Net-Zero America - montana 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	0.752	0.765	0	0	0	0
Sale of space heating units by type - Electric Heat Pump	0.058	0.17	0.173	0.179	0.184	0.19	0.194
Sale of space heating units by type - Electric Resistance	0.078	0.124	0.122	0.122	0.121	0.118	0.112
Sale of space heating units by type - Fossil	0.128	0.178	0.181	0.175	0.163	0.158	0.164
Sale of space heating units by type - Gas	0.737	0.528	0.524	0.525	0.532	0.534	0.53
Sales of cooking units - Electric Resistance	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Sales of cooking units - Gas	0.55	0.55	0.55	0.55	0.55	0.55	0.55
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	0.141	0.263	0.265	0.267	0.269	0.27	0.271
Sales of water heating units by type - Gas Furnace	0.846	0.722	0.721	0.719	0.716	0.715	0.714
Sales of water heating units by type - Other	0.013	0.014	0.015	0.015	0.015	0.015	0.015

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	0.021	0.038	0.043	0.052	0.064	0.076	0.087
End-use technology sales by technology - LDV - gasoline	0.926	0.894	0.881	0.868	0.852	0.833	0.815
End-use technology sales by technology - LDV - hybrid	0.03	0.04	0.048	0.054	0.061	0.068	0.076
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	7554
Carbon sink enhancement potential - All (not counting overlap)	0	0	87761.9
Carbon sink enhancement potential - Avoid deforestation	0	0	1504.898
Carbon sink enhancement potential - Extend rotation length	0	0	12412.7
Carbon sink enhancement potential - Improve plantations	0	0	215.283
Carbon sink enhancement potential - Increase retention of HWP	0	0	3150
Carbon sink enhancement potential - Increase trees outside forests	0	0	3542
Carbon sink enhancement potential - Reforest cropland	0	0	31779.5
Carbon sink enhancement potential - Reforest pasture	0	0	15007.1
Carbon sink enhancement potential - Restore productivity	0	0	12596.5
Land impacted for carbon sink enhancement - Accelerate regeneration	0	0	3044.58
Land impacted for carbon sink enhancement - All (not counting overlap)	0	0	18935
Land impacted for carbon sink enhancement - Avoid deforestation	0	0	403.969
Land impacted for carbon sink enhancement - Extend rotation length	0	0	6838
Land impacted for carbon sink enhancement - Improve plantations	0	0	119.65
Land impacted for carbon sink enhancement - Increase retention of HWP	0	0	629.999
Land impacted for carbon sink enhancement - Increase trees outside forests	0	0	999.164
Land impacted for carbon sink enhancement - Natural uptake	-13.79	5.117	1.467
Land impacted for carbon sink enhancement - Reforest cropland	0	0	10580.704
Land impacted for carbon sink enhancement - Reforest pasture	0	0	1134.767
Land impacted for carbon sink enhancement - Restore productivity	0	0	7108.2
Land impacted for carbon sink enhancement - Retained in Hardwood Products	-0.514	-1.068	-1.124
Land impacted for carbon sink enhancement - Total	-14.304	4.049	0.342
Land impacted for carbon sink enhancement - Total impacted (over 30 years)	0	0	11924

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

variable_name	2050
Business-as-usual carbon sink - Accelerate regeneration	705.984
Business-as-usual carbon sink - Avoid deforestation	128.686
Business-as-usual carbon sink - Extend rotation length	3740.8
Business-as-usual carbon sink - Improve plantations	45.437

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	200.89
Business-as-usual carbon sink - Reforest cropland	1200.6
Business-as-usual carbon sink - Reforest pasture	277.223
Business-as-usual carbon sink - Restore productivity	2502.3
Business-as-usual carbon sink - Total impacted (over 30 years)	1200.6

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

variable_name	2020	2025	2030	2035	2040	2045	2050
Final energy demand by sector - commercial	0.04	0.041	0.041	0.041	0.041	0.042	0.044
Final energy demand by sector - industry	0.06	0.064	0.068	0.071	0.076	0.082	0.088
Final energy demand by sector - residential	0.053	0.051	0.05	0.05	0.05	0.05	0.051
Final energy demand by sector - transportation	0.114	0.108	0.099	0.094	0.093	0.096	0.099

