# Impacts of long-term temperature change and variability on electricity investments - Supplementary Information (SI)

**Zarrar Khan[1]*, Gokul Iyer[1], Pralit Patel[1], Son Kim[1], Mohamad Hejazi[1], Casey Burleyson[2], Marshall Wise[1]**

[1] Joint Global Change Research institute, Pacific Northwest National Laboratory (PNNL), College Park, MD 20740, USA

[2] Pacific Northwest National Laboratory (PNNL), 902 Battelle Blvd, Richland, WA 99354

* Corresponding Author. zarrar.khan@pnnl.gov

## CONTENTS

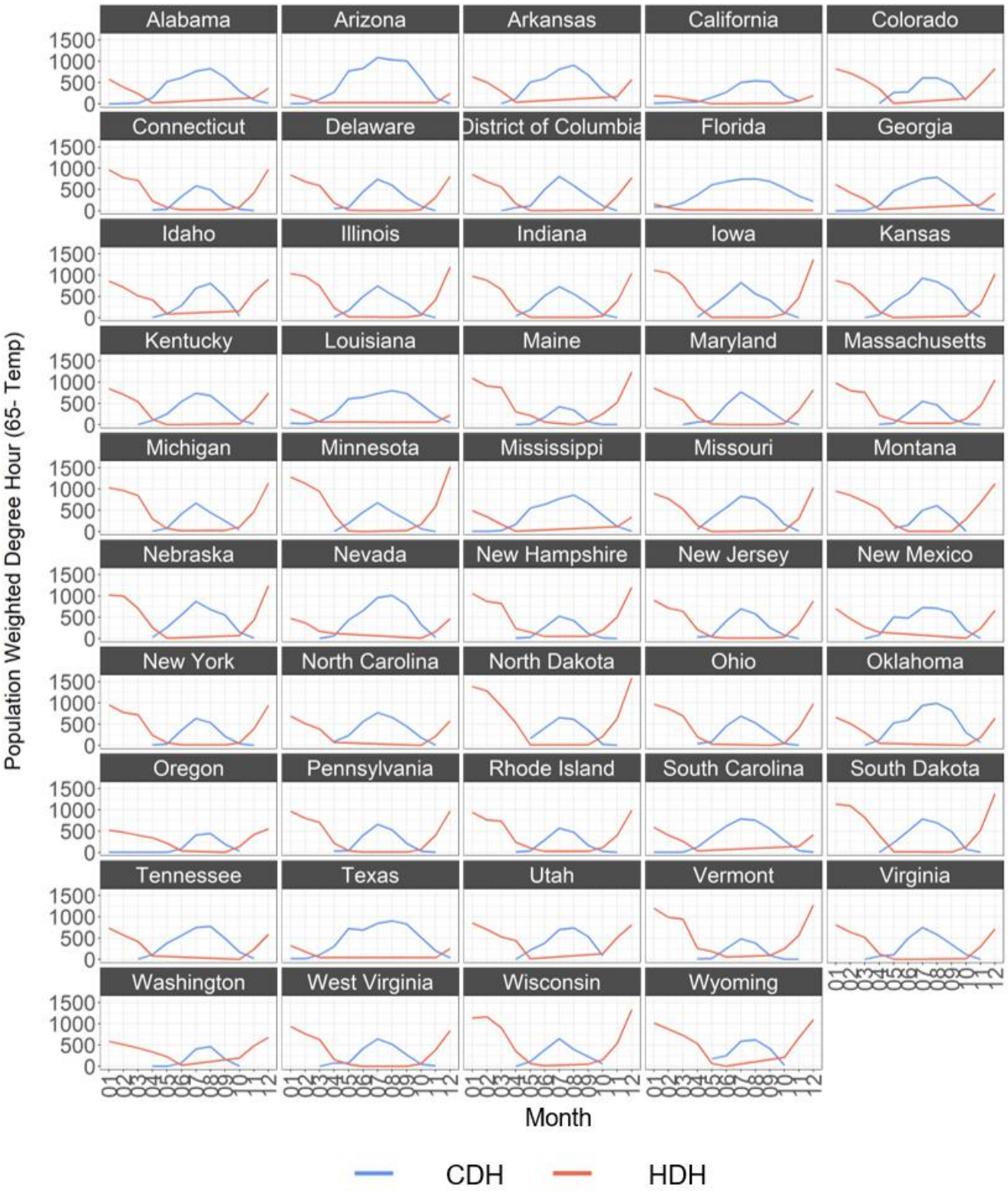
## Supplementary Note 1. MEAN VS PEAK ELECTRICITY DEMAND GROWTH IN LITERATURE

Electricity demand projections vary significantly both spatially and temporally with peak demands estimated to increase significantly more as compared to national annual means[1–5]. Some examples from the literature are:

- In their 2018 review of studies looking at climate impacts on US power systems Craig et al. 2018 [1] found that air temperature changes increased average annual electricity demand in the US by less than 5% while annual peak demand increased between 10-20% by the end of the century.
- Huang et al. 2016[2] contrast a 9% increase (2010 to 2100) in national annual electricity consumption for the US compared with a summer peak increase of 50% in Oregon in response to temperature.
- Dirks et al. 2015[3] showed a 17% increase (2004 to 2089) in total annual electricity in the US as compared to a 42% increase in the peak national annual electricity demand (with the peak increases varying between 6% to 136% across states).

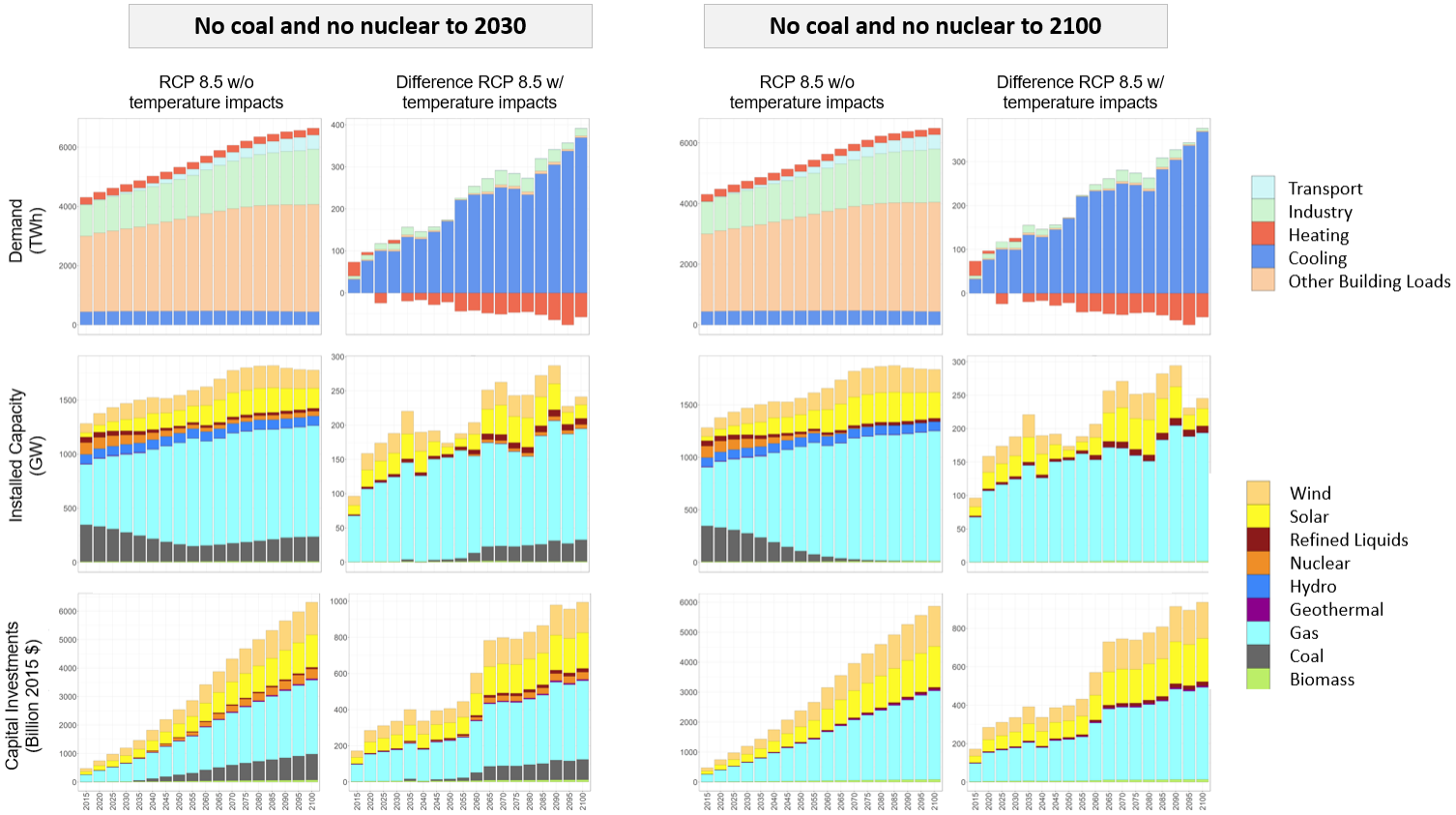
This difference in the rate of change of peaks versus mean demand has been highlighted in the literature because it has important implications for effective capacity factors in that a significant amount of new capacity will have to be added to meet short periods of peaks while left unused for the remaining year.

## Supplementary Note 2. HDH/CDH DISTRIBUTION BY STATE BY MONTH

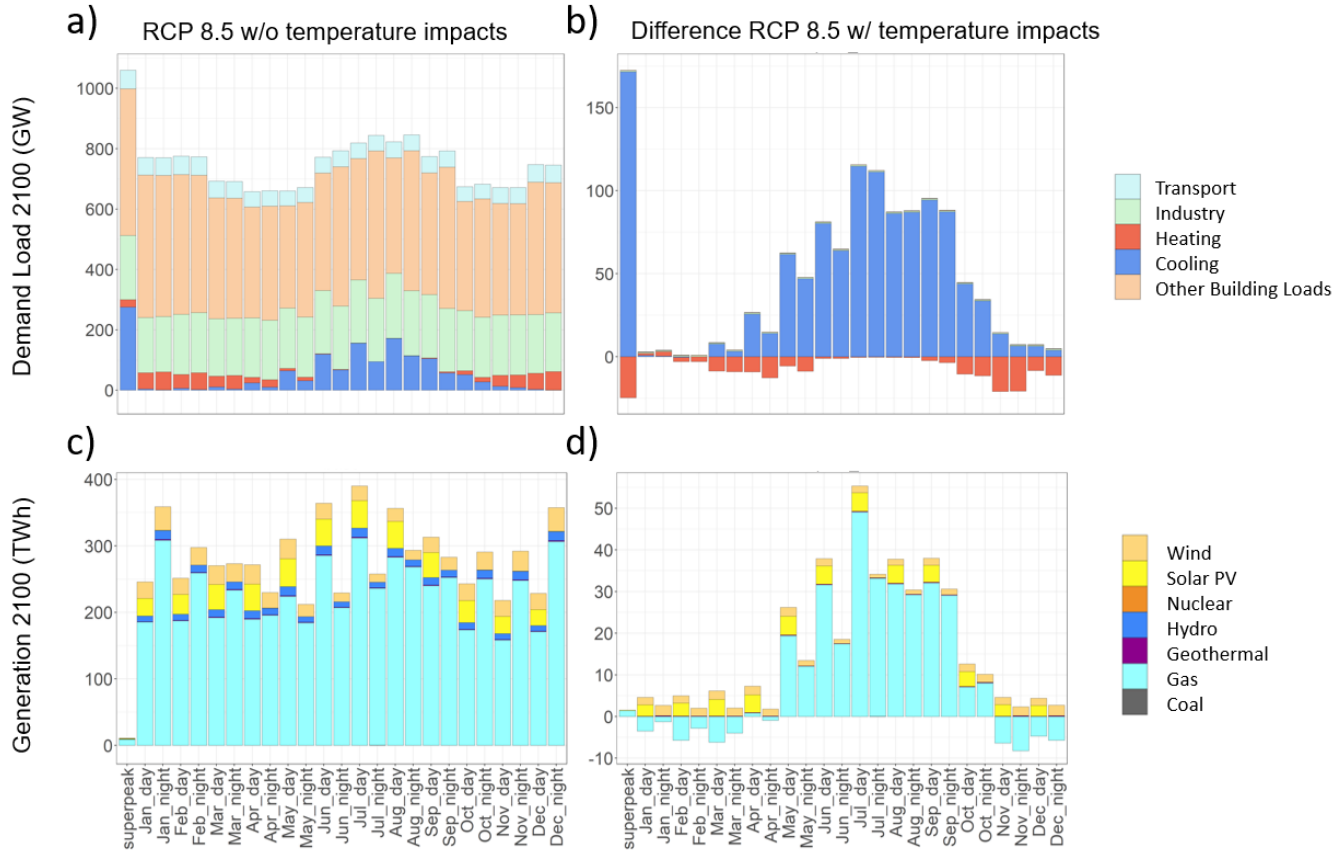



*Supplementary Figure 1: HDH and CDH distribution by state by month for RCP 8.5 in 2100*

