Princeton's Net-Zero America study

Annex G: Electricity Distribution System Transition

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11 August 2021

Contents

Method and Results

This appendix describes how national and state-level capital investment schedules for 2020 to 2050 were estimated for electricity distribution in the REF, E+, and E- scenarios.

The starting point for a given scenario is the aggregated state-level hourly electricity load profile, combining residential, commercial, industrial, and transportation sector loads. These profiles are generated in the EnergyPathways model.[a] Their development is described in Annex A [1]. The EnergyPathway load profiles are an input to the RIO model, which finds the least-cost energy supply mix satisfying demands for fuels and electricity subject to constraints that vary with each scenario. RIO has the flexibility to delay light-duty electric vehicle (LDEV) charging by up to 5 hours for half the LDEV fleet relative to the "native" charging profile for LDEVs defined in the EnergyPathways load profile. It also has the flexibility to time-shift electric water heating loads in the residential and commercial sectors forward or backward by up to 2 hours. Time-shifting these loads is adopted by RIO as part of the strategy for minimizing overall energy-system costs [1], by reducing peak electricity distribution needs.

The state-level electricity distribution load estimates used to estimate distribution system capital investments assume that the peak-hour distribution load in EnergyPathways is coincident with the peak LDEV charging and peak residential and commercial water heating native loads. We assume that RIO time-shifts the LDEV and water heating loads, and so we subtract 50% of the LDEV peak charging load and 20% of the residential and commercial peak water heating load from the peak-hour total load found in EnergyPathways. The results are estimates of the peak loads on state distribution systems (Table 1). For purposes of estimating capital invested in distribution systems, we assume that the peak load is a surrogate for the installed capacity of the distribution system. This understates the installed distribution capacity, since it does not consider a margin in capacity beyond the peak load.

[a] The EnergyPathways (EP) output file called subsector_profiles.csv gives peak electricity loads by state in units of MMBtu/hour.

Peak loads on the distribution system increase from 2020 to 2050 at a slower rate than does the installed generating capacity because the average capacity factor for the entire generating mix is decreasing over time due to increasing amounts of solar and wind capacity and decreasing utilization of thermal capacity.

It is also worth noting in Table 1 that in some states the increase in peak distribution-system load over time in REF is higher than in E-. Three factors explain this result. First, in E- all electricity-using devices like lights and plug loads are replaced at the end of their economic lives with the most efficient technology available among options included in the model. (Options include all technologies in the NEMS (National Energy Modeling System) that underlie the Annual Energy Outlook 2019 [2] projections.) In REF, end-of-life technology replacements follow those for the AEO2019 Reference Case projection, which are generally not the most efficient options available in NEMS. Second, the limited extent of electrification assumed in E- includes deployment of heat pumps in the 2020s to replace electric resistance heating (predominantly in southern states), which is results in a net reduction in electricity loads. Third, the higher penetration of electric vehicles (EV) and heat pump water heating in E- compared with REF contributes to requiring total electricity generation levels that are higher in E- than REF, but because up to 50% of EV charging loads and 20% of electric water heating loads can be time-shifted off the distribution system peak (as discussed above), these do not contribute to distribution peak load to the same degree that they contribute to total electricity use. It should be additionally noted that the large flexible loads constituting electrolysis and electric boilers that are primarily responsible for electricity demand in E- exceeding that in REF, are modeled as higher-voltage loads, i.e., not part of the distribution system load.

The next step in the analysis estimates the capital investment per unit of installed distribution-system capacity in the following manner. The 2019 Annual Energy Outlook [2] includes state-by-state estimates of the average levelized cost ($/MWh) of delivered electricity by sector in 2020, disaggregated into generation, transmission, and distribution components. For each state we multiply the distribution component (shown in Table 2) by final electricity demand in 2020 from EnergyPathways output (also shown in Table 2). This gives state-level total distribution revenues for 2020, which includes both capital recovery and operating/maintenance components. Analysis from the Energy Information Administration [3] indicates that about 50% of total distribution charges on average in the US today are for capital recovery. Applying this percentage results in an estimate of the 2020 distribution capital recovery revenues by state (Table 2).