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	2877344847	3018632634	0	0	0	0
Sales of cooking units - Electric Resistance	0.419	0.447	0.447	0.446	0.444	0.445	0.446
Sales of cooking units - Gas	0.581	0.553	0.553	0.554	0.556	0.555	0.554
Sales of space heating units - Electric Heat Pump	0.015	0.139	0.469	0.739	0.783	0.788	0.788
Sales of space heating units - Electric Resistance	0.015	0.043	0.087	0.156	0.199	0.206	0.207
Sales of space heating units - Fossil	0.007	0.002	0.001	0	0	0	0
Sales of space heating units - Gas Furnace	0.962	0.816	0.443	0.104	0.017	0.006	0.005
Sales of water heating units - Electric Heat Pump	0	0	0	0	0	0	0
Sales of water heating units - Electric Resistance	0.007	0.015	0.015	0.015	0.015	0.015	0.015
Sales of water heating units - Gas Furnace	0.991	0.981	0.981	0.981	0.981	0.981	0.981
Sales of water heating units - Other	0.002	0.004	0.004	0.004	0.004	0.004	0.004

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	0.658	0.684	0.911	0.962	0.877	0.911

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	0.766	0.814	0	0	0	0
Sale of space heating units by type - Electric Heat Pump	0.064	0.15	0.368	0.808	0.89	0.896	0.894
Sale of space heating units by type - Electric Resistance	0.077	0.127	0.1	0.044	0.034	0.034	0.034
Sale of space heating units by type - Fossil	0.127	0.187	0.151	0.073	0.056	0.054	0.055
Sale of space heating units by type - Gas	0.732	0.537	0.381	0.075	0.021	0.017	0.017
Sales of cooking units - Electric Resistance	0.457	0.573	0.927	0.996	1	1	1
Sales of cooking units - Gas	0.543	0.427	0.073	0.004	0	0	0
Sales of water heating units by type - Electric Heat Pump	0	0.009	0.121	0.366	0.409	0.411	0.411
Sales of water heating units by type - Electric Resistance	0.141	0.27	0.355	0.538	0.572	0.574	0.574
Sales of water heating units by type - Gas Furnace	0.846	0.707	0.51	0.081	0.005	0	0
Sales of water heating units by type - Other	0.013	0.014	0.014	0.015	0.015	0.015	0.015

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	0.025	0.108	0.394	0.79	0.96	0.993	1
End-use technology sales by technology - LDV - gasoline	0.923	0.83	0.561	0.194	0.037	0.006	0
End-use technology sales by technology - LDV - hybrid	0.03	0.035	0.027	0.011	0.002	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	354919015	906905592	1474125688	2231222414	2430336751	2316133105
Number of public EV charging plugs - DC Fast Charging	64	0	766.87	0	3410	0	5522.2
Number of public EV charging plugs - L2 Charging	76	0	18486	0	82202.1	0	133118

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	0	0	0
Power generation capital investment - biomass w/ccu power plant	0	0	0	0	0	0	0
Power generation capital investment - Wind - Base	0	0	6.094	15.368	28.051	21.195	1.681
Power generation capital investment - Wind - Constrained	0	0	14.109	16.863	22.737	17.558	1.656

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	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	171.342	3068.6	10134.1	26562	39341.7	40465.4
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	30.413	707.603	2416.4	6900.2	10625.7	10945.6
HV transmission for wind and solar - constrained all	0	461.406	6592.6	14197.7	27701.7	39187	40135.6
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	111.469	1707.5	3482.8	6504.7	9258	9498.5

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

variable_name	2020	2025	2030	2035	2040	2045	2050
Biomass purchases	0	0	0	0	0.049	0.23	0.331
Capital investment	0	0	0	0	0.613	0	3.562
Number of facilities - allam power w ccu	0	0	0	0	0	0	0
Number of facilities - beccs hydrogen	0	0	0	0	1	7	11
Number of facilities - diesel	0	0	0	0	0	0	0
Number of facilities - diesel ccu	0	0	0	0	0	0	0
Number of facilities - power	0	0	0	0	0	0	0
Number of facilities - power ccu	0	0	0	0	0	0	0
Number of facilities - pyrolysis	0	0	0	0	0	0	0
Number of facilities - pyrolysis ccu	0	0	0	0	0	0	0
Number of facilities - sng	0	0	0	0	0	0	0
Number of facilities - sng ccu	0	0	0	0	0	0	0