## Supplementary Note 3. SSP2 NO COAL OR NUCLEAR TO 2030 AND 2100 COMPARISON

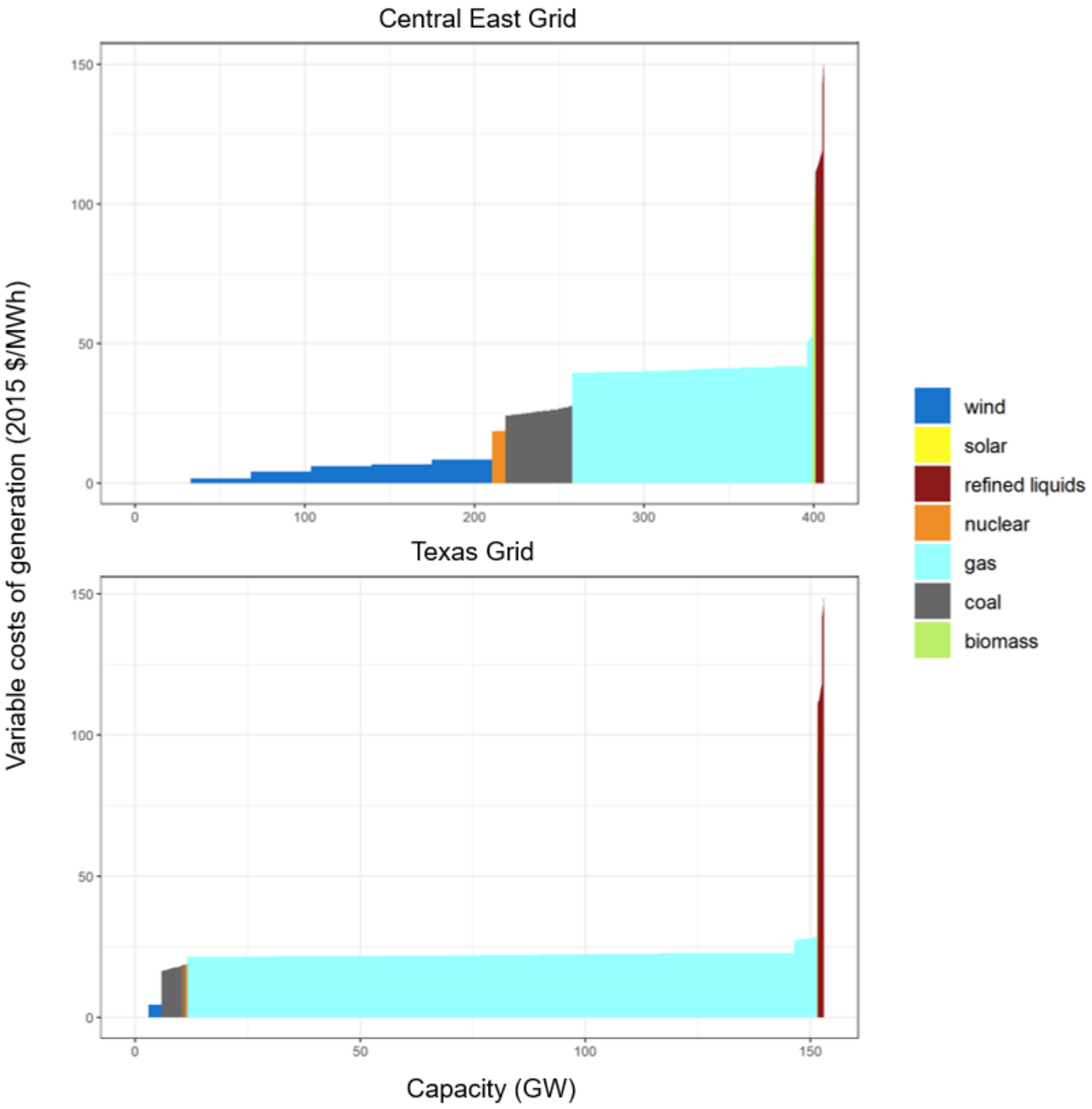



*Supplementary Figure 2: Comparison of SSP2 scenario with coal and nuclear restricted through 2030 (1st and 2nd columns) vs SSP2 with coal and nuclear restricted through 2100 (3rd and 4th columns)*

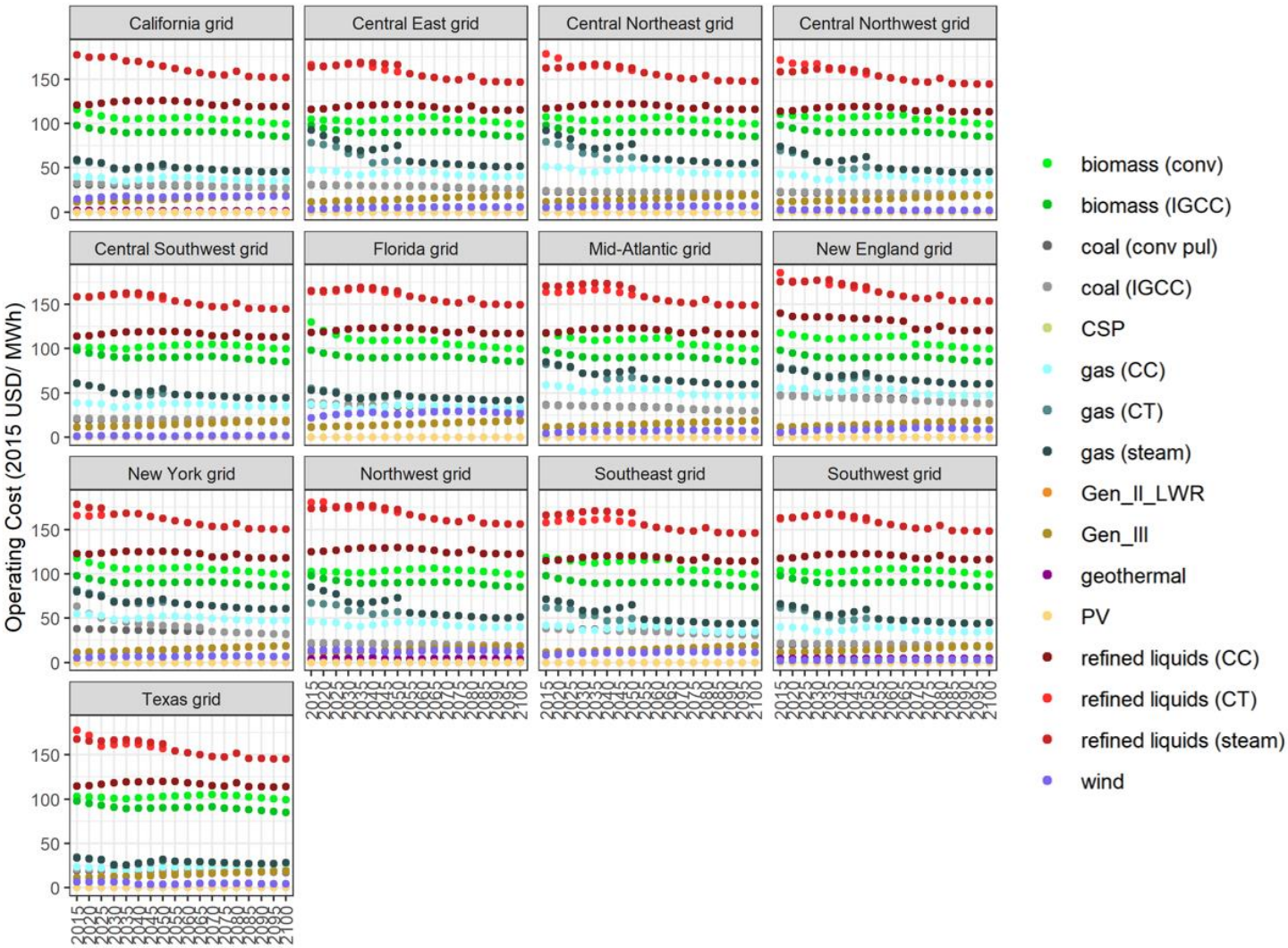



*Supplementary Figure 3: For scenario with no coal and no nuclear to 2100 (a) Electricity load (GW) by segment and end-use service in 2100 under RCP 8.5 w/o temperature impacts scenario; (b) difference in electricity load (GW) by segment and service in 2100 under RCP 8.5 w/ temperature impacts relative to RCP 8.5 w/o temperature impacts scenario; (c) Electricity generation (TWh) by segment and fuel in 2100 under RCP 8.5 w/o temperature impacts scenario; (d) difference in electricity generation (TWh) by segment and fuel in 2100 under RCP 8.5 w/ temperature impacts relative to RCP 8.5 w/o temperature impacts scenario. Note: Units in (a) and (b) are in GW and in (c) and (d) are in TWh.*

## Supplementary Note 4. MERIT ORDER DISPATCH & COSTS BY FUEL




*Supplementary Figure 4: Example of merit order dispatch for Texas and Central East Grid in 2100*

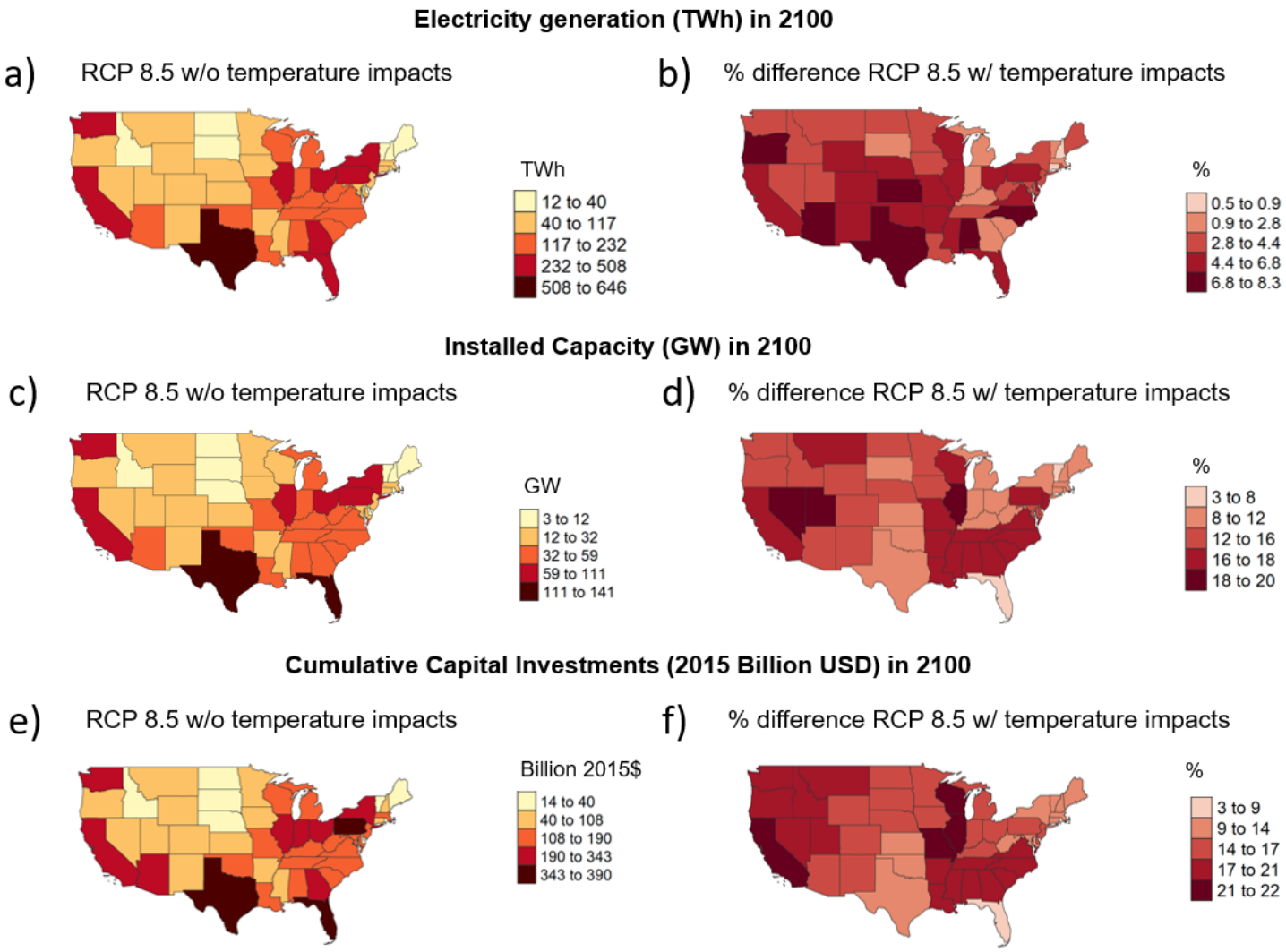



*Supplementary Figure 5: Operating costs (2015 USD/MWh) for different fuel types by year. (IGCC = Integrated Gasification Combined Cycle; conv. pul. = Conventional Pulverized; CSP = Concentrated Solar Power; CC = Combined Cycle; CT = Combustion Turbine; Gen_II_LWR = Generation II Light water nuclear reactor; Gen_III = Generation III nuclear reactor )*