Working from the capital recovery revenues, we then estimate the gross capital assets (i.e., total undepreciated capital) in the distribution system in 2020 by assuming:

1) annual replacement of existing undepreciated capacity equals 2.5% of the gross capital assets in the prior year (corresponding to 40-year straight-line depreciation). We derive an estimate of the fraction of installed capacity that is not yet fully depreciated in 2020 based on a weighted-average age of the 2020 generation fleet. We estimate the latter as follows. Annual total electricity generation [4,5] is taken as a surrogate for installed distribution capacity over the 40-year period from 1980 – 2019. We calculate an age-weighting factor for installed capacity in a given year as being equal to the annual generation for that year divided by the average annual generation over the 40-year period (3,463 TWh). For each year, we then multiply the weighting factor and the years' difference from 2020 (e.g., the 1980 weighting factor is multiplied by 40, the 1981 factor is multiplied by 39, etc.) and sum the products across all 40 years. We divide that sum by the sum of the weighting factors to come up with an estimated average asset age in 2020 of 18.4 years. On that basis, 46% of (distribution) assets (18.4/40) are estimated to be fully depreciated in 2020.

2) annual capital charges for investments in distribution capacity expansion from the previous year are based on a weighted average cost of capital of 4.4%/y (real) [6] and a 40-year economic life.

With the above assumptions, distribution system gross capital assets in 2020 (Table 2) are calculated as the annual distribution capital recovery in 2020 divided by 0.0539.[b]

We assume the national estimate of gross capital assets per kW of peak distribution capacity in 2020 ($1,351/kW, Table 2) is representative for 2030, 2040, and 2050, and we use it to estimate gross assets for those years using modeled peak loads (Table 3). We linearly interpolate to estimate gross capital assets for intervening years (Table 4).

The annual capital invested is then calculated as the sum of capital invested to new capacity (which is given by the difference in gross assets between the current and prior year) and the capital invested to replace depreciated assets (i.e., 2.5% of the current year's gross assets). Table 5 shows annual capital investments and Table 6 shows investments by decade for the E+, E-, and REF scenarios.

To estimate annual capital investments from 2020 to 2050 for each state, we assume that a state's gross capital assets in distribution is in proportion to the ratio of its peak electricity load to the national peak load. We then apply the same calculation at the state level as applied nationally, i.e., we sum capital invested in new capacity (given by the difference in gross capital assets between the current and prior year) and the capital invested to replace depreciated assets (i.e., 2.5% of the prior year's gross capital assets). Table 7 shows an illustrative set of year-by-year results for one state, California. Figure 1 shows decadal capital investments for each state for the REF, E+, and E- scenarios.

[b] $Gross\ Capital\ Assets = \frac{Annual\ Capital\ Recovery}{{}^{1}/_{40}+\frac{0.044}{\left(1+1.044^{-40}\right)}} = \frac{Annual\ Capital\ Recovery}{0.0539}$

Table 1. Estimated peak electricity distribution system loads (MW) by state in 2020, 2030, 2040, and 2050 for E+, E-, and REF scenarios.[c]