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

variable_name	2025	2030	2035	2040	2045	2050
Annual - All	0	0	0.02	0.86	3.99	5.78
Annual - BECCS	0	0	0	0.84	3.96	5.7
Annual - Cement	0	0	0	0	0	0
Annual - NGCC	0	0	0.02	0.03	0.03	0.09
Cumulative - All	0	0	0.02	0.88	4.87	10.65
Cumulative - BECCS	0	0	0	0.84	4.8	10.5
Cumulative - Cement	0	0	0	0	0	0
Cumulative - NGCC	0	0	0.02	0.05	0.08	0.17

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

variable_name	2025	2030	2035	2040	2045	2050
Annual	0	1.1	3.52	6.32	9.47	13.05
Injection wells	0	2	8	14	23	28
Resource characterization, appraisal and permitting costs cumulative	70.31	210.93	281.24	281.24	281.24	281.24
Wells and facilities construction costs cumulative	0	58.52	228.06	406.43	679.59	843.72

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

variable_name	2025	2030	2035	2040	2045	2050
CO2 pipelines - All	0	1000466.088	1096642.322	1102101.369	1441406.7	1719921.8
CO2 pipelines - Spur	0	89276.31	185452.943	190911.991	530216.702	808732
CO2 pipelines - Trunk	0	911189.778	911189.778	911189.778	911189.778	911189.778

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

variable_name	2020	2025	2030	2035	2040	2045	2050
Jobs by economic sector - agriculture	0.756	0.872	1.77	0.676	61.459	236.86	281.936
Jobs by economic sector - construction	2589	2302.8	4690.1	9474.6	18098.8	20939.6	17188.3
Jobs by economic sector - manufacturing	1889.5	1801.3	2738.3	3857	4732.3	4622.9	4154.9
Jobs by economic sector - mining	2521.4	1560.4	977.037	756.86	522.969	419.872	315.556
Jobs by economic sector - other	271.199	208.381	388.766	889.876	1773.6	2244.8	2228.3
Jobs by economic sector - pipeline	180.814	183.101	299.123	186.612	155.158	165.66	158.636

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

variable_name	2020	2025	2030	2035	2040	2045	2050
Jobs by economic sector - professional	1378.7	1255.6	2527.5	6074.1	12320.3	15731.4	14430.5
Jobs by economic sector - trade	2117.5	1473.8	1736.6	3435.9	6579.3	8408.5	7903.8
Jobs by economic sector - utilities	1355	1592.8	3821.5	8066.4	16793.8	18506.8	13362.4
Jobs by resource sector - Biomass	3.134	3.741	4.88	1.927	185.011	863.856	1204
Jobs by resource sector - CO2	0	37.294	1181.6	507.62	539.243	965.567	1160.7
Jobs by resource sector - Coal	2817.8	1275	289.492	38.326	28.355	22.053	18.527
Jobs by resource sector - Grid	1518.1	2065.4	5617	14735.4	31817.7	34432.1	23747.2
Jobs by resource sector - Natural Gas	1119.4	1057.1	865.936	677.793	516.274	355.719	304.34
Jobs by resource sector - Nuclear	0	0	0.003	0.007	0	0	0
Jobs by resource sector - Oil	3206.4	2935.7	2510.6	2051.3	1457.9	1047.3	650.274
Jobs by resource sector - Solar	2566.5	1500.7	1611.7	2267.8	2400	2542	3997.2
Jobs by resource sector - Wind	1072.6	1504.1	5099.6	12461.9	24093.2	31047.9	28942.1
Median wages - All	56992.5	58900.8	59961.1	61023.2	62415.2	63409.9	64071.7
Required Level of Education - Associates degree or some college	3637.1	3131.1	5443.7	10496.9	19726.2	22975.3	19267.6
Required Level of Education - Bachelors degree	2568.4	2231.9	3577.7	6825.2	12703.9	15069.1	12959.7
Required Level of Education - Doctoral degree	82.493	73.695	127.638	271.576	527.387	658.327	595.065
Required Level of Education - High school diploma or less	5437	4426.1	7161.6	13403	24741.3	28549.3	23705
Required Level of Education - Masters or professional degree	578.979	516.307	870.194	1745.4	3338.9	4024.6	3497
Wage income - All	701279897	611376300	1030255208	1998202821	3810047501	4520101143	3846320411