*Supplementary Table 1: Fuel prices by Grid Region in 2100 (2015$).*

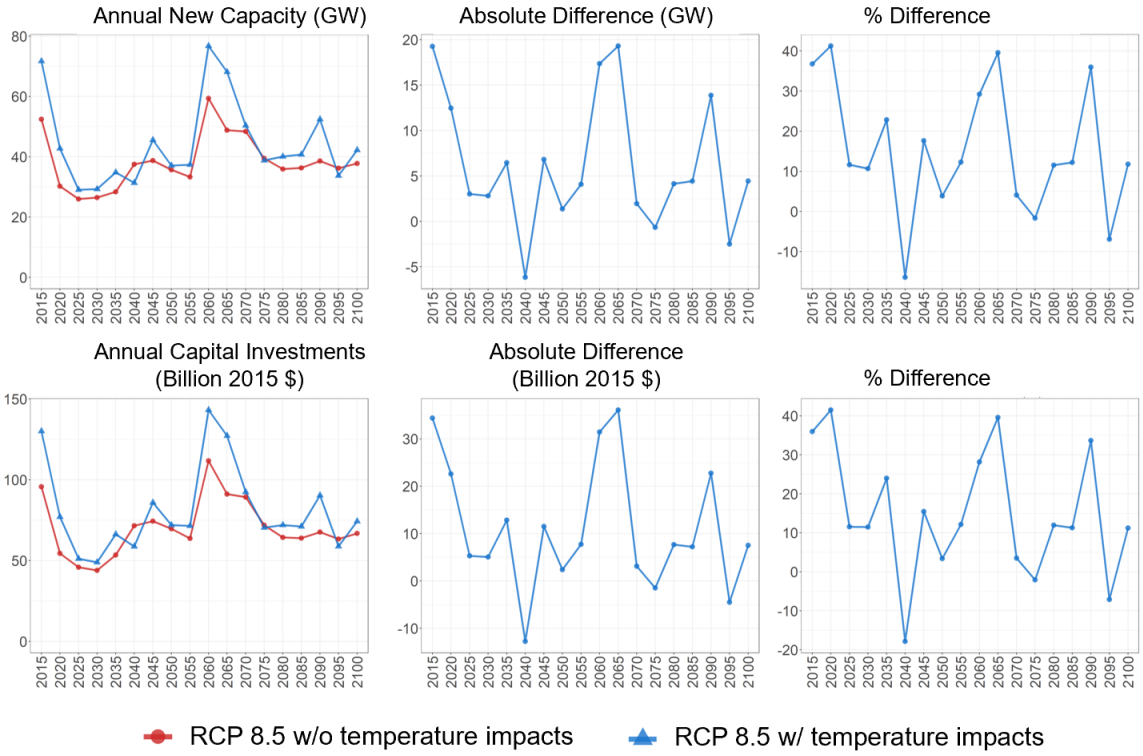
| Grid Region | regional coal | delivered coal | wholesale gas | delivered gas | refined liquids enduse | refined liquids industrial |
|---|---|---|---|---|---|---|
| Alaska | 5.3 | 6.0 | 8.2 | 13.7 | 32.1 | 27.2 |
| California | 3.9 | 4.5 | 7.4 | 12.9 | 30.8 | 25.9 |
| Central East | 3.6 | 4.3 | 8.4 | 13.9 | 29.8 | 25.0 |
| Central Northeast | 2.7 | 3.3 | 9.0 | 14.5 | 30.0 | 25.2 |
| Central Northwest | 2.5 | 3.1 | 7.3 | 12.8 | 29.4 | 24.6 |
| Central Southwest | 2.3 | 2.9 | 7.1 | 12.6 | 29.5 | 24.6 |
| Florida | 4.6 | 5.2 | 6.7 | 12.2 | 30.3 | 25.5 |
| Hawaii | 2.4 | 3.0 | 29.4 | 34.9 | 33.5 | 28.7 |
| Mid-Atlantic | 4.3 | 4.9 | 9.8 | 15.3 | 30.2 | 25.4 |
| New England | 5.8 | 6.4 | 9.9 | 15.4 | 31.0 | 26.2 |
| New York | 4.7 | 5.3 | 9.9 | 15.4 | 30.5 | 25.6 |
| Northwest | 2.4 | 3.0 | 8.2 | 13.7 | 31.5 | 26.6 |
| Southeast | 4.6 | 5.2 | 7.1 | 12.6 | 29.7 | 24.8 |
| Southwest | 2.3 | 3.0 | 7.2 | 12.7 | 30.1 | 25.3 |
| Texas | 2.2 | 2.9 | 4.2 | 9.7 | 29.6 | 24.7 |

## Supplementary Note 5. ELECTRICITY GENERATION & CAPACITY BY STATE

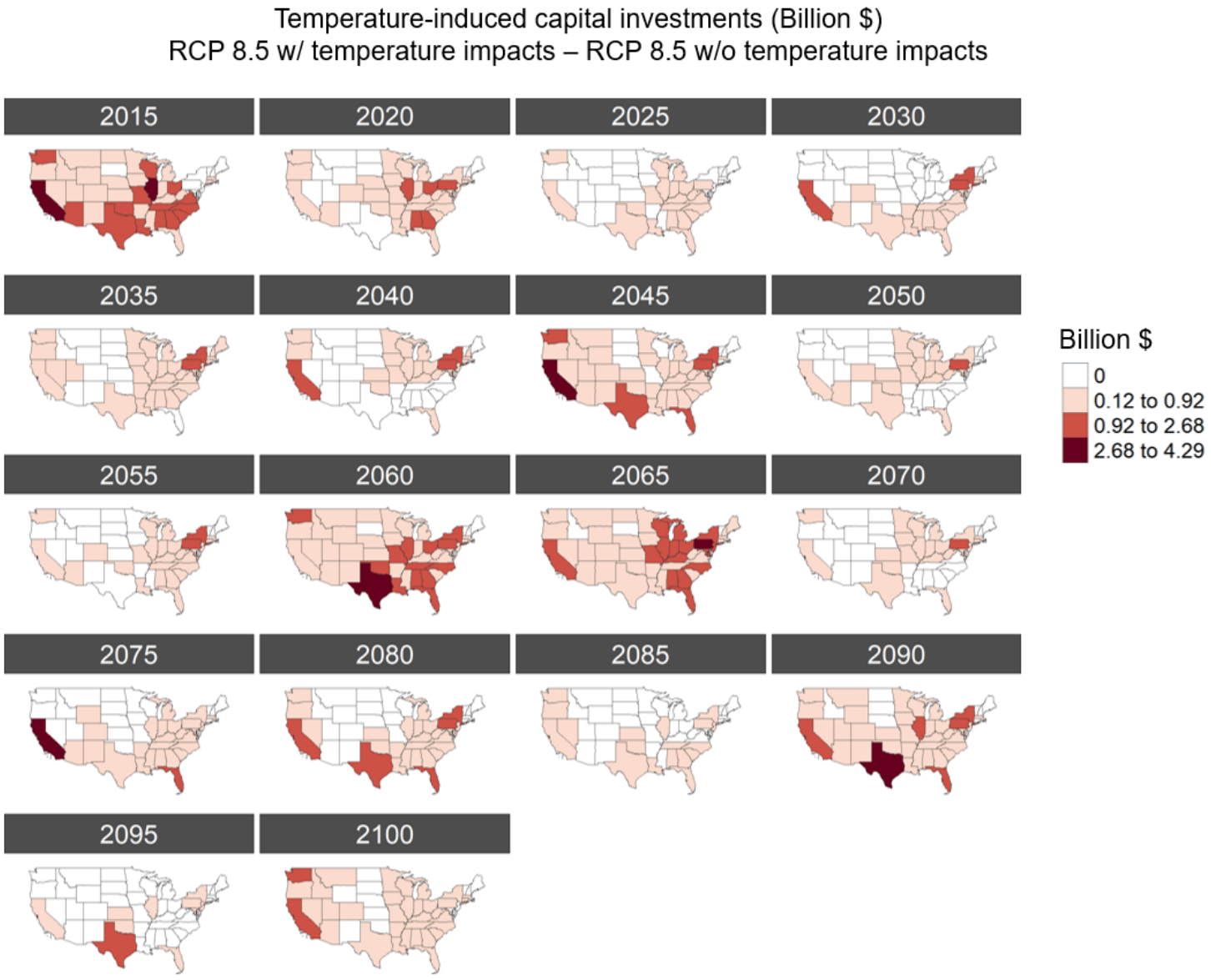



*Supplementary Figure 6: Electricity generation (TWh) and installed capacity (GW) in 2100 a) RCP 8.5 w/o temperature impacts and b) % difference for RCP 8.5 w/ temperature impacts scenario*

## Supplementary Note 6. DETAILS ON ANNUAL INVESTMENT COSTS




*Supplementary Figure 7: Annual New Capacity (GW) (top row) and Annual Capital investments (Billion 2015$) (Bottom row) for SSP2 RCP8.5 w and w/o temperature impacts*




*Supplementary Figure 8: Temperature-induced annual capital investments (Billion $) (RCP 8.5 w/ temperature impacts – RCP 8.5 w/o temperature impacts)*

*Supplementary Table 2: Temperature-induced increases in cumulative capital investments (2015-2100; billion USD) by state for different discount rates.*

| State | Code | Undiscounted | Discount rate 3% | Discount rate 5% | Discount rate 7% |
|---|---|---|---|---|---|
| California | CA | 71 | 36 | 28 | 24 |
| Illinois | IL | 67 | 34 | 27 | 24 |
| Pennsylvania | PA | 57 | 25 | 18 | 15 |
| Washington | WA | 39 | 16 | 11 | 10 |
| Georgia | GA | 39 | 20 | 16 | 15 |
| Texas | TX | 39 | 19 | 15 | 13 |
| Missouri | MO | 35 | 18 | 14 | 12 |
| Ohio | OH | 34 | 18 | 15 | 13 |
| Alabama | AL | 34 | 17 | 14 | 12 |
| New York | NY | 33 | 13 | 9 | 8 |
| Arizona | AZ | 32 | 15 | 12 | 10 |
| North Carolina | NC | 29 | 15 | 13 | 11 |
| Indiana | IN | 28 | 14 | 11 | 10 |
| Wisconsin | WI | 27 | 14 | 11 | 10 |
| Michigan | MI | 26 | 13 | 11 | 9 |
| Kentucky | KY | 26 | 13 | 10 | 9 |
| Louisiana | LA | 25 | 13 | 11 | 10 |
| South Carolina | SC | 23 | 12 | 10 | 9 |
| Tennessee | TN | 23 | 12 | 9 | 8 |
| Virginia | VA | 22 | 12 | 10 | 9 |
| New Jersey | NJ | 19 | 8 | 6 | 5 |
| Oklahoma | OK | 19 | 10 | 8 | 7 |
| West Virginia | WV | 17 | 9 | 7 | 6 |
| Mississippi | MS | 17 | 9 | 7 | 7 |
| Maryland | MD | 17 | 7 | 5 | 4 |
| Oregon | OR | 16 | 6 | 5 | 4 |
| Arkansas | AR | 16 | 8 | 7 | 6 |
| Colorado | CO | 16 | 7 | 6 | 5 |
| Nevada | NV | 14 | 5 | 4 | 3 |
| Massachusetts | MA | 12 | 6 | 5 | 4 |
| Kansas | KS | 12 | 5 | 4 | 3 |
| Florida | FL | 11 | 3 | 1 | -1 |
| Minnesota | MN | 11 | 5 | 4 | 4 |
| Iowa | IA | 11 | 5 | 4 | 4 |
| Utah | UT | 10 | 5 | 4 | 3 |
| New Mexico | NM | 10 | 4 | 3 | 2 |
| Wyoming | WY | 9 | 4 | 3 | 3 |
| Connecticut | CT | 8 | 4 | 3 | 2 |
| Montana | MT | 8 | 3 | 2 | 2 |
| Nebraska | NE | 6 | 3 | 2 | 2 |
| Idaho | ID | 5 | 2 | 1 | 1 |
| North Dakota | ND | 5 | 2 | 2 | 2 |
| New Hampshire | NH | 5 | 2 | 2 | 1 |
| Maine | ME | 4 | 2 | 1 | 1 |
| Delaware | DE | 4 | 2 | 1 | 1 |
| South Dakota | SD | 3 | 1 | 1 | 1 |
| Rhode Island | RI | 2 | 1 | 1 | 1 |
| Vermont | VT | 1 | 1 | 0 | 0 |
| National | USA | 993 | 475 | 374 | 327 |