	E+				E-				REF			
	2020	**2030**	**2040**	**2050**	**2020**	**2030**	**2040**	**2050**	**2020**	**2030**	**2040**	**2050**
Alabama	18,134	19,062	22,742	24,369	18,119	18,090	19,193	21,980	18,109	19,456	22,653	24,320
Arizona	18,737	22,115	26,905	30,559	18,729	21,427	24,161	28,143	18,728	22,117	26,085	30,365
Arkansas	11,197	11,942	14,553	16,746	11,194	11,492	12,377	14,721	11,203	11,752	13,835	15,579
California	54,635	59,441	86,554	100,575	54,611	54,726	64,533	85,242	54,594	57,727	73,146	81,691
Colorado	11,099	12,423	17,544	21,963	11,098	11,730	13,560	17,560	11,091	12,008	14,082	16,370
Connecticut	6,027	6,428	10,232	12,545	6,026	5,965	6,838	9,564	6,024	6,033	8,403	10,288
Delaware	2,660	2,768	3,405	3,873	2,659	2,669	2,875	3,446	2,661	2,715	2,980	3,441
District of Col.	2,336	2,379	2,997	3,461	2,335	2,287	2,401	3,043	2,335	2,339	2,935	3,574
Florida	63,520	59,526	64,410	72,073	63,463	57,400	56,814	63,714	63,430	60,110	65,983	71,327
Georgia	27,920	31,186	39,171	42,727	27,892	29,307	33,046	38,719	27,921	31,845	39,073	43,092
Idaho	4,465	5,209	7,096	8,484	4,464	4,937	5,716	7,294	4,459	5,054	5,764	6,528
Illinois	29,178	31,573	40,470	48,217	29,172	29,846	32,991	39,770	29,153	30,298	34,324	40,732
Indiana	20,629	22,500	28,431	31,987	20,625	21,414	23,572	27,886	20,625	21,718	23,160	25,712
Iowa	11,513	13,035	17,638	20,585	11,512	12,259	13,989	17,336	11,492	12,348	13,343	14,383
Kansas	8,567	9,321	11,821	13,733	8,565	8,839	9,630	11,595	8,562	8,973	9,517	10,774
Kentucky	14,169	15,388	18,643	19,917	14,160	14,615	15,731	17,972	14,162	15,420	17,913	19,655
Louisiana	21,398	24,674	33,405	36,821	21,389	22,941	26,244	32,744	21,354	25,199	33,088	36,720
Maine	3,295	3,400	4,305	5,056	3,294	3,192	3,353	4,116	3,294	3,318	3,586	3,798
Maryland	15,239	15,826	20,508	23,231	15,235	15,184	16,750	20,590	15,242	15,450	18,568	21,333
Massachusetts	11,342	12,292	18,713	23,595	11,339	11,335	12,914	17,767	11,339	11,313	14,881	18,263
Michigan	23,910	25,534	32,679	37,369	23,902	24,143	26,555	32,016	23,894	24,737	26,992	28,997
Minnesota	17,224	18,584	25,313	29,337	17,219	17,437	19,019	23,298	17,207	18,440	21,365	22,999
Mississippi	9,172	9,854	12,714	13,882	9,169	9,367	10,125	12,129	9,170	10,255	13,099	14,356
Missouri	17,300	18,560	22,922	26,190	17,296	17,684	18,971	22,621	17,297	18,055	19,042	20,941