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

variable_name	2050
Carbon sink enhancement potential - Accelerate regeneration	7554
Carbon sink enhancement potential - All (not counting overlap)	87761.9
Carbon sink enhancement potential - Avoid deforestation	1504.898
Carbon sink enhancement potential - corn-ethanol to energy grasses	0
Carbon sink enhancement potential - cropland measures	-5963.1
Carbon sink enhancement potential - Extend rotation length	12412.7
Carbon sink enhancement potential - Improve plantations	215.283
Carbon sink enhancement potential - Increase retention of HWP	3150
Carbon sink enhancement potential - Increase trees outside forests	3542
Carbon sink enhancement potential - permanent conservation cover	-568.524
Carbon sink enhancement potential - Reforest cropland	31779.5
Carbon sink enhancement potential - Reforest pasture	15007.1
Carbon sink enhancement potential - Restore productivity	12596.5
Carbon sink enhancement potential - total	-6531.624
Land impacted for carbon sink enhancement - Accelerate regeneration	3044.58
Land impacted for carbon sink enhancement - All (not counting overlap)	18935
Land impacted for carbon sink enhancement - Avoid deforestation	403.969
Land impacted for carbon sink enhancement - corn-ethanol to energy grasses	0
Land impacted for carbon sink enhancement - cropland measures	9234
Land impacted for carbon sink enhancement - Extend rotation length	6838
Land impacted for carbon sink enhancement - Improve plantations	119.65
Land impacted for carbon sink enhancement - Increase retention of HWP	629.999
Land impacted for carbon sink enhancement - Increase trees outside forests	999.164
Land impacted for carbon sink enhancement - permanent conservation cover	879.432
Land impacted for carbon sink enhancement - Reforest cropland	10580.704
Land impacted for carbon sink enhancement - Reforest pasture	1134.767
Land impacted for carbon sink enhancement - Restore productivity	7108.2
Land impacted for carbon sink enhancement - total	10113.4
Land impacted for carbon sink enhancement - Total impacted (over 30 years)	11924

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

variable_name	2050
Business-as-usual carbon sink - Accelerate regeneration	705.984
Business-as-usual carbon sink - Avoid deforestation	128.686
Business-as-usual carbon sink - Extend rotation length	3740.8
Business-as-usual carbon sink - Improve plantations	45.437
Business-as-usual carbon sink - Increase retention of HWP	0
Business-as-usual carbon sink - Increase trees outside forests	200.89
Business-as-usual carbon sink - Reforest cropland	1200.6
Business-as-usual carbon sink - Reforest pasture	277.223
Business-as-usual carbon sink - Restore productivity	2502.3
Business-as-usual carbon sink - Total impacted (over 30 years)	1200.6

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

variable_name	2020	2025	2030	2035	2040	2045	2050
Natural gas consumption	66380.4	67366.2	56785.9	45544.6	34285.3	21571.2	14961.2
Oil consumption	39996.6	38083.3	33415.4	26299.3	19301.3	13817.6	9018.4

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

variable_name	2020	2025	2030	2035	2040	2045	2050
Final energy demand by sector - commercial	0.04	0.04	0.039	0.037	0.034	0.032	0.031
Final energy demand by sector - industry	0.06	0.062	0.062	0.063	0.067	0.068	0.07
Final energy demand by sector - residential	0.053	0.05	0.048	0.043	0.036	0.032	0.028
Final energy demand by sector - transportation	0.114	0.107	0.094	0.079	0.065	0.057	0.053

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	2913312463	3240965940	0	0	0	0
Sales of cooking units - Electric Resistance	0.419	0.546	0.83	0.886	0.889	0.889	0.889
Sales of cooking units - Gas	0.581	0.454	0.17	0.114	0.111	0.111	0.111
Sales of space heating units - Electric Heat Pump	0.015	0.082	0.312	0.813	0.902	0.908	0.908
Sales of space heating units - Electric Resistance	0.015	0.034	0.049	0.081	0.087	0.087	0.087
Sales of space heating units - Fossil	0.007	0.002	0	0	0	0	0
Sales of space heating units - Gas Furnace	0.962	0.882	0.639	0.106	0.011	0.005	0.005
Sales of water heating units - Electric Heat Pump	0	0.011	0.144	0.437	0.489	0.492	0.492
Sales of water heating units - Electric Resistance	0.007	0.025	0.158	0.448	0.501	0.504	0.504
Sales of water heating units - Gas Furnace	0.991	0.96	0.694	0.111	0.007	0	0
Sales of water heating units - Other	0.002	0.004	0.004	0.004	0.004	0.004	0.004