## Supplementary Note 7. DETAILS ON CAPACITY AND INVESTMENTS BY FUEL BY STATE

*Supplementary Table 3: SSP2 RCP 8.5 w/o Temperature Impacts - Installed Capacity (GW) in 2100*

| State | biomass | coal | gas | nuclear | refined liquids | solar | wind | Total |
|---|---|---|---|---|---|---|---|---|
| AL | 0 | 4 | 36 | 1 | 1 | 5 | 3 | 54 |
| AR | 0 | 2 | 16 | 1 | 0 | 2 | 2 | 25 |
| AZ | 0 | 9 | 33 | 1 | 1 | 4 | 4 | 55 |
| CA | 0 | 10 | 59 | 2 | 1 | 10 | 6 | 102 |
| CO | 0 | 4 | 16 | 0 | 0 | 2 | 3 | 26 |
| CT | 0 | 2 | 9 | 1 | 0 | 4 | 3 | 19 |
| DE | 0 | 1 | 2 | 0 | 0 | 1 | 1 | 6 |
| FL | 0 | 8 | 88 | 2 | 2 | 9 | 3 | 113 |
| GA | 0 | 4 | 37 | 1 | 1 | 5 | 7 | 57 |
| IA | 0 | 3 | 11 | 0 | 0 | 2 | 2 | 18 |
| ID | 0 | 1 | 3 | 0 | 0 | 1 | 1 | 9 |
| IL | 0 | 18 | 34 | 2 | 1 | 11 | 7 | 75 |
| IN | 0 | 8 | 26 | 2 | 1 | 7 | 7 | 50 |
| KS | 0 | 4 | 14 | 0 | 0 | 2 | 2 | 23 |
| KY | 0 | 7 | 23 | 1 | 1 | 6 | 8 | 47 |
| LA | 0 | 3 | 26 | 1 | 1 | 4 | 2 | 36 |
| MA | 0 | 3 | 12 | 1 | 1 | 5 | 4 | 27 |
| MD | 0 | 4 | 11 | 1 | 1 | 4 | 5 | 27 |
| ME | 0 | 1 | 4 | 0 | 0 | 2 | 1 | 9 |
| MI | 0 | 7 | 25 | 1 | 1 | 6 | 7 | 48 |
| MN | 0 | 3 | 12 | 0 | 0 | 2 | 2 | 19 |
| MO | 0 | 8 | 16 | 1 | 1 | 5 | 7 | 39 |
| MS | 0 | 2 | 17 | 1 | 0 | 2 | 2 | 25 |
| MT | 0 | 2 | 5 | 0 | 0 | 1 | 1 | 13 |
| NC | 0 | 4 | 31 | 1 | 1 | 4 | 2 | 45 |
| ND | 0 | 1 | 5 | 0 | 0 | 1 | 1 | 9 |
| NE | 0 | 2 | 6 | 0 | 0 | 1 | 1 | 10 |
| NH | 0 | 1 | 5 | 0 | 0 | 2 | 2 | 11 |
| NJ | 0 | 5 | 13 | 1 | 1 | 5 | 4 | 30 |
| NM | 0 | 3 | 10 | 0 | 0 | 1 | 2 | 16 |
| NV | 0 | 4 | 10 | 0 | 0 | 2 | 2 | 20 |
| NY | 1 | 10 | 28 | 3 | 1 | 12 | 12 | 71 |
| OH | 0 | 9 | 33 | 2 | 1 | 8 | 8 | 61 |
| OK | 0 | 6 | 24 | 1 | 1 | 3 | 4 | 39 |
| OR | 0 | 5 | 12 | 1 | 0 | 2 | 1 | 31 |
| PA | 1 | 15 | 37 | 4 | 2 | 15 | 14 | 88 |
| RI | 0 | 1 | 2 | 0 | 0 | 1 | 1 | 5 |
| SC | 0 | 3 | 23 | 1 | 1 | 3 | 3 | 34 |
| SD | 0 | 1 | 3 | 0 | 0 | 0 | 1 | 6 |
| TN | 0 | 2 | 21 | 1 | 0 | 3 | 4 | 35 |
| TX | 0 | 5 | 128 | 1 | 1 | 3 | 3 | 141 |
| UT | 0 | 3 | 7 | 0 | 0 | 1 | 1 | 13 |
| VA | 0 | 3 | 23 | 1 | 1 | 3 | 2 | 33 |
| VT | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 3 |
| WA | 0 | 13 | 30 | 2 | 1 | 6 | 1 | 76 |
| WI | 0 | 7 | 13 | 1 | 1 | 4 | 5 | 31 |
| WV | 0 | 5 | 16 | 1 | 1 | 4 | 5 | 32 |
| WY | 0 | 2 | 9 | 0 | 0 | 1 | 2 | 15 |
| US Total | 9 | 227 | 1027 | 45 | 27 | 185 | 168 | 1776 |

*Supplementary Table 4: SSP2 RCP 8.5 w/ Temperature Impacts - Installed Capacity (GW) in 2100*

| State | biomass | coal | gas | nuclear | refined liquids | solar | wind | Total |
|---|---|---|---|---|---|---|---|---|
| AL | 0 | 5 | 43 | 1 | 1 | 5 | 3 | 63 |
| AR | 0 | 2 | 19 | 1 | 0 | 2 | 3 | 29 |
| AZ | 0 | 10 | 38 | 1 | 1 | 5 | 5 | 63 |
| CA | 1 | 12 | 72 | 3 | 2 | 12 | 6 | 120 |
| CO | 0 | 5 | 18 | 1 | 0 | 2 | 3 | 30 |
| CT | 0 | 2 | 10 | 1 | 0 | 4 | 3 | 21 |
| DE | 0 | 1 | 3 | 0 | 0 | 1 | 1 | 6 |
| FL | 0 | 9 | 90 | 2 | 2 | 9 | 3 | 116 |
| GA | 0 | 5 | 44 | 1 | 1 | 6 | 7 | 67 |
| IA | 0 | 3 | 12 | 0 | 0 | 2 | 2 | 20 |
| ID | 0 | 2 | 4 | 0 | 0 | 1 | 1 | 11 |
| IL | 1 | 21 | 42 | 3 | 2 | 12 | 8 | 88 |
| IN | 0 | 8 | 30 | 2 | 1 | 7 | 7 | 56 |
| KS | 0 | 4 | 16 | 1 | 0 | 2 | 3 | 26 |
| KY | 0 | 7 | 27 | 1 | 1 | 6 | 9 | 53 |
| LA | 0 | 4 | 31 | 1 | 1 | 4 | 2 | 43 |
| MA | 0 | 3 | 14 | 1 | 1 | 6 | 4 | 30 |
| MD | 0 | 5 | 13 | 1 | 1 | 5 | 5 | 30 |
| ME | 0 | 1 | 4 | 0 | 0 | 2 | 1 | 10 |
| MI | 0 | 8 | 29 | 2 | 1 | 7 | 7 | 54 |
| MN | 0 | 4 | 13 | 0 | 0 | 2 | 2 | 21 |
| MO | 0 | 10 | 20 | 1 | 1 | 5 | 8 | 46 |
| MS | 0 | 2 | 21 | 1 | 1 | 3 | 2 | 29 |
| MT | 0 | 3 | 7 | 0 | 0 | 1 | 2 | 16 |
| NC | 0 | 4 | 37 | 1 | 1 | 5 | 2 | 52 |
| ND | 0 | 1 | 5 | 0 | 0 | 1 | 1 | 10 |
| NE | 0 | 2 | 7 | 0 | 0 | 1 | 1 | 11 |
| NH | 0 | 1 | 5 | 1 | 0 | 2 | 2 | 12 |
| NJ | 0 | 6 | 16 | 1 | 1 | 6 | 4 | 34 |
| NM | 0 | 3 | 11 | 0 | 0 | 1 | 2 | 19 |
| NV | 0 | 5 | 12 | 1 | 0 | 2 | 2 | 23 |
| NY | 1 | 11 | 32 | 3 | 2 | 13 | 13 | 79 |
| OH | 0 | 10 | 37 | 2 | 1 | 9 | 8 | 68 |
| OK | 0 | 7 | 27 | 1 | 1 | 3 | 4 | 43 |
| OR | 0 | 6 | 15 | 1 | 0 | 3 | 1 | 36 |
| PA | 1 | 16 | 45 | 4 | 3 | 17 | 15 | 102 |
| RI | 0 | 1 | 2 | 0 | 0 | 1 | 1 | 5 |
| SC | 0 | 3 | 28 | 1 | 1 | 3 | 3 | 40 |
| SD | 0 | 1 | 3 | 0 | 0 | 0 | 1 | 7 |
| TN | 0 | 3 | 25 | 1 | 1 | 3 | 5 | 40 |
| TX | 0 | 5 | 140 | 1 | 1 | 3 | 3 | 154 |
| UT | 0 | 3 | 8 | 0 | 0 | 2 | 1 | 16 |
| VA | 0 | 3 | 28 | 1 | 1 | 3 | 2 | 39 |
| VT | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 4 |
| WA | 0 | 15 | 37 | 2 | 1 | 7 | 2 | 87 |
| WI | 0 | 8 | 16 | 1 | 1 | 4 | 5 | 36 |
| WV | 0 | 5 | 18 | 1 | 1 | 4 | 5 | 35 |
| WY | 0 | 3 | 11 | 0 | 0 | 1 | 2 | 18 |
| US Total | 10 | 258 | 1189 | 51 | 36 | 205 | 180 | 2017 |

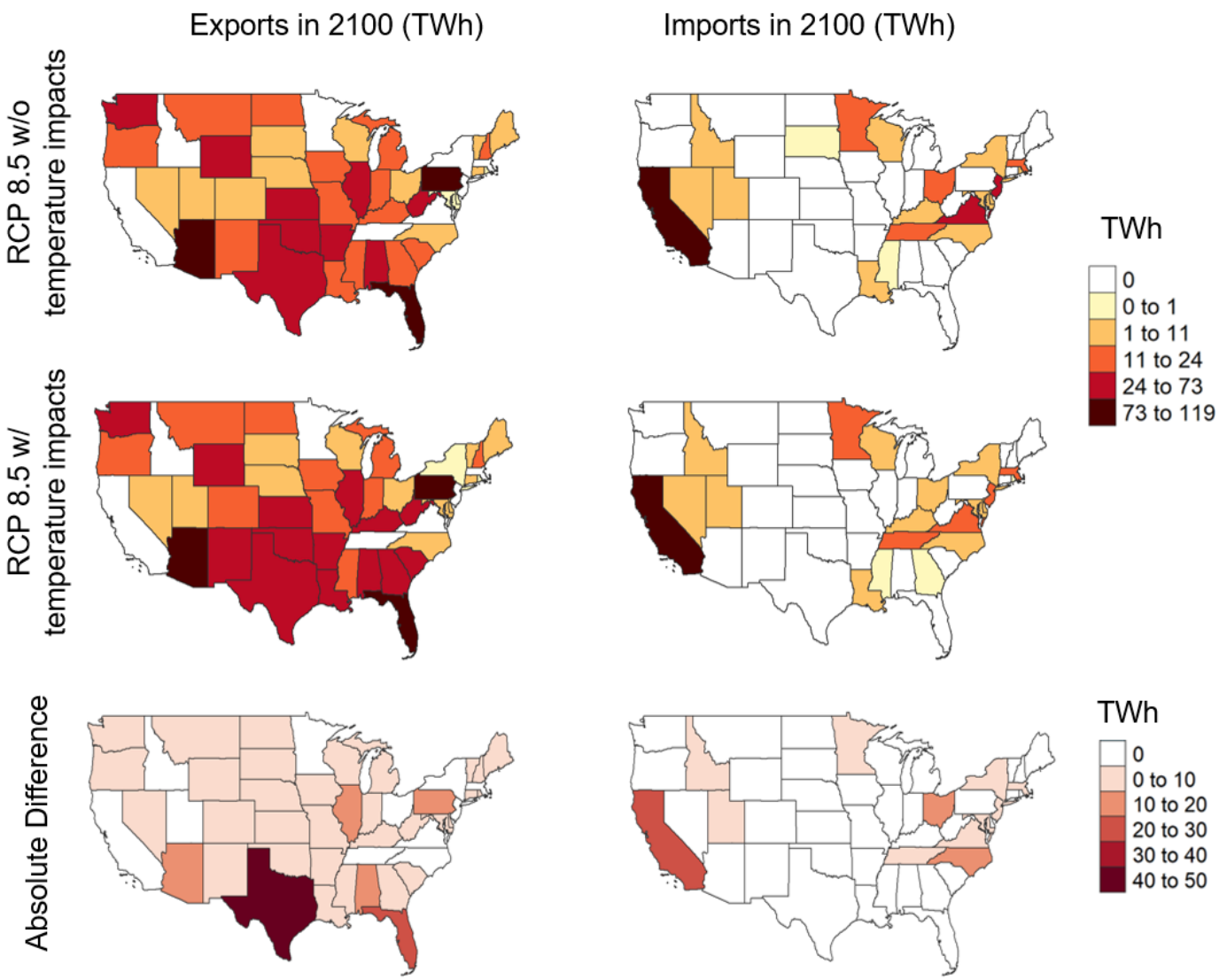
*Supplementary Table 5: SSP2 RCP 8.5 w/o Temperature Impacts - Cumulative Capital Costs (Billion 2015 USD) 2015 to 2100*