Montana	2,591	2,938	4,352	5,235	2,590	2,725	3,152	4,097	2,589	2,900	3,494	3,898
Nebraska	6,270	7,057	9,432	11,153	6,269	6,645	7,553	9,321	6,262	6,681	7,147	7,749
Nevada	7,532	8,886	11,127	12,821	7,529	8,560	9,950	11,789	7,528	8,759	10,183	11,840
New Hampshire	2,622	2,754	3,602	4,164	2,621	2,563	2,799	3,406	2,621	2,641	2,872	3,050
New Jersey	15,922	17,053	28,887	36,163	15,916	16,011	18,314	27,355	15,919	16,028	23,871	29,515
New Mexico	3,915	4,557	6,643	8,107	3,914	4,203	4,952	6,556	3,911	4,307	5,647	6,826
New York	35,027	37,385	54,151	67,187	35,018	35,176	39,283	50,628	35,006	35,626	44,190	54,299
North Carolina	28,641	30,420	37,489	43,167	28,614	29,243	31,742	37,999	28,627	30,675	34,915	37,866
North Dakota	3,388	3,676	4,920	5,960	3,387	3,476	3,794	4,701	3,383	3,600	4,000	4,376
Ohio	27,450	29,704	41,320	49,883	27,446	28,008	31,040	39,364	27,435	28,543	36,644	42,859
Oklahoma	13,993	14,853	18,126	20,843	13,990	14,236	15,197	18,208	13,994	14,660	17,346	19,450
Oregon	9,151	10,331	13,417	15,320	9,145	9,620	10,452	12,984	9,144	10,224	10,669	11,270
Pennsylvania	29,342	30,993	40,007	47,964	29,337	29,505	32,429	38,877	29,328	29,791	33,984	39,768
Rhode Island	1,530	1,641	2,925	3,746	1,530	1,512	1,809	2,744	1,529	1,510	2,278	2,838
South Carolina	17,194	18,110	21,783	23,596	17,181	17,212	18,657	21,428	17,176	18,635	22,354	24,448
South Dakota	3,230	3,639	5,029	5,997	3,229	3,413	3,902	4,904	3,224	3,426	3,713	4,002
Tennessee	22,310	23,783	27,748	29,389	22,293	22,816	24,103	26,587	22,295	23,843	26,554	28,320
Texas	88,770	99,630	130,104	143,213	88,722	94,576	106,029	128,538	88,712	101,908	131,841	146,714
Utah	5,958	6,965	9,815	12,653	5,957	6,559	7,768	9,795	5,950	6,701	7,757	9,337
Vermont	1,371	1,485	2,000	2,308	1,370	1,372	1,507	1,843	1,370	1,417	1,576	1,677
Virginia	23,662	24,736	30,281	34,386	23,657	23,757	25,784	29,474	23,669	24,217	27,712	31,018
Washington	17,066	18,317	23,115	25,934	17,052	17,156	18,823	22,462	17,051	17,751	19,150	20,158
West Virginia	4,466	4,747	6,362	7,317	4,464	4,569	5,111	6,326	4,462	4,696	5,063	5,552
Wisconsin	15,423	16,519	21,815	24,947	15,416	15,489	16,904	20,674	15,407	16,340	18,229	19,424
Wyoming	1,968	2,168	3,037	3,565	1,967	2,027	2,271	2,924	1,964	2,131	2,334	2,608
US total	812,457	875,367	1,140,658	1,312,315	812,079	828,713	914,683	1,116,254	811,901	863,691	1,027,342	1,154,103