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	0.684	0.713	1.499	1.619	1.362	1.437

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	0.764	0.811	0	0	0	0
Sale of space heating units by type - Electric Heat Pump	0.064	0.134	0.146	0.189	0.289	0.411	0.479
Sale of space heating units by type - Electric Resistance	0.077	0.128	0.126	0.122	0.112	0.097	0.087
Sale of space heating units by type - Fossil	0.127	0.189	0.19	0.176	0.149	0.127	0.12
Sale of space heating units by type - Gas	0.732	0.548	0.537	0.513	0.45	0.366	0.313
Sales of cooking units - Electric Resistance	0.455	0.469	0.519	0.651	0.833	0.946	0.986
Sales of cooking units - Gas	0.545	0.531	0.481	0.349	0.167	0.054	0.014
Sales of water heating units by type - Electric Heat Pump	0	0.002	0.009	0.03	0.082	0.148	0.187
Sales of water heating units by type - Electric Resistance	0.141	0.265	0.271	0.289	0.33	0.379	0.409
Sales of water heating units by type - Gas Furnace	0.846	0.718	0.705	0.666	0.573	0.458	0.39
Sales of water heating units by type - Other	0.013	0.014	0.015	0.015	0.015	0.015	0.015

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	0.095	0.22	0.441	0.692	0.864
End-use technology sales by technology - LDV - gasoline	0.933	0.896	0.834	0.715	0.51	0.279	0.122
End-use technology sales by technology - LDV - hybrid	0.031	0.04	0.046	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	56922684	120701878	406554749	1282666784	1867560170
Number of public EV charging plugs - DC Fast Charging	64	0	231.13	0	1260	0	3537
Number of public EV charging plugs - L2 Charging	76	0	5571.6	0	30372.7	0	85262

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

variable_name	2050
Carbon sink enhancement potential - Accelerate regeneration	7554
Carbon sink enhancement potential - All (not counting overlap)	87761.9
Carbon sink enhancement potential - Avoid deforestation	1504.898
Carbon sink enhancement potential - corn-ethanol to energy grasses	0

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

variable_name	2050
Carbon sink enhancement potential - cropland measures	-5963.1
Carbon sink enhancement potential - Extend rotation length	12412.7
Carbon sink enhancement potential - Improve plantations	215.283
Carbon sink enhancement potential - Increase retention of HWP	3150
Carbon sink enhancement potential - Increase trees outside forests	3542
Carbon sink enhancement potential - permanent conservation cover	-568.524
Carbon sink enhancement potential - Reforest cropland	31779.5
Carbon sink enhancement potential - Reforest pasture	15007.1
Carbon sink enhancement potential - Restore productivity	12596.5
Carbon sink enhancement potential - total	-6531.624
Land impacted for carbon sink enhancement - Accelerate regeneration	3044.58
Land impacted for carbon sink enhancement - All (not counting overlap)	18935
Land impacted for carbon sink enhancement - Avoid deforestation	403.969
Land impacted for carbon sink enhancement - corn-ethanol to energy grasses	0
Land impacted for carbon sink enhancement - cropland measures	9234
Land impacted for carbon sink enhancement - Extend rotation length	6838
Land impacted for carbon sink enhancement - Improve plantations	119.65
Land impacted for carbon sink enhancement - Increase retention of HWP	629.999
Land impacted for carbon sink enhancement - Increase trees outside forests	999.164
Land impacted for carbon sink enhancement - permanent conservation cover	879.432
Land impacted for carbon sink enhancement - Reforest cropland	10580.704
Land impacted for carbon sink enhancement - Reforest pasture	1134.767
Land impacted for carbon sink enhancement - Restore productivity	7108.2
Land impacted for carbon sink enhancement - total	10113.4
Land impacted for carbon sink enhancement - Total impacted (over 30 years)	11924