| State | biomass | coal | gas | nuclear | refined liquids | solar | wind | Total |
|---|---|---|---|---|---|---|---|---|
| AL | 2 | 17 | 90 | 9 | 2 | 29 | 20 | 168 |
| AR | 1 | 7 | 39 | 4 | 1 | 13 | 15 | 80 |
| AZ | 2 | 34 | 84 | 8 | 2 | 27 | 31 | 191 |
| CA | 3 | 41 | 147 | 17 | 2 | 53 | 35 | 322 |
| CO | 1 | 16 | 40 | 4 | 1 | 13 | 18 | 95 |
| CT | 1 | 9 | 23 | 7 | 1 | 23 | 19 | 83 |
| DE | 0 | 3 | 5 | 2 | 0 | 5 | 9 | 25 |
| FL | 4 | 33 | 221 | 17 | 4 | 60 | 26 | 364 |
| GA | 2 | 17 | 91 | 9 | 2 | 30 | 42 | 193 |
| IA | 1 | 11 | 27 | 3 | 0 | 9 | 14 | 65 |
| ID | 0 | 6 | 9 | 1 | 0 | 5 | 5 | 28 |
| IL | 4 | 72 | 90 | 19 | 3 | 64 | 50 | 303 |
| IN | 2 | 31 | 66 | 12 | 2 | 37 | 42 | 191 |
| KS | 1 | 15 | 37 | 3 | 1 | 12 | 18 | 87 |
| KY | 2 | 27 | 57 | 10 | 1 | 32 | 49 | 179 |
| LA | 1 | 12 | 65 | 6 | 1 | 21 | 13 | 121 |
| MA | 2 | 13 | 32 | 10 | 1 | 32 | 28 | 118 |
| MD | 2 | 17 | 29 | 8 | 1 | 28 | 32 | 117 |
| ME | 1 | 4 | 10 | 3 | 0 | 10 | 9 | 36 |
| MI | 2 | 29 | 62 | 11 | 2 | 35 | 42 | 184 |
| MN | 1 | 12 | 29 | 3 | 0 | 10 | 11 | 67 |
| MO | 2 | 34 | 41 | 9 | 1 | 29 | 43 | 160 |
| MS | 1 | 8 | 43 | 4 | 1 | 14 | 13 | 84 |
| MT | 0 | 9 | 14 | 2 | 0 | 7 | 10 | 45 |
| NC | 2 | 14 | 77 | 8 | 1 | 25 | 16 | 142 |
| ND | 0 | 5 | 12 | 1 | 0 | 4 | 7 | 29 |
| NE | 0 | 6 | 14 | 2 | 0 | 5 | 8 | 35 |
| NH | 1 | 5 | 12 | 4 | 0 | 12 | 11 | 45 |
| NJ | 2 | 21 | 35 | 10 | 1 | 34 | 28 | 132 |
| NM | 0 | 10 | 25 | 2 | 0 | 8 | 11 | 59 |
| NV | 1 | 15 | 25 | 4 | 1 | 13 | 17 | 79 |
| NY | 5 | 40 | 76 | 22 | 3 | 75 | 84 | 304 |
| OH | 3 | 38 | 81 | 14 | 2 | 46 | 48 | 232 |
| OK | 1 | 24 | 62 | 6 | 1 | 20 | 27 | 142 |
| OR | 1 | 20 | 32 | 5 | 1 | 17 | 11 | 89 |
| PA | 6 | 59 | 99 | 28 | 4 | 96 | 98 | 390 |
| RI | 0 | 2 | 6 | 2 | 0 | 6 | 6 | 22 |
| SC | 1 | 11 | 57 | 6 | 1 | 19 | 18 | 112 |
| SD | 0 | 3 | 7 | 1 | 0 | 2 | 4 | 17 |
| TN | 1 | 10 | 52 | 5 | 1 | 17 | 26 | 112 |
| TX | 1 | 18 | 314 | 4 | 3 | 16 | 17 | 374 |
| UT | 1 | 11 | 18 | 3 | 0 | 9 | 10 | 54 |
| VA | 1 | 11 | 58 | 6 | 1 | 19 | 12 | 108 |
| VT | 0 | 1 | 3 | 1 | 0 | 3 | 5 | 14 |
| WA | 3 | 49 | 82 | 12 | 2 | 43 | 13 | 209 |
| WI | 2 | 27 | 34 | 7 | 1 | 24 | 30 | 124 |
| WV | 1 | 19 | 40 | 7 | 1 | 23 | 30 | 121 |
| WY | 0 | 10 | 24 | 2 | 0 | 7 | 11 | 56 |
| US Total | 73 | 908 | 2597 | 341 | 57 | 1138 | 1144 | 6306 |

*Supplementary Table 6: SSP2 RCP 8.5 w/ Temperature Impacts - Cumulative Capital Costs (Billion 2015 USD) 2015 to 2100*

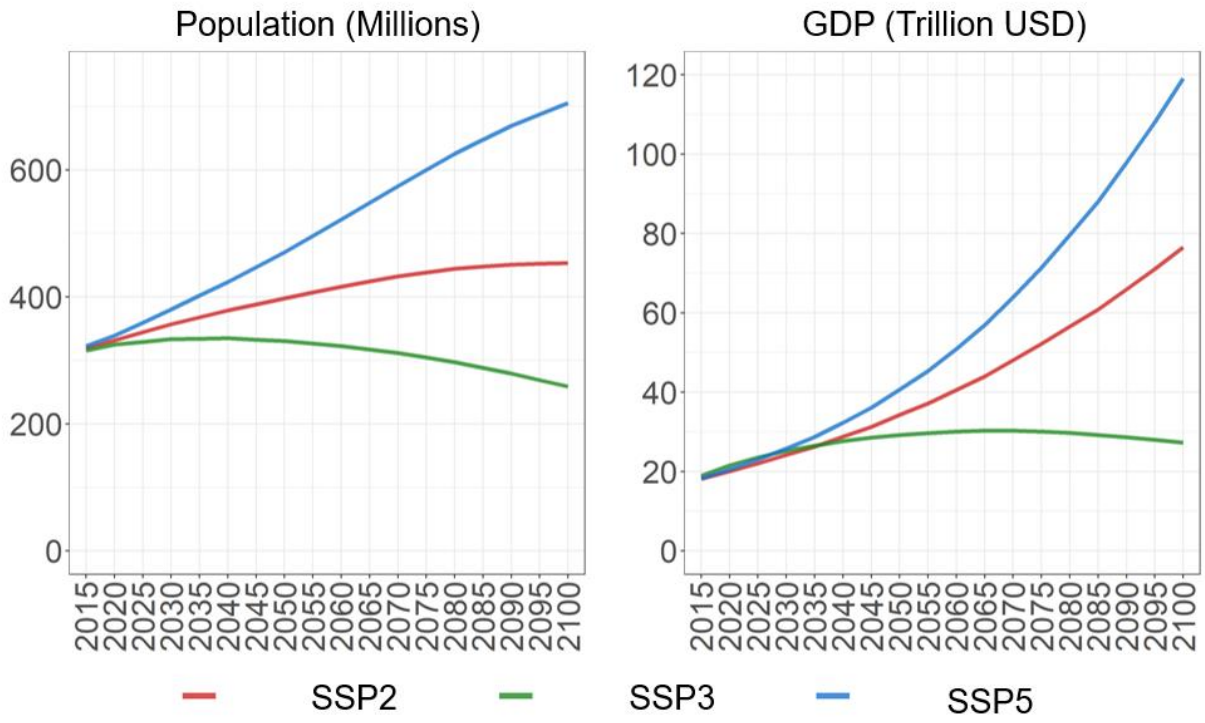
| State | biomass | coal | gas | nuclear | refined liquids | solar | wind | Total |
|---|---|---|---|---|---|---|---|---|
| AL | 2 | 19 | 109 | 10 | 2 | 36 | 23 | 202 |
| AR | 1 | 8 | 47 | 4 | 1 | 16 | 18 | 96 |
| AZ | 2 | 38 | 99 | 9 | 2 | 31 | 36 | 223 |
| CA | 4 | 46 | 185 | 19 | 3 | 66 | 42 | 393 |
| CO | 1 | 18 | 47 | 4 | 1 | 15 | 21 | 111 |
| CT | 2 | 10 | 25 | 7 | 1 | 25 | 21 | 91 |
| DE | 0 | 4 | 6 | 2 | 0 | 6 | 10 | 28 |
| FL | 4 | 34 | 227 | 18 | 4 | 62 | 27 | 375 |
| GA | 2 | 20 | 110 | 10 | 3 | 36 | 50 | 231 |
| IA | 1 | 13 | 31 | 3 | 1 | 11 | 17 | 76 |
| ID | 0 | 7 | 11 | 2 | 0 | 6 | 6 | 32 |
| IL | 5 | 84 | 113 | 22 | 4 | 79 | 62 | 370 |
| IN | 3 | 34 | 76 | 13 | 2 | 43 | 48 | 219 |
| KS | 1 | 16 | 43 | 4 | 1 | 14 | 21 | 99 |
| KY | 2 | 30 | 66 | 11 | 2 | 37 | 56 | 205 |
| LA | 2 | 14 | 79 | 7 | 2 | 26 | 15 | 145 |
| MA | 2 | 14 | 36 | 10 | 1 | 36 | 30 | 130 |
| MD | 2 | 19 | 34 | 9 | 2 | 32 | 36 | 134 |
| ME | 1 | 4 | 11 | 3 | 0 | 11 | 10 | 40 |
| MI | 3 | 32 | 72 | 12 | 2 | 41 | 48 | 210 |
| MN | 1 | 14 | 35 | 3 | 1 | 12 | 12 | 77 |
| MO | 2 | 39 | 52 | 10 | 2 | 36 | 53 | 195 |
| MS | 1 | 9 | 52 | 5 | 1 | 17 | 15 | 101 |
| MT | 1 | 10 | 17 | 2 | 0 | 9 | 12 | 52 |
| NC | 2 | 16 | 93 | 9 | 2 | 30 | 19 | 171 |
| ND | 0 | 6 | 14 | 1 | 0 | 5 | 8 | 34 |
| NE | 0 | 7 | 17 | 2 | 0 | 6 | 9 | 41 |
| NH | 1 | 5 | 14 | 4 | 1 | 13 | 12 | 50 |
| NJ | 3 | 23 | 42 | 11 | 2 | 39 | 31 | 151 |
| NM | 1 | 11 | 29 | 3 | 1 | 9 | 13 | 69 |
| NV | 1 | 18 | 29 | 4 | 1 | 15 | 20 | 93 |
| NY | 5 | 43 | 86 | 23 | 4 | 83 | 92 | 336 |
| OH | 3 | 42 | 94 | 16 | 3 | 53 | 55 | 266 |
| OK | 1 | 26 | 71 | 6 | 2 | 23 | 31 | 161 |
| OR | 1 | 23 | 38 | 6 | 1 | 20 | 12 | 105 |
| PA | 7 | 65 | 117 | 31 | 6 | 111 | 110 | 447 |
| RI | 0 | 2 | 6 | 2 | 0 | 6 | 7 | 24 |
| SC | 1 | 12 | 69 | 6 | 2 | 23 | 21 | 135 |
| SD | 0 | 3 | 8 | 1 | 0 | 3 | 4 | 20 |
| TN | 1 | 11 | 63 | 6 | 1 | 21 | 31 | 135 |
| TX | 1 | 20 | 345 | 5 | 4 | 19 | 20 | 413 |
| UT | 1 | 13 | 21 | 3 | 1 | 11 | 12 | 64 |
| VA | 1 | 13 | 71 | 7 | 2 | 23 | 14 | 130 |
| VT | 0 | 1 | 4 | 1 | 0 | 4 | 5 | 15 |
| WA | 3 | 59 | 98 | 14 | 2 | 51 | 15 | 248 |
| WI | 2 | 31 | 42 | 8 | 2 | 30 | 37 | 152 |
| WV | 2 | 21 | 46 | 8 | 1 | 26 | 34 | 138 |
| WY | 1 | 11 | 28 | 2 | 1 | 9 | 13 | 65 |
| US Total | 85 | 1020 | 3033 | 381 | 77 | 1336 | 1313 | 7300 |

## Supplementary Note 8. ELECTRICITY TRADE MAPS

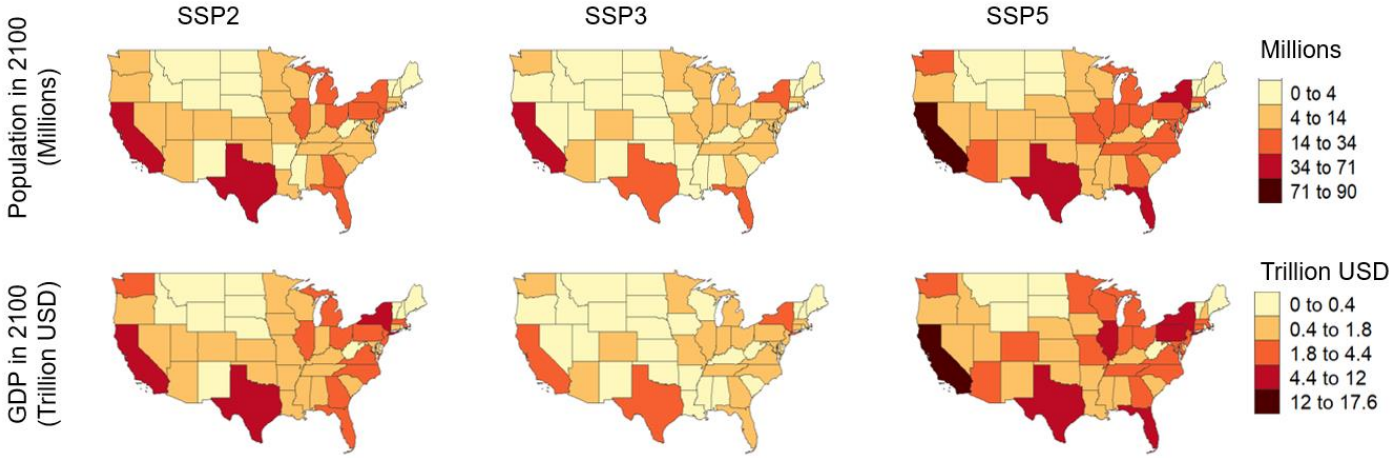



*Supplementary Figure 9: Electricity trade maps showing imports and exports of electricity by state for RCP 8.5 w/o temperature impacts (1st row), RCP 8.5 w/ temperature impacts (2nd row) and the difference between the two scenarios (3rd row)*