[c] Differences in the 2020 peak loads between E+, E- and REF scenarios arise from rounding errors.

Table 2. Estimation of gross capital assets in electricity distribution in 2020 (2019$).

State	Generation (MWh)	Distribution price (c/kWh)	Total dist. rev. (M$)	Dist. capital recov. (M$)	Gross assets (M$)	Gross assets ($/kW)
Alabama	8.317E+10	2.77	2302	1,151	21,348	1,177
Arizona	7.655E+10	3.24	2479	1,239	22,990	1,227
Arkansas	4.802E+10	2.13	1024	512	9,493	848
California	2.870E+11	6.66	19,121	9,560	177,338	3,246
Colorado	5.748E+10	3.00	1,727	863	16,013	1,443
Connecticut	3.162E+10	5.10	1,614	807	14,970	2,484
Delaware	1.090E+10	3.69	403	201	3,735	1,404
District of Columbia	9.648E+09	3.69	356	178	3,306	1,415
Florida	2.430E+11	2.48	6,014	3,007	55,780	878
Georgia	1.340E+11	2.77	3,706	1,853	34,370	1,231
Idaho	2.330E+10	3.07	716	358	6,638	1,487
Illinois	1.340E+11	2.40	3,215	1,607	29,815	1,022
Indiana	1.040E+11	2.40	2,496	1,248	23,152	1,122
Iowa	5.670E+10	2.29	1,301	650	12,063	1,048
Kansas	3.779E+10	2.80	1,060	530	9,830	1,147
Kentucky	7.635E+10	2.67	2,042	1,021	18,938	1,337
Louisiana	9.898E+10	2.13	2,110	1,055	19,567	914
Maine	1.462E+10	5.10	747	373	6,924	2,101
Maryland	6.762E+10	3.69	2,498	1,249	23,171	1,521
Massachusetts	5.472E+10	5.10	2,794	1,397	25,909	2,284
Michigan	1.090E+11	3.00	3,255	1,628	30,189	1,263
Minnesota	7.294E+10	2.29	1,673	837	15,519	901
Mississippi	4.362E+10	2.13	930	465	8,623	940
Missouri	7.728E+10	2.40	1,855	927	17,201	994
Montana	1.321E+10	3.84	508	254	4,710	1,818
Nebraska	3.060E+10	2.80	858	429	7,959	1,269
Nevada	3.333E+10	3.07	1,024	512	9,493	1,260
New Hampshire	1.158E+10	5.10	591	296	5,482	2,091
New Jersey	7.097E+10	3.69	2,622	1,311	24,319	1,527
New Mexico	1.963E+10	3.24	636	318	5,895	1,506
New York	1.560E+11	6.69	10,465	5,233	97,060	2,771
North Carolina	1.350E+11	2.17	2,934	1,467	27,211	950
North Dakota	1.453E+10	2.03	296	148	2,742	809
Ohio	1.390E+11	2.63	3,639	1,819	33,750	1,229
Oklahoma	5.839E+10	2.57	1,501	750	13,917	995
Oregon	4.435E+10	3.84	1,705	852	15,811	1,728
Pennsylvania	1.410E+11	3.69	5,195	2,598	48,184	1,642
Rhode Island	7.717E+09	5.10	394	197	3,654	2,388
South Carolina	7.472E+10	2.17	1,619	810	15,017	873
South Dakota	1.391E+10	2.03	283	142	2,625	813
Tennessee	1.070E+11	2.67	2,865	1,432	26,567	1,191
Texas	4.100E+11	1.41	5,802	2,901	53,812	606
Utah	2.978E+10	3.07	915	457	8,484	1,424
Vermont	6.238E+09	5.10	318	159	2,953	2,155
Virginia	1.100E+11	2.88	3,176	1,588	29,456	1,245
Washington	7.858E+10	3.84	3,021	1,510	28,015	1,642
West Virginia	2.271E+10	2.63	597	298	5,532	1,239
Wisconsin	7.190E+10	2.29	1,649	825	15,298	992
Wyoming	1.108E+10	3.07	340	170	3,157	1,604
US total			**118,387**	**59,193**	**1,097,984**	**1,351**

Table 3. Modeled US national electricity peak demands (MW) and estimated gross capital assets (billion $) in distribution systems.

	E+		E-		REF	
	Peak load, MW	Gross assets, B$	Peak load, MW	Gross assets, B$	Peak load, MW	Gross assets, B$
2020	812,457	1,098	812,079	1,097	811,901	1,097
2030	875,367	1,183	828,713	1,120	863,691	1,167
2040	1,140,658	1,542	914,683	1,236	1,027,342	1,388
2050	1,312,315	1,774	1,116,254	1,509	1,154,103	1,560

Table 4. Estimated gross capital assets in US distribution systems, 2020 to 2050 (Billion 2019$)

	E+	E-	REF
2020	1,098	1,097	1,097
2021	1,106	1,100	1,105
2022	1,115	1,102	1,112
2023	1,123	1,105	1,119
2024	1,132	1,107	1,126
2025	1,140	1,109	1,133
2026	1,149	1,111	1,140
2027	1,157	1,113	1,146
2028	1,166	1,116	1,153
2029	1,175	1,118	1,160
2030	1,183	1,120	1,167
2031	1,219	1,132	1,189
2032	1,255	1,143	1,211
2033	1,291	1,155	1,234
2034	1,326	1,166	1,256
2035	1,362	1,178	1,278
2036	1,398	1,190	1,300
2037	1,434	1,201	1,322
2038	1,470	1,213	1,344
2039	1,506	1,225	1,366
2040	1,542	1,236	1,388
2041	1,565	1,263	1,406
2042	1,588	1,291	1,423
2043	1,611	1,318	1,440
2044	1,634	1,345	1,457
2045	1,658	1,372	1,474
2046	1,681	1,400	1,491
2047	1,704	1,427	1,508
2048	1,727	1,454	1,525
2049	1,750	1,481	1,543
2050	1,774	1,509	1,560