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

variable_name	2050
Business-as-usual carbon sink - Accelerate regeneration	705.984
Business-as-usual carbon sink - Avoid deforestation	128.686
Business-as-usual carbon sink - Extend rotation length	3740.8
Business-as-usual carbon sink - Improve plantations	45.437
Business-as-usual carbon sink - Increase retention of HWP	0
Business-as-usual carbon sink - Increase trees outside forests	200.89
Business-as-usual carbon sink - Reforest cropland	1200.6
Business-as-usual carbon sink - Reforest pasture	277.223
Business-as-usual carbon sink - Restore productivity	2502.3
Business-as-usual carbon sink - Total impacted (over 30 years)	1200.6

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

variable_name	2020	2025	2030	2035	2040	2045	2050
Final energy demand by sector - commercial	0.04	0.04	0.04	0.039	0.039	0.039	0.038
Final energy demand by sector - industry	0.06	0.062	0.063	0.065	0.069	0.071	0.072
Final energy demand by sector - residential	0.053	0.05	0.049	0.048	0.046	0.044	0.042
Final energy demand by sector - transportation	0.114	0.108	0.098	0.09	0.085	0.078	0.07

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	2912748176	3235954082	0	0	0	0
Sales of cooking units - Electric Resistance	0.419	0.462	0.502	0.608	0.754	0.846	0.878
Sales of cooking units - Gas	0.581	0.538	0.498	0.392	0.246	0.154	0.122
Sales of space heating units - Electric Heat Pump	0.015	0.068	0.081	0.123	0.226	0.356	0.432
Sales of space heating units - Electric Resistance	0.015	0.033	0.034	0.037	0.044	0.053	0.058
Sales of space heating units - Fossil	0.007	0.003	0.002	0.002	0.002	0.001	0.001
Sales of space heating units - Gas Furnace	0.962	0.896	0.883	0.838	0.728	0.59	0.509
Sales of water heating units - Electric Heat Pump	0	0.003	0.011	0.037	0.099	0.178	0.224
Sales of water heating units - Electric Resistance	0.007	0.017	0.025	0.051	0.112	0.191	0.237
Sales of water heating units - Gas Furnace	0.991	0.976	0.96	0.909	0.785	0.628	0.535
Sales of water heating units - Other	0.002	0.004	0.004	0.004	0.004	0.004	0.004

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	0.533	0.545	0.763	0.799	1.203	1.283

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	6.968	38.525	52.769	45.984	55.729

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	461.406	3779.6	23739.2	53732	83580.4	121605.1
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	111.469	882.646	6095.7	14684.6	23085.4	33194.6

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

variable_name	2050
Carbon sink enhancement potential - Accelerate regeneration	7554
Carbon sink enhancement potential - All (not counting overlap)	87761.9
Carbon sink enhancement potential - Avoid deforestation	1504.898
Carbon sink enhancement potential - corn-ethanol to energy grasses	0
Carbon sink enhancement potential - cropland measures	-5963.1
Carbon sink enhancement potential - Extend rotation length	12412.7
Carbon sink enhancement potential - Improve plantations	215.283
Carbon sink enhancement potential - Increase retention of HWP	3150
Carbon sink enhancement potential - Increase trees outside forests	3542
Carbon sink enhancement potential - permanent conservation cover	-568.524
Carbon sink enhancement potential - Reforest cropland	31779.5
Carbon sink enhancement potential - Reforest pasture	15007.1
Carbon sink enhancement potential - Restore productivity	12596.5
Carbon sink enhancement potential - total	-6531.624
Land impacted for carbon sink enhancement - Accelerate regeneration	3044.58
Land impacted for carbon sink enhancement - All (not counting overlap)	18935
Land impacted for carbon sink enhancement - Avoid deforestation	403.969
Land impacted for carbon sink enhancement - corn-ethanol to energy grasses	0
Land impacted for carbon sink enhancement - cropland measures	9234
Land impacted for carbon sink enhancement - Extend rotation length	6838
Land impacted for carbon sink enhancement - Improve plantations	119.65
Land impacted for carbon sink enhancement - Increase retention of HWP	629.999
Land impacted for carbon sink enhancement - Increase trees outside forests	999.164
Land impacted for carbon sink enhancement - permanent conservation cover	879.432
Land impacted for carbon sink enhancement - Reforest cropland	10580.704
Land impacted for carbon sink enhancement - Reforest pasture	1134.767
Land impacted for carbon sink enhancement - Restore productivity	7108.2
Land impacted for carbon sink enhancement - total	10113.4
Land impacted for carbon sink enhancement - Total impacted (over 30 years)	11924