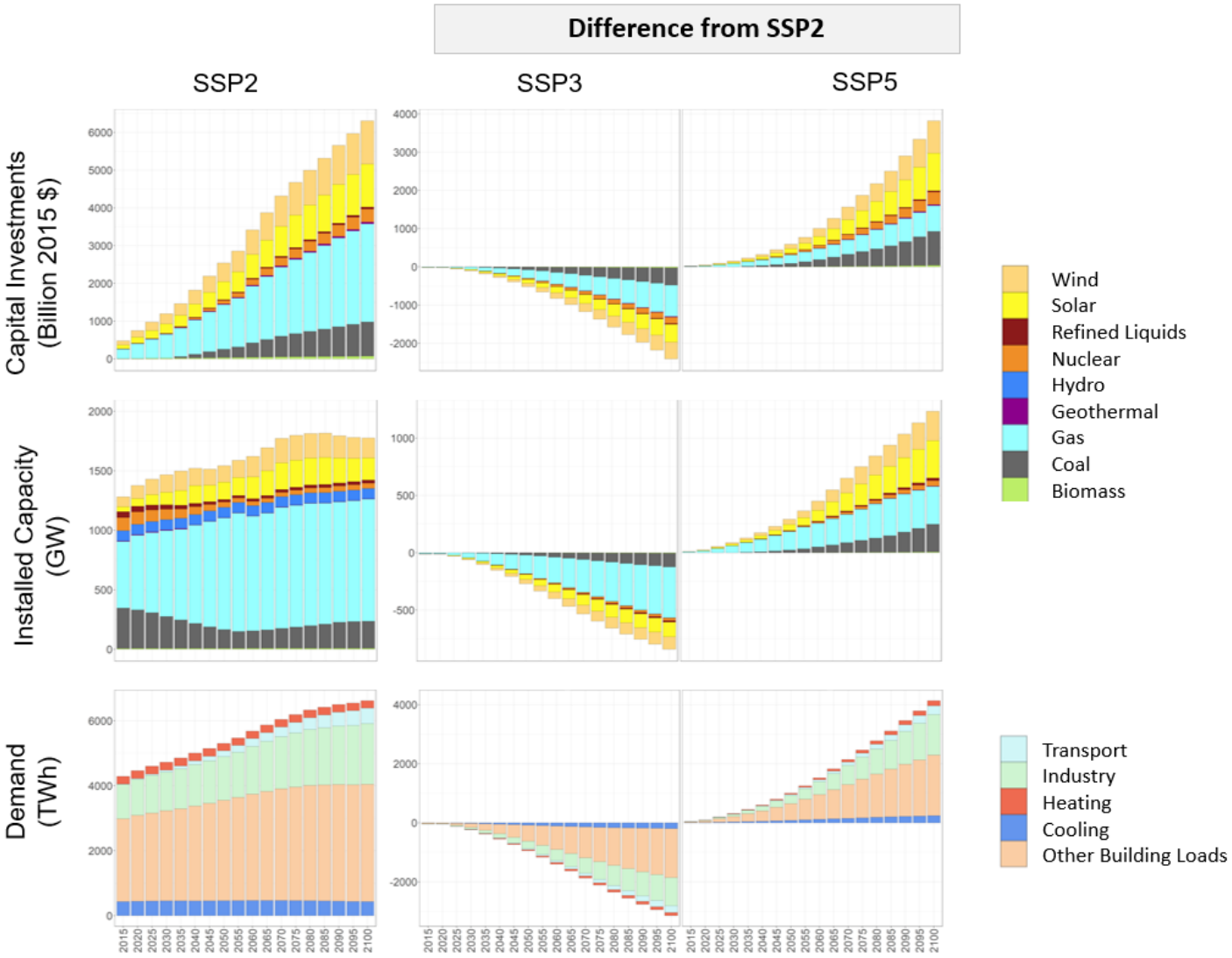
## Supplementary Note 9. SENSITIVITY ANALYSIS DETAILS



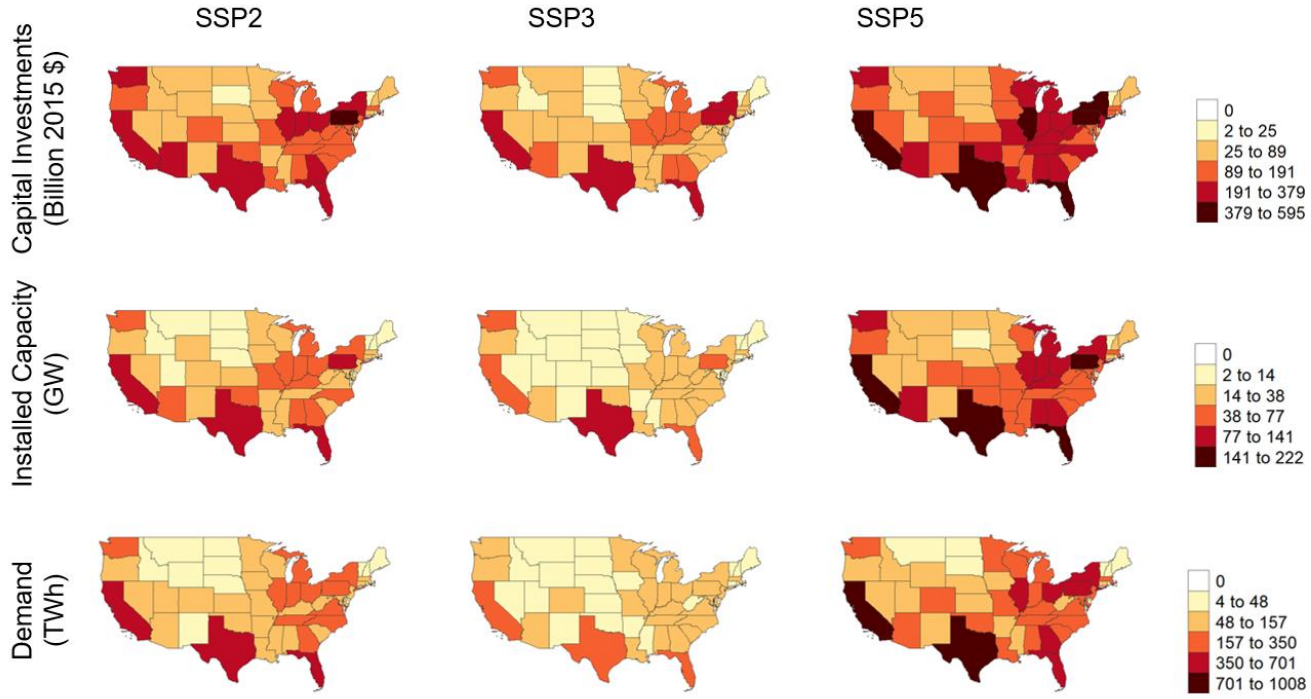

*Supplementary Figure 10: National population (Millions) and GDP (Trillion USD) assumptions for sensitivity analysis scenarios SSP2, SSP3 and SSP5 from 2015 to 2100*




*Supplementary Figure 11: State population (Millions) and GDP (Trillion USD) assumptions for sensitivity analysis scenarios SSP2, SSP3 and SSP5 in 2100*

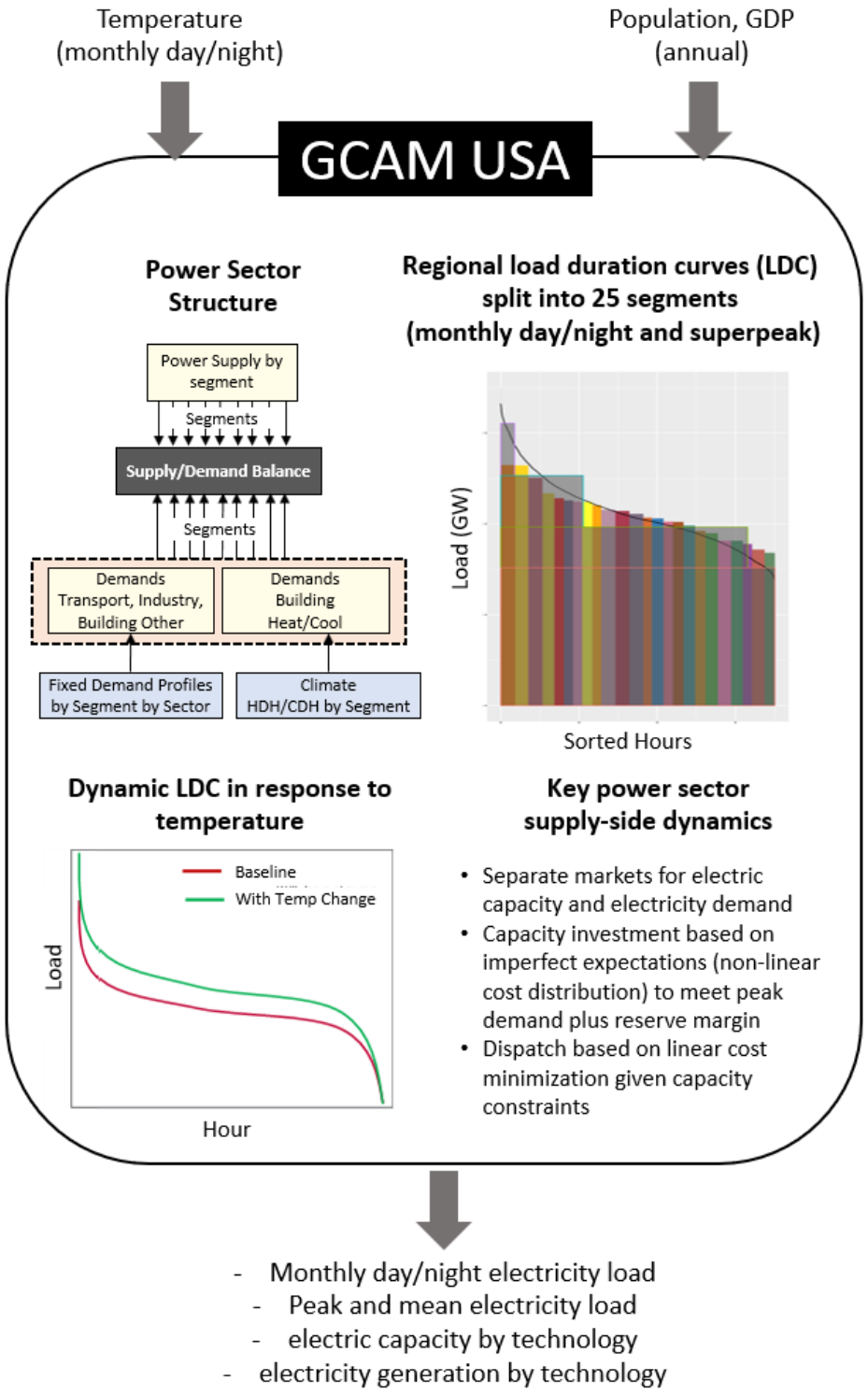



*Supplementary Figure 12: Sensitivity analysis comparing installed capacity, capital investments and electricity demand from central (SSP2) assumptions for population and GDP to results from low (SSP3) and high (SSP5) assumptions*



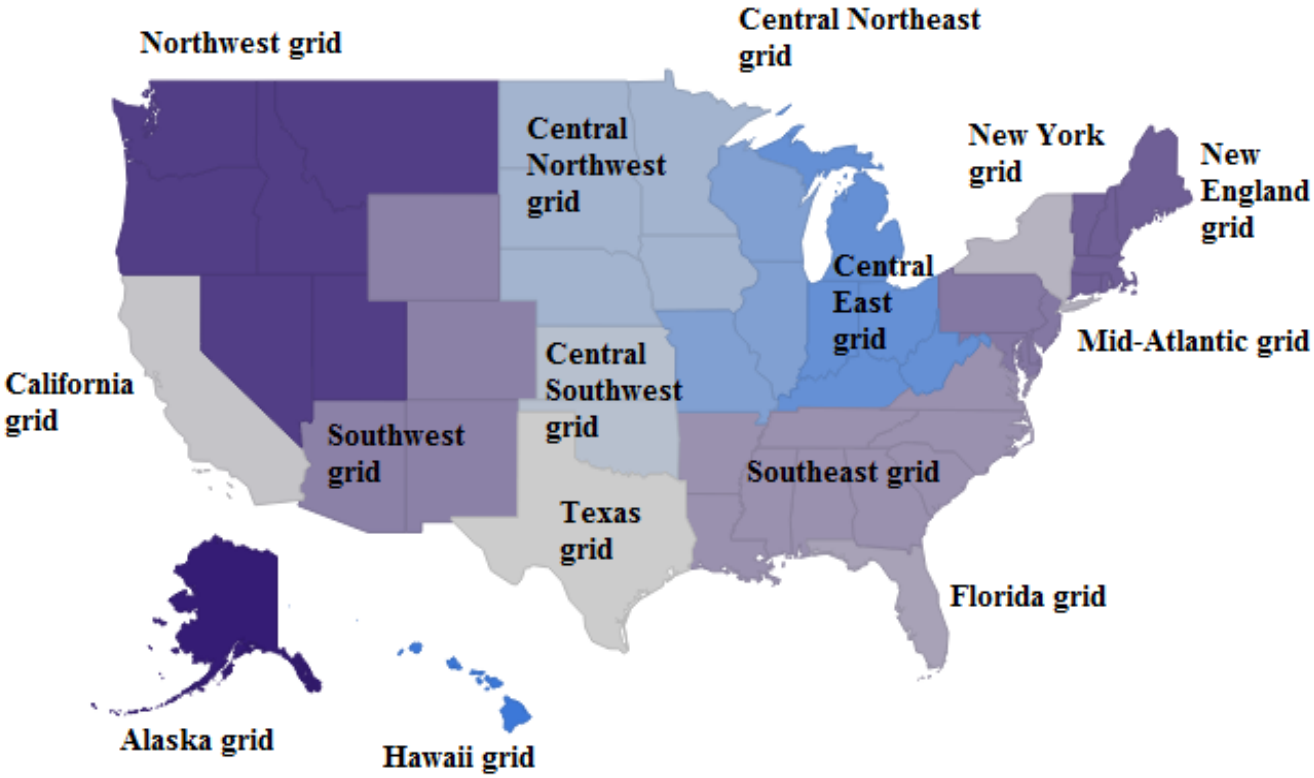

*Supplementary Figure 13: Sensitivity analysis comparing spatial distribution of installed capacity, capital investments and electricity demand from central (SSP2) assumptions for population and GDP to results from low (SSP3) and high (SSP5) assumptions*