Table 5. Annual capital investments in electricity distribution (Billion 2019$)

	E+			E-			REF		
	Capital replaced	New assets	Total capital	Capital replaced	New assets	Total capital	Capital replaced	New assets	Total capital
2021	27.4	8.5	36.0	27.4	2.2	29.6	27.4	6.9	34.4
2022	27.7	8.5	36.2	27.5	2.2	29.7	27.6	6.9	34.5
2023	27.9	8.5	36.4	27.6	2.2	29.8	27.8	6.9	34.7
2024	28.1	8.5	36.6	27.6	2.2	29.8	28.0	6.9	34.9
2025	28.3	8.5	36.8	27.7	2.2	29.9	28.1	6.9	35.1
2026	28.5	8.5	37.0	27.7	2.2	29.9	28.3	6.9	35.2
2027	28.7	8.5	37.2	27.8	2.2	30.0	28.5	6.9	35.4
2028	28.9	8.5	37.4	27.8	2.2	30.0	28.7	6.9	35.6
2029	29.1	8.5	37.7	27.9	2.2	30.1	28.8	6.9	35.8
2030	29.4	8.5	37.9	27.9	2.2	30.1	29.0	6.9	35.9
2031	29.6	35.9	65.4	28.0	11.6	39.6	29.2	22.1	51.3
2032	30.5	35.9	66.3	28.3	11.6	39.9	29.7	22.1	51.8
2033	31.4	35.9	67.2	28.6	11.6	40.2	30.3	22.1	52.4
2034	32.3	35.9	68.1	28.9	11.6	40.5	30.8	22.1	53.0
2035	33.2	35.9	69.0	29.2	11.6	40.8	31.4	22.1	53.5
2036	34.1	35.9	69.9	29.5	11.6	41.1	31.9	22.1	54.1
2037	35.0	35.9	70.8	29.7	11.6	41.4	32.5	22.1	54.6
2038	35.8	35.9	71.7	30.0	11.6	41.7	33.1	22.1	55.2
2039	36.7	35.9	72.6	30.3	11.6	41.9	33.6	22.1	55.7
2040	37.6	35.9	73.5	30.6	11.6	42.2	34.2	22.1	56.3
2041	38.5	23.2	61.7	30.9	27.2	58.1	34.7	17.1	51.8
2042	39.1	23.2	62.3	31.6	27.2	58.8	35.1	17.1	52.3
2043	39.7	23.2	62.9	32.3	27.2	59.5	35.6	17.1	52.7
2044	40.3	23.2	63.5	32.9	27.2	60.2	36.0	17.1	53.1
2045	40.9	23.2	64.1	33.6	27.2	60.9	36.4	17.1	53.6
2046	41.4	23.2	64.6	34.3	27.2	61.5	36.9	17.1	54.0
2047	42.0	23.2	65.2	35.0	27.2	62.2	37.3	17.1	54.4
2048	42.6	23.2	65.8	35.7	27.2	62.9	37.7	17.1	54.8
2049	43.2	23.2	66.4	36.4	27.2	63.6	38.1	17.1	55.3
2050	43.8	23.2	67.0	37.0	27.2	64.3	38.6	17.1	55.7

Table 6. Decadal investments in electricity distribution (Billion 2019$)

	E+	E-	REF
2021-2030	369	299	352
2031-2040	695	409	538
2041-2050	644	612	538

Table 7. Annual capital investments in electricity distribution for California (Billion 2019$).