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

variable_name	2050
Business-as-usual carbon sink - Accelerate regeneration	705.984
Business-as-usual carbon sink - Avoid deforestation	128.686
Business-as-usual carbon sink - Extend rotation length	3740.8
Business-as-usual carbon sink - Improve plantations	45.437
Business-as-usual carbon sink - Increase retention of HWP	0
Business-as-usual carbon sink - Increase trees outside forests	200.89
Business-as-usual carbon sink - Reforest cropland	1200.6
Business-as-usual carbon sink - Reforest pasture	277.223
Business-as-usual carbon sink - Restore productivity	2502.3
Business-as-usual carbon sink - Total impacted (over 30 years)	1200.6

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	0	0.007	0
Power generation capital investment - biomass w/ccu power plant	0	0	0	0	0	0.029	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	0	0	7.375	7.391
Power generation by technology - biomass w/ccu power plant	0	0	0	0	0	32.273	32.273

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

variable_name	2020	2025	2030	2035	2040	2045	2050
Biomass purchases	0	0	0	0	0.26	0.371	0.456
Capital investment	0	0	0	0	3.02	0	2.296
Number of facilities - allam power w ccu	0	0	0	0	0	1	2
Number of facilities - beccs hydrogen	0	0	0	0	4	6	8
Number of facilities - diesel	0	0	0	0	0	0	0
Number of facilities - diesel ccu	0	0	0	0	0	1	1
Number of facilities - power	0	0	0	0	0	0	0
Number of facilities - power ccu	0	0	0	0	0	1	1
Number of facilities - pyrolysis	0	0	0	0	0	0	0
Number of facilities - pyrolysis ccu	0	0	0	0	0	1	1
Number of facilities - sng	0	0	0	0	0	0	0
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	0.02	4.15	5.92	7.33
Annual - BECCS	0	0	0	4.12	5.89	7.23
Annual - Cement	0	0	0	0	0	0
Annual - NGCC	0	0	0.02	0.03	0.03	0.09
Cumulative - All	0	0	0.02	4.17	10.09	17.42
Cumulative - BECCS	0	0	0	4.12	10.01	17.24
Cumulative - Cement	0	0	0	0	0	0
Cumulative - NGCC	0	0	0.02	0.05	0.08	0.17

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

variable_name	2025	2030	2035	2040	2045	2050
Annual	0	2.77	10.7	21.39	28.56	30.93
Injection wells	0	5	20	35	59	73
Resource characterization, appraisal and permitting costs cumulative	70.31	323.43	506.23	506.23	506.23	506.23
Wells and facilities construction costs cumulative	0	152.15	592.97	1056.7	1766.9	2193.7

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

variable_name	2025	2030	2035	2040	2045	2050
CO2 pipelines - All	0	1000537.588	1102455.322	1205394.8	1383023.8	1842044.1
CO2 pipelines - Spur	0	89347.91	191265.543	294204.81	471834.334	930854
CO2 pipelines - Trunk	0	911189.778	911189.778	911189.778	911189.778	911189.778

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

variable_name	2050
Carbon sink enhancement potential - Accelerate regeneration	7554
Carbon sink enhancement potential - All (not counting overlap)	87761.9
Carbon sink enhancement potential - Avoid deforestation	1504.898
Carbon sink enhancement potential - corn-ethanol to energy grasses	-82.12
Carbon sink enhancement potential - cropland measures	-5876.547
Carbon sink enhancement potential - Cropland to woody energy crops	0
Carbon sink enhancement potential - Extend rotation length	12412.7
Carbon sink enhancement potential - Improve plantations	215.283
Carbon sink enhancement potential - Increase retention of HWP	3150
Carbon sink enhancement potential - Increase trees outside forests	3542
Carbon sink enhancement potential - pasture to energy crops	0
Carbon sink enhancement potential - permanent conservation cover	-558.98
Carbon sink enhancement potential - Reforest cropland	31779.5
Carbon sink enhancement potential - Reforest pasture	15007.1
Carbon sink enhancement potential - Restore productivity	12596.5
Carbon sink enhancement potential - total	-6517.648
Land impacted for carbon sink enhancement - Accelerate regeneration	3044.58
Land impacted for carbon sink enhancement - All (not counting overlap)	18935
Land impacted for carbon sink enhancement - Avoid deforestation	403.969
Land impacted for carbon sink enhancement - corn-ethanol to energy grasses	143.824
Land impacted for carbon sink enhancement - cropland measures	17869.7