## Supplementary Note 10. MODELING FRAMEWORK




*Supplementary Figure 14: Conceptual figure showing GCAM-USA model structure with new developments including: Supply & demand balance by 25 sub-annual segments; endogenous heating and cooling demands.*

## Supplementary Note 11. STATES TO GRID REGION MAPPING IN GCAM-USA




*Supplementary Figure 15: Mapping of states in GCAM-USA to grid regions*

## Supplementary Note 12. ANALYSIS USING ALTERNATIVE COST PATHWAYS

*Supplementary Table 7: Comparison of overnight capital costs (2015 USD) between data used in main text[6] with latest cost projections from NREL 2019[7]*

| Technology | 2015 Original | 2015 ATB | 2025 Original | 2025 ATB | 2030 Original | 2030 ATB | 2075 Original | 2075 ATB | 2100 Original | 2100 ATB |
|---|---|---|---|---|---|---|---|---|---|---|
| biomass (conv CCS) | 10498 | 9869 | 9557 | 8933 | 8408 | 7863 | 7955 | 7531 | 7722 | 7427 |
| biomass (conv) | 5452 | 5127 | 5324 | 4800 | 5047 | 4386 | 4836 | 4237 | 4668 | 4183 |
| biomass (IGCC CCS) | 12065 | 11343 | 10798 | 9950 | 9161 | 8286 | 8523 | 7735 | 8259 | 7550 |
| biomass (IGCC) | 8180 | 7689 | 7537 | 6838 | 6569 | 5759 | 6120 | 5370 | 5909 | 5230 |
| coal (conv pul CCS) | 7907 | 7186 | 7176 | 6862 | 6296 | 6377 | 5949 | 6150 | 5777 | 6045 |
| coal (conv pul) | 3951 | 4655 | 3859 | 4484 | 3661 | 4228 | 3507 | 4108 | 3384 | 4053 |
| coal (IGCC CCS) | 8998 | 10596 | 7999 | 9576 | 6741 | 8282 | 6270 | 7816 | 6085 | 7648 |
| coal (IGCC) | 5452 | 5087 | 5025 | 4695 | 4382 | 4197 | 4079 | 4018 | 3938 | 3953 |
| CSP | 6543 | 3874 | 5491 | 3034 | 4360 | 2262 | 4048 | 2098 | 3960 | 2063 |
| gas (CC CCS) | 2864 | 2813 | 2600 | 2495 | 2279 | 2145 | 2156 | 2039 | 2090 | 2006 |
| gas (CC) | 1430 | 1267 | 1399 | 1115 | 1324 | 975 | 1267 | 946 | 1228 | 939 |
| gas (CT) | 1021 | 704 | 999 | 687 | 946 | 652 | 906 | 624 | 876 | 603 |
| Gen_III | 7498 | 7778 | 7317 | 7267 | 6943 | 6503 | 6648 | 6146 | 6420 | 5979 |
| geothermal | 5997 | 5875 | 5856 | 5343 | 5553 | 4669 | 5320 | 4425 | 5135 | 4338 |
| PV | 2543 | 2934 | 2345 | 1844 | 2046 | 988 | 1905 | 849 | 1839 | 826 |
| refined liquids (CC CCS) | 3406 | 3349 | 3058 | 2960 | 2640 | 2519 | 2490 | 2381 | 2420 | 2336 |
| refined liquids (CC) | 1430 | 1267 | 1399 | 1115 | 1324 | 975 | 1267 | 946 | 1228 | 939 |
| refined liquids (CT) | 1021 | 704 | 999 | 687 | 946 | 652 | 906 | 624 | 876 | 603 |
| wind | 2728 | 1985 | 2512 | 1672 | 2191 | 1275 | 2042 | 1132 | 1971 | 1081 |

*Supplementary Table 8: Temperature-induced increases in cumulative capital investments (2015-2100; billion USD) by state and fuel for model run with updated costs (NREL 2019[7])*

| State | biomass | coal | gas | nuclear | refined liquids | solar | wind | Total |
|---|---|---|---|---|---|---|---|---|
| CA | 0 | 1 | 24 | 1 | 1 | 19 | 5 | 54 |
| IL | 1 | 2 | 14 | 1 | 1 | 21 | 11 | 52 |
| PA | 0 | 1 | 11 | 1 | 1 | 21 | 12 | 47 |
| MO | 0 | 1 | 14 | 1 | 1 | 11 | 10 | 36 |
| GA | 0 | 1 | 7 | 1 | 0 | 11 | 14 | 36 |
| NY | 0 | 0 | 23 | 0 | 0 | 4 | 2 | 30 |
| WA | 0 | 2 | 10 | 1 | 0 | 14 | 2 | 29 |
| OH | 0 | 1 | 14 | 1 | 0 | 10 | 3 | 29 |
| AL | 0 | 1 | 6 | 1 | 0 | 13 | 8 | 29 |
| KY | 0 | 1 | 8 | 1 | 0 | 11 | 7 | 29 |
| AZ | 0 | 1 | 11 | 0 | 0 | 9 | 5 | 28 |
| TX | 0 | 1 | 6 | 0 | 0 | 9 | 10 | 27 |
| IN | 0 | 1 | 12 | 0 | 0 | 9 | 3 | 25 |
| WI | 0 | 1 | 7 | 0 | 0 | 9 | 7 | 24 |
| NC | 0 | 1 | 6 | 0 | 0 | 8 | 8 | 24 |
| MI | 0 | 0 | 8 | 0 | 0 | 6 | 7 | 23 |
| TN | 0 | 1 | 7 | 0 | 0 | 8 | 6 | 23 |
| LA | 0 | 1 | 10 | 0 | 0 | 7 | 2 | 21 |
| SC | 0 | 0 | 9 | 0 | 0 | 6 | 3 | 20 |
| VA | 0 | 0 | 9 | 0 | 0 | 7 | 2 | 19 |
| OK | 0 | 1 | 7 | 0 | 0 | 5 | 5 | 18 |
| NJ | 0 | 1 | 6 | 0 | 0 | 4 | 4 | 15 |
| CO | 0 | 0 | 4 | 0 | 0 | 7 | 3 | 15 |
| WV | 0 | 0 | 4 | 0 | 0 | 5 | 4 | 15 |
| MS | 0 | 0 | 6 | 0 | 0 | 5 | 2 | 15 |
| AR | 0 | 0 | 6 | 0 | 0 | 4 | 3 | 14 |
| MD | 0 | 0 | 3 | 0 | 0 | 6 | 3 | 13 |
| NV | 0 | 1 | 3 | 0 | 0 | 4 | 3 | 13 |
| OR | 0 | 1 | 4 | 0 | 0 | 5 | 2 | 13 |
| KS | 0 | 0 | 4 | 0 | 0 | 3 | 4 | 12 |
| MA | 0 | 0 | 3 | 0 | 0 | 3 | 4 | 11 |
| IA | 0 | 0 | 2 | 0 | 0 | 5 | 3 | 10 |
| NM | 0 | 0 | 3 | 0 | 0 | 3 | 3 | 10 |
| WY | 0 | 0 | 3 | 0 | 0 | 3 | 3 | 9 |
| MN | 0 | 0 | 4 | 0 | 0 | 3 | 2 | 9 |
| UT | 0 | 1 | 2 | 0 | 0 | 3 | 2 | 8 |
| MT | 0 | 0 | 2 | 0 | 0 | 3 | 2 | 8 |
| CT | 0 | 0 | 2 | 0 | 0 | 4 | 2 | 7 |
| NE | 0 | 0 | 2 | 0 | 0 | 2 | 2 | 6 |
| ND | 0 | 0 | 2 | 0 | 0 | 1 | 2 | 5 |
| ID | 0 | 0 | 1 | 0 | 0 | 2 | 1 | 4 |
| NH | 0 | 0 | 1 | 0 | 0 | 2 | 1 | 4 |
| DE | 0 | 0 | 1 | 0 | 0 | 1 | 2 | 4 |
| ME | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 3 |
| SD | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 3 |
| RI | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 |
| VT | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| FL | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| US Total | 7 | 29 | 292 | 16 | 13 | 301 | 191 | 853 |

*Supplementary Table 9: SSP2 RCP 8.5 w/o Temperature Impacts - Installed Capacity (GW) in 2100 for model run with updated costs (NREL 2019[7])*

| State | biomass | coal | gas | nuclear | refined liquids | solar | wind | Total |
|---|---|---|---|---|---|---|---|---|
| AL | 0 | 1 | 27 | 1 | 1 | 28 | 4 | 65 |
| AR | 0 | 0 | 12 | 0 | 0 | 13 | 5 | 32 |
| AZ | 0 | 2 | 26 | 1 | 1 | 24 | 9 | 65 |
| CA | 0 | 3 | 44 | 1 | 1 | 64 | 9 | 133 |
| CO | 0 | 1 | 13 | 0 | 0 | 12 | 8 | 36 |
| CT | 0 | 1 | 5 | 0 | 0 | 20 | 4 | 30 |
| DE | 0 | 0 | 1 | 0 | 0 | 6 | 4 | 12 |
| FL | 0 | 3 | 83 | 1 | 2 | 65 | 4 | 158 |
| GA | 0 | 1 | 29 | 1 | 1 | 31 | 18 | 83 |
| IA | 0 | 1 | 9 | 0 | 0 | 10 | 8 | 28 |
| ID | 0 | 0 | 2 | 0 | 0 | 4 | 2 | 12 |
| IL | 0 | 4 | 21 | 1 | 1 | 56 | 11 | 94 |
| IN | 0 | 2 | 17 | 1 | 1 | 38 | 14 | 72 |
| KS | 0 | 1 | 12 | 0 | 0 | 10 | 8 | 32 |
| KY | 0 | 2 | 17 | 1 | 1 | 39 | 28 | 88 |
| LA | 0 | 1 | 20 | 0 | 0 | 20 | 2 | 44 |
| MA | 0 | 1 | 7 | 1 | 0 | 28 | 6 | 43 |
| MD | 0 | 1 | 6 | 0 | 0 | 24 | 8 | 40 |
| ME | 0 | 0 | 2 | 0 | 0 | 8 | 2 | 14 |
| MI | 0 | 2 | 16 | 1 | 1 | 36 | 14 | 69 |
| MN | 0 | 1 | 8 | 0 | 0 | 9 | 3 | 21 |
| MO | 0 | 2 | 12 | 1 | 0 | 32 | 22 | 70 |
| MS | 0 | 1 | 13 | 0 | 0 | 13 | 3 | 31 |
| MT | 0 | 1 | 4 | 0 | 0 | 7 | 4 | 19 |
| NC | 0 | 1 | 23 | 0 | 0 | 24 | 3 | 54 |
| ND | 0 | 0 | 4 | 0 | 0 | 5 | 4 | 14 |
| NE | 0 | 0 | 5 | 0 | 0 | 5 | 5 | 16 |
| NH | 0 | 0 | 3 | 0 | 0 | 10 | 3 | 17 |
| NJ | 0 | 1 | 7 | 1 | 0 | 28 | 6 | 44 |
| NM | 0 | 1 | 8 | 0 | 0 | 8 | 5 | 22 |
| NV | 0 | 1 | 7 | 0 | 0 | 12 | 6 | 28 |
| NY | 0 | 2 | 15 | 1 | 1 | 59 | 22 | 105 |
| OH | 0 | 2 | 21 | 1 | 1 | 45 | 14 | 85 |
| OK | 0 | 1 | 19 | 0 | 0 | 15 | 9 | 46 |
| OR | 0 | 1 | 8 | 0 | 0 | 14 | 2 | 36 |
| PA | 0 | 3 | 21 | 2 | 1 | 81 | 24 | 133 |
| RI | 0 | 0 | 1 | 0 | 0 | 5 | 1 | 7 |
| SC | 0 | 1 | 17 | 0 | 0 | 18 | 5 | 43 |
| SD | 0 | 0 | 2 | 0 | 0 | 3 | 2 | 9 |
| TN | 0 | 1 | 18 | 0 | 0 | 19 | 14 | 56 |
| TX | 0 | 1 | 124 | 0 | 1 | 9 | 4 | 140 |
| UT | 0 | 1 | 5 | 0 | 0 | 8 | 3 | 17 |
| VA | 0 | 1 | 17 | 0 | 0 | 18 | 2 | 40 |
| VT | 0 | 0 | 1 | 0 | 0 | 3 | 2 | 6 |
| WA | 0 | 3 | 21 | 1 | 1 | 36 | 2 | 87 |
| WI | 0 | 2 | 8 | 0 | 0 | 23 | 10 | 45 |
| WV | 0 | 1 | 11 | 0 | 0 | 23 | 10 | 46 |
| WY | 0 | 1 | 8 | 0 | 0 | 8 | 5 | 22 |
| US Total | 4 | 54 | 780 | 21 | 19 | 1076 | 365 | 2408 |