	E+				E-				REF			
	Gross assets	**Capital replaced**	**New assets**	**Total capital**	**Gross assets**	**Capital replaced**	**New assets**	**Total capital**	**Gross assets**	**Capital replaced**	**New assets**	**Total capital**
2020	73.8				73.8				73.8			
2021	74.5	1.8	0.65	2.5	73.8	1.8	0.02	1.9	74.2	1.8	0.42	2.3
2022	75.1	1.9	0.65	2.5	73.8	1.8	0.02	1.9	74.6	1.9	0.42	2.3
2023	75.8	1.9	0.65	2.5	73.8	1.8	0.02	1.9	75.1	1.9	0.42	2.3
2024	76.4	1.9	0.65	2.5	73.9	1.8	0.02	1.9	75.5	1.9	0.42	2.3
2025	77.1	1.9	0.65	2.6	73.9	1.8	0.02	1.9	75.9	1.9	0.42	2.3
2026	77.7	1.9	0.65	2.6	73.9	1.8	0.02	1.9	76.3	1.9	0.42	2.3
2027	78.4	1.9	0.65	2.6	73.9	1.8	0.02	1.9	76.7	1.9	0.42	2.3
2028	79.0	2.0	0.65	2.6	73.9	1.8	0.02	1.9	77.2	1.9	0.42	2.3
2029	79.7	2.0	0.65	2.6	73.9	1.8	0.02	1.9	77.6	1.9	0.42	2.4
2030	80.3	2.0	0.65	2.6	74.0	1.8	0.02	1.9	78.0	1.9	0.42	2.4
2031	84.0	2.0	3.7	5.7	75.3	1.8	1.3	3.2	80.1	2.0	2.1	4.0
2032	87.7	2.1	3.7	5.8	76.6	1.9	1.3	3.2	82.2	2.0	2.1	4.1
2033	91.3	2.2	3.7	5.9	77.9	1.9	1.3	3.2	84.3	2.1	2.1	4.1
2034	95.0	2.3	3.7	5.9	79.3	1.9	1.3	3.3	86.3	2.1	2.1	4.2
2035	98.7	2.4	3.7	6.0	80.6	2.0	1.3	3.3	88.4	2.2	2.1	4.2
2036	102	2.5	3.7	6.1	81.9	2.0	1.3	3.3	90.5	2.2	2.1	4.3
2037	106	2.6	3.7	6.2	83.2	2.0	1.3	3.4	92.6	2.3	2.1	4.3
2038	110	2.6	3.7	6.3	84.6	2.1	1.3	3.4	94.7	2.3	2.1	4.4
2039	113	2.7	3.7	6.4	85.9	2.1	1.3	3.4	96.8	2.4	2.1	4.5
2040	117	2.8	3.7	6.5	87.2	2.1	1.3	3.5	98.9	2.4	2.1	4.5
2041	119	2.9	1.9	4.8	90.0	2.2	2.8	5.0	100	2.5	1.2	3.6
2042	121	3.0	1.9	4.9	92.8	2.3	2.8	5.0	101	2.5	1.2	3.7
2043	123	3.0	1.9	4.9	95.6	2.3	2.8	5.1	102	2.5	1.2	3.7
2044	125	3.1	1.9	5.0	98.4	2.4	2.8	5.2	103	2.6	1.2	3.7
2045	126	3.1	1.9	5.0	101	2.5	2.8	5.3	105	2.6	1.2	3.7
2046	128	3.2	1.9	5.1	104	2.5	2.8	5.3	106	2.6	1.2	3.8
2047	130	3.2	1.9	5.1	107	2.6	2.8	5.4	107	2.6	1.2	3.8
2048	132	3.3	1.9	5.2	110	2.7	2.8	5.5	108	2.7	1.2	3.8
2049	134	3.3	1.9	5.2	112	2.7	2.8	5.5	109	2.7	1.2	3.9
2050	136	3.4	1.9	5.2	115	2.8	2.8	5.6	110	2.7	1.2	3.9