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	52.444
Land impacted for carbon sink enhancement - Extend rotation length	6838
Land impacted for carbon sink enhancement - Improve plantations	119.65
Land impacted for carbon sink enhancement - Increase retention of HWP	629.999
Land impacted for carbon sink enhancement - Increase trees outside forests	999.164
Land impacted for carbon sink enhancement - pasture to energy crops	23.408
Land impacted for carbon sink enhancement - permanent conservation cover	864.712
Land impacted for carbon sink enhancement - Reforest cropland	10580.704
Land impacted for carbon sink enhancement - Reforest pasture	1134.767
Land impacted for carbon sink enhancement - Restore productivity	7108.2
Land impacted for carbon sink enhancement - total	18954.1
Land impacted for carbon sink enhancement - Total impacted (over 30 years)	11924

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

variable_name	2050
Business-as-usual carbon sink - Accelerate regeneration	705.984
Business-as-usual carbon sink - Avoid deforestation	128.686
Business-as-usual carbon sink - Extend rotation length	3740.8
Business-as-usual carbon sink - Improve plantations	45.437
Business-as-usual carbon sink - Increase retention of HWP	0
Business-as-usual carbon sink - Increase trees outside forests	200.89
Business-as-usual carbon sink - Reforest cropland	1200.6
Business-as-usual carbon sink - Reforest pasture	277.223
Business-as-usual carbon sink - Restore productivity	2502.3
Business-as-usual carbon sink - Total impacted (over 30 years)	1200.6

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

variable_name	2050
Carbon sink enhancement potential - Accelerate regeneration	7554
Carbon sink enhancement potential - All (not counting overlap)	87761.9
Carbon sink enhancement potential - Avoid deforestation	1504.898
Carbon sink enhancement potential - corn-ethanol to energy grasses	0
Carbon sink enhancement potential - cropland measures	-5963.1
Carbon sink enhancement potential - Extend rotation length	12412.7
Carbon sink enhancement potential - Improve plantations	215.283
Carbon sink enhancement potential - Increase retention of HWP	3150
Carbon sink enhancement potential - Increase trees outside forests	3542
Carbon sink enhancement potential - permanent conservation cover	-568.524
Carbon sink enhancement potential - Reforest cropland	31779.5
Carbon sink enhancement potential - Reforest pasture	15007.1
Carbon sink enhancement potential - Restore productivity	12596.5
Carbon sink enhancement potential - total	-6531.624
Land impacted for carbon sink enhancement - Accelerate regeneration	3044.58
Land impacted for carbon sink enhancement - All (not counting overlap)	18935
Land impacted for carbon sink enhancement - Avoid deforestation	403.969
Land impacted for carbon sink enhancement - corn-ethanol to energy grasses	0
Land impacted for carbon sink enhancement - cropland measures	9234
Land impacted for carbon sink enhancement - Extend rotation length	6838
Land impacted for carbon sink enhancement - Improve plantations	119.65
Land impacted for carbon sink enhancement - Increase retention of HWP	629.999
Land impacted for carbon sink enhancement - Increase trees outside forests	999.164
Land impacted for carbon sink enhancement - permanent conservation cover	879.432
Land impacted for carbon sink enhancement - Reforest cropland	10580.704
Land impacted for carbon sink enhancement - Reforest pasture	1134.767
Land impacted for carbon sink enhancement - Restore productivity	7108.2
Land impacted for carbon sink enhancement - total	10113.4
Land impacted for carbon sink enhancement - Total impacted (over 30 years)	11924

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

variable_name	2050
Business-as-usual carbon sink - Accelerate regeneration	705.984
Business-as-usual carbon sink - Avoid deforestation	128.686
Business-as-usual carbon sink - Extend rotation length	3740.8
Business-as-usual carbon sink - Improve plantations	45.437
Business-as-usual carbon sink - Increase retention of HWP	0
Business-as-usual carbon sink - Increase trees outside forests	200.89
Business-as-usual carbon sink - Reforest cropland	1200.6
Business-as-usual carbon sink - Reforest pasture	277.223
Business-as-usual carbon sink - Restore productivity	2502.3
Business-as-usual carbon sink - Total impacted (over 30 years)	1200.6