enhancement - Increase retention of HWP	1555.8
Land impacted for carbon sink enhancement - Increase trees outside forests	1423.317
Land impacted for carbon sink enhancement - pasture to energy crops	273.136
Land impacted for carbon sink enhancement - permanent conservation cover	1052.429
Land impacted for carbon sink enhancement - Reforest cropland	4701.238
Land impacted for carbon sink enhancement - Reforest pasture	966.756
Land impacted for carbon sink enhancement - Restore productivity	4065.719
Land impacted for carbon sink enhancement - total	24081.2
Land impacted for carbon sink enhancement - Total impacted (over 30 years)	9591.8

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

variable_name	2050
Business-as-usual carbon sink - Accelerate regeneration	78.288
Business-as-usual carbon sink - Avoid deforestation	253.263
Business-as-usual carbon sink - Extend rotation length	4337.8
Business-as-usual carbon sink - Improve plantations	292.226
Business-as-usual carbon sink - Increase retention of HWP	0
Business-as-usual carbon sink - Increase trees outside forests	286.177
Business-as-usual carbon sink - Reforest cropland	533.47
Business-as-usual carbon sink - Reforest pasture	236.178
Business-as-usual carbon sink - Restore productivity	1431.2
Business-as-usual carbon sink - Total impacted (over 30 years)	533.47

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

variable_name	2050
Carbon sink enhancement potential - Accelerate regeneration	837.679
Carbon sink enhancement potential - All (not counting overlap)	66512.6
Carbon sink enhancement potential - Avoid deforestation	2961.8
Carbon sink enhancement potential - corn-ethanol to energy grasses	-4846.658
Carbon sink enhancement potential - cropland measures	-21104.579
Carbon sink enhancement potential - Extend rotation length	14393.6
Carbon sink enhancement potential - Improve plantations	1384.593
Carbon sink enhancement potential - Increase retention of HWP	7779.1
Carbon sink enhancement potential - Increase trees outside forests	5045.8
Carbon sink enhancement potential - permanent conservation cover	-620.655
Carbon sink enhancement potential - Reforest cropland	14120.3
Carbon sink enhancement potential - Reforest pasture	12785.1
Carbon sink enhancement potential - Restore productivity	7204.7
Carbon sink enhancement potential - total	-26571.892
Land impacted for carbon sink enhancement - Accelerate regeneration	337.616
Land impacted for carbon sink enhancement - All (not counting overlap)	12952.3
Land impacted for carbon sink enhancement - Avoid deforestation	795.042
Land impacted for carbon sink enhancement - corn-ethanol to energy grasses	2194.6
Land impacted for carbon sink enhancement - cropland measures	10648.8
Land impacted for carbon sink enhancement - Extend rotation length	7929.1
Land impacted for carbon sink enhancement - Improve plantations	769.528
Land impacted for carbon sink enhancement - Increase retention of HWP	1555.8
Land impacted for carbon sink enhancement - Increase trees outside forests	1423.317
Land impacted for carbon sink enhancement - permanent conservation cover	1128.86
Land impacted for carbon sink enhancement - Reforest cropland	4701.238
Land impacted for carbon sink enhancement - Reforest pasture	966.756
Land impacted for carbon sink enhancement - Restore productivity	4065.719
Land impacted for carbon sink enhancement - total	13972.2
Land impacted for carbon sink enhancement - Total impacted (over 30 years)	9591.8

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

variable_name	2050
Business-as-usual carbon sink - Accelerate regeneration	78.288
Business-as-usual carbon sink - Avoid deforestation	253.263
Business-as-usual carbon sink - Extend rotation length	4337.8
Business-as-usual carbon sink - Improve plantations	292.226
Business-as-usual carbon sink - Increase retention of HWP	0
Business-as-usual carbon sink - Increase trees outside forests	286.177
Business-as-usual carbon sink - Reforest cropland	533.47
Business-as-usual carbon sink - Reforest pasture	236.178
Business-as-usual carbon sink - Restore productivity	1431.2
Business-as-usual carbon sink - Total impacted (over 30 years)	533.47