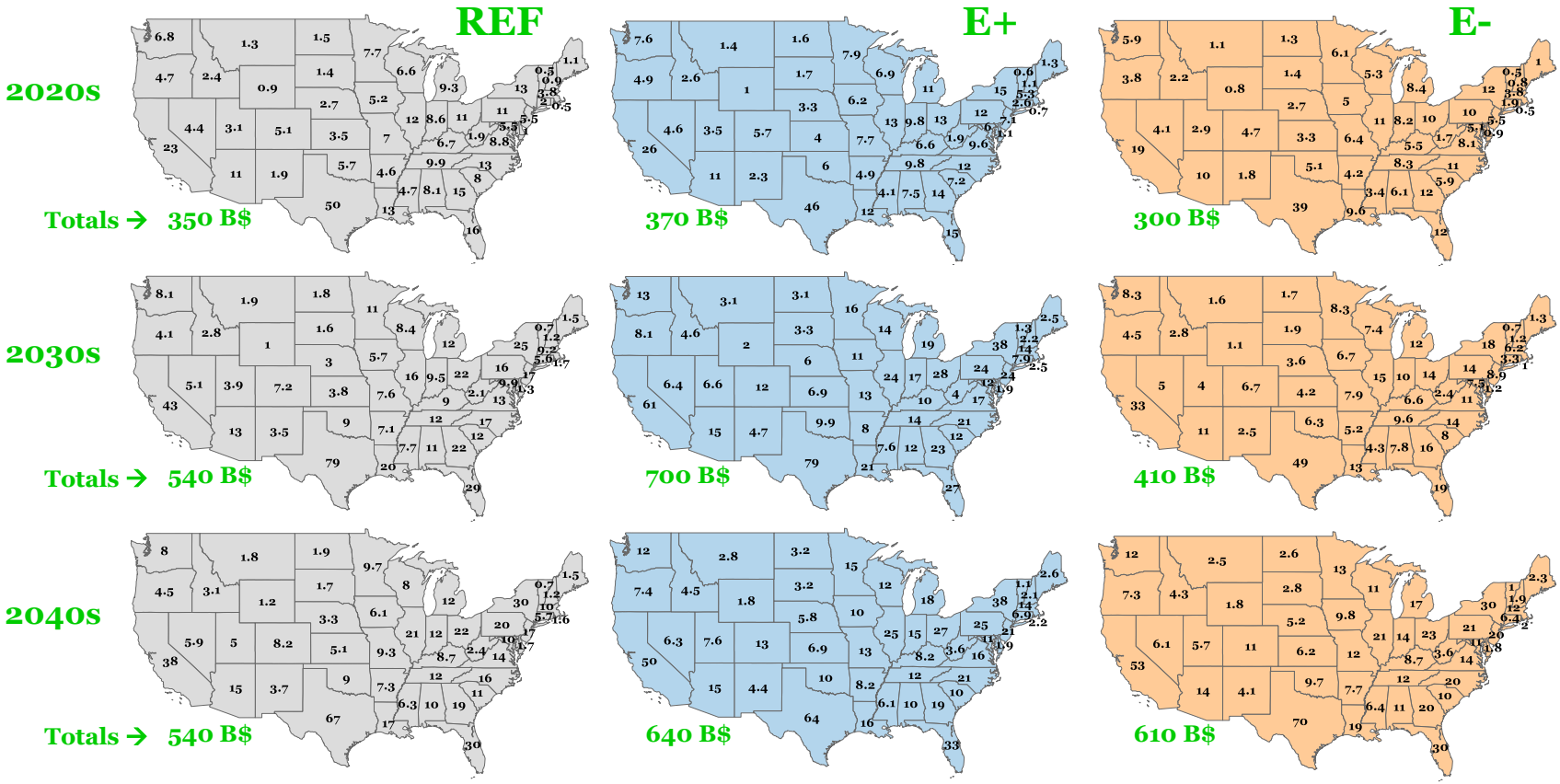

Figure 1. Decadal capital investments in electricity distribution by state for REF, E+ and E- scenarios (billion 2019 $).

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