*Supplementary Table 10: SSP2 RCP 8.5 w/ Temperature Impacts - Installed Capacity (GW) in 2100 for model run with updated costs (NREL 2019[7])*

| State | biomass | coal | gas | nuclear | refined liquids | solar | wind | Total |
|---|---|---|---|---|---|---|---|---|
| AL | 0 | 1 | 33 | 1 | 1 | 31 | 4 | 75 |
| AR | 0 | 1 | 15 | 0 | 0 | 14 | 6 | 37 |
| AZ | 0 | 2 | 31 | 1 | 1 | 28 | 10 | 76 |
| CA | 0 | 3 | 52 | 1 | 1 | 73 | 9 | 152 |
| CO | 0 | 1 | 16 | 0 | 0 | 15 | 9 | 42 |
| CT | 0 | 1 | 5 | 0 | 0 | 21 | 5 | 32 |
| DE | 0 | 0 | 2 | 0 | 0 | 6 | 5 | 13 |
| FL | 0 | 3 | 82 | 1 | 2 | 63 | 4 | 155 |
| GA | 0 | 1 | 36 | 1 | 1 | 34 | 19 | 94 |
| IA | 0 | 1 | 10 | 0 | 0 | 11 | 9 | 31 |
| ID | 0 | 0 | 3 | 0 | 0 | 5 | 2 | 14 |
| IL | 0 | 4 | 25 | 1 | 1 | 63 | 13 | 109 |
| IN | 0 | 2 | 20 | 1 | 1 | 40 | 15 | 79 |
| KS | 0 | 1 | 14 | 0 | 0 | 11 | 9 | 36 |
| KY | 0 | 2 | 20 | 1 | 1 | 42 | 29 | 95 |
| LA | 0 | 1 | 24 | 0 | 1 | 23 | 3 | 52 |
| MA | 0 | 1 | 8 | 1 | 0 | 30 | 7 | 46 |
| MD | 0 | 1 | 7 | 0 | 1 | 26 | 9 | 45 |
| ME | 0 | 0 | 2 | 0 | 0 | 9 | 2 | 15 |
| MI | 0 | 2 | 19 | 1 | 1 | 39 | 14 | 76 |
| MN | 0 | 1 | 9 | 0 | 0 | 10 | 3 | 24 |
| MO | 0 | 2 | 14 | 1 | 1 | 36 | 24 | 79 |
| MS | 0 | 1 | 16 | 0 | 0 | 15 | 4 | 36 |
| MT | 0 | 1 | 5 | 0 | 0 | 9 | 5 | 23 |
| NC | 0 | 1 | 28 | 1 | 1 | 27 | 3 | 62 |
| ND | 0 | 0 | 5 | 0 | 0 | 5 | 4 | 15 |
| NE | 0 | 0 | 6 | 0 | 0 | 6 | 5 | 18 |
| NH | 0 | 0 | 3 | 0 | 0 | 11 | 3 | 18 |
| NJ | 0 | 1 | 9 | 1 | 1 | 31 | 6 | 49 |
| NM | 0 | 1 | 10 | 0 | 0 | 9 | 6 | 26 |
| NV | 0 | 1 | 9 | 0 | 0 | 15 | 7 | 33 |
| NY | 0 | 2 | 18 | 1 | 1 | 64 | 24 | 116 |
| OH | 0 | 2 | 24 | 1 | 1 | 49 | 15 | 93 |
| OK | 0 | 2 | 22 | 0 | 1 | 17 | 10 | 52 |
| OR | 0 | 1 | 10 | 0 | 0 | 17 | 3 | 41 |
| PA | 0 | 4 | 26 | 2 | 2 | 89 | 27 | 150 |
| RI | 0 | 0 | 1 | 0 | 0 | 5 | 1 | 8 |
| SC | 0 | 1 | 21 | 0 | 1 | 20 | 5 | 49 |
| SD | 0 | 0 | 3 | 0 | 0 | 3 | 2 | 10 |
| TN | 0 | 1 | 22 | 0 | 1 | 21 | 16 | 63 |
| TX | 0 | 1 | 135 | 0 | 1 | 11 | 5 | 153 |
| UT | 0 | 1 | 6 | 0 | 0 | 10 | 3 | 21 |
| VA | 0 | 1 | 21 | 0 | 1 | 20 | 2 | 47 |
| VT | 0 | 0 | 1 | 0 | 0 | 3 | 2 | 7 |
| WA | 0 | 3 | 25 | 1 | 1 | 44 | 2 | 101 |
| WI | 0 | 2 | 10 | 1 | 1 | 26 | 12 | 51 |
| WV | 0 | 1 | 12 | 0 | 0 | 25 | 10 | 50 |
| WY | 0 | 1 | 10 | 0 | 0 | 9 | 6 | 26 |
| US Total | 5 | 61 | 901 | 24 | 26 | 1192 | 396 | 2694 |

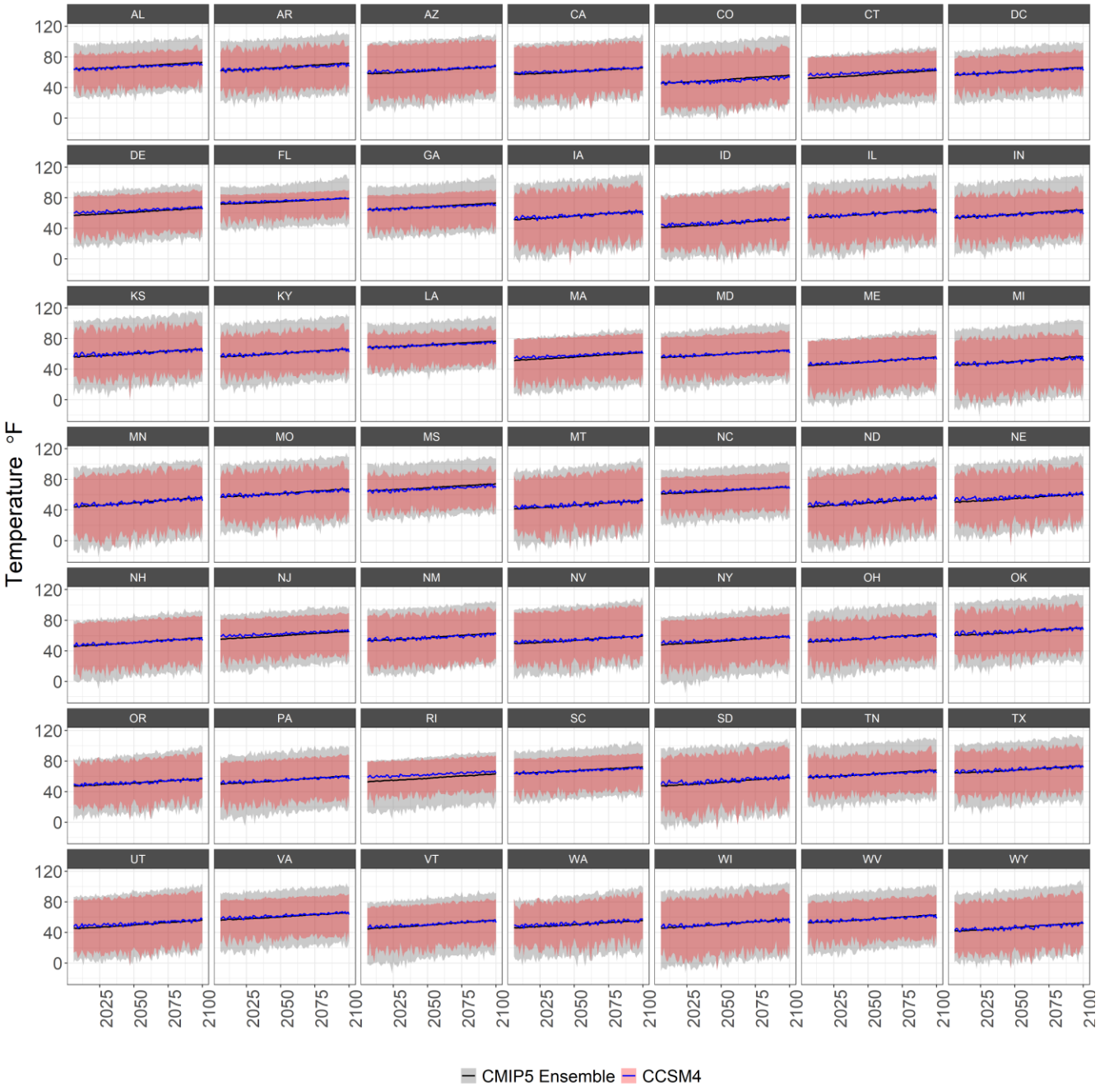
*Supplementary Table 11: SSP2 RCP 8.5 w/o Temperature Impacts – Cumulative Capital Costs (Billion 2015 USD) in 2100 for model run with updated costs (NREL 2019[7])*

| State | biomass | coal | gas | nuclear | refined liquids | solar | wind | Total |
|---|---|---|---|---|---|---|---|---|
| AL | 1 | 5 | 56 | 4 | 1 | 54 | 17 | 138 |
| AR | 0 | 2 | 25 | 2 | 0 | 24 | 18 | 72 |
| AZ | 1 | 9 | 55 | 4 | 1 | 51 | 35 | 158 |
| CA | 2 | 12 | 90 | 8 | 1 | 107 | 29 | 262 |
| CO | 0 | 5 | 27 | 2 | 0 | 26 | 27 | 90 |
| CT | 1 | 3 | 12 | 3 | 0 | 39 | 17 | 74 |
| DE | 0 | 1 | 3 | 1 | 0 | 11 | 15 | 32 |
| FL | 2 | 12 | 161 | 9 | 3 | 128 | 20 | 335 |
| GA | 1 | 6 | 59 | 4 | 1 | 60 | 57 | 187 |
| IA | 0 | 3 | 18 | 1 | 0 | 19 | 24 | 65 |
| ID | 0 | 2 | 6 | 1 | 0 | 9 | 6 | 24 |
| IL | 2 | 18 | 48 | 8 | 2 | 110 | 44 | 232 |
| IN | 1 | 9 | 37 | 5 | 1 | 70 | 46 | 169 |
| KS | 0 | 4 | 26 | 2 | 1 | 23 | 30 | 86 |
| KY | 1 | 9 | 36 | 5 | 1 | 71 | 79 | 202 |
| LA | 1 | 4 | 41 | 3 | 1 | 40 | 10 | 99 |
| MA | 1 | 4 | 17 | 4 | 1 | 55 | 25 | 106 |
| MD | 1 | 5 | 15 | 3 | 1 | 48 | 33 | 107 |
| ME | 0 | 1 | 5 | 1 | 0 | 17 | 9 | 34 |
| MI | 1 | 8 | 35 | 5 | 1 | 67 | 46 | 164 |
| MN | 0 | 3 | 17 | 1 | 0 | 18 | 11 | 51 |
| MO | 1 | 10 | 26 | 5 | 1 | 62 | 68 | 173 |
| MS | 0 | 2 | 27 | 2 | 0 | 26 | 13 | 71 |
| MT | 0 | 3 | 10 | 1 | 0 | 15 | 15 | 45 |
| NC | 1 | 4 | 48 | 3 | 1 | 46 | 13 | 116 |
| ND | 0 | 1 | 8 | 1 | 0 | 9 | 11 | 30 |
| NE | 0 | 2 | 10 | 1 | 0 | 10 | 14 | 37 |
| NH | 0 | 1 | 6 | 2 | 0 | 21 | 11 | 41 |
| NJ | 1 | 6 | 18 | 4 | 1 | 57 | 24 | 111 |
| NM | 0 | 3 | 17 | 1 | 0 | 17 | 17 | 57 |
| NV | 0 | 4 | 17 | 2 | 0 | 26 | 22 | 74 |
| NY | 2 | 10 | 40 | 9 | 2 | 122 | 88 | 273 |
| OH | 1 | 10 | 45 | 6 | 1 | 85 | 49 | 198 |
| OK | 1 | 6 | 41 | 2 | 1 | 36 | 38 | 125 |
| OR | 1 | 5 | 20 | 2 | 0 | 30 | 9 | 70 |
| PA | 3 | 16 | 52 | 12 | 2 | 165 | 98 | 348 |
| RI | 0 | 1 | 3 | 1 | 0 | 9 | 5 | 19 |
| SC | 1 | 3 | 36 | 2 | 1 | 35 | 18 | 95 |
| SD | 0 | 1 | 5 | 0 | 0 | 5 | 6 | 17 |
| TN | 1 | 3 | 35 | 3 | 1 | 36 | 42 | 121 |
| TX | 0 | 3 | 233 | 1 | 2 | 21 | 14 | 274 |
| UT | 0 | 3 | 11 | 1 | 0 | 17 | 11 | 46 |
| VA | 1 | 3 | 37 | 3 | 1 | 35 | 10 | 89 |
| VT | 0 | 0 | 2 | 0 | 0 | 6 | 6 | 15 |
| WA | 2 | 13 | 52 | 5 | 1 | 77 | 10 | 163 |
| WI | 1 | 7 | 19 | 3 | 1 | 45 | 36 | 113 |
| WV | 1 | 5 | 23 | 3 | 1 | 44 | 34 | 111 |
| WY | 0 | 3 | 16 | 1 | 0 | 16 | 18 | 55 |
| US Total | 36 | 255 | 1645 | 153 | 31 | 2124 | 1299 | 5573 |

*Supplementary Table 12: SSP2 RCP 8.5 w/ Temperature Impacts – Cumulative Capital Costs (Billion 2015 USD) in 2100 for model run with updated costs (NREL 2019[7])*

| State | biomass | coal | gas | nuclear | refined liquids | solar | wind | Total |
|---|---|---|---|---|---|---|---|---|
| AL | 1 | 6 | 70 | 4 | 1 | 64 | 20 | 167 |
| AR | 0 | 3 | 31 | 2 | 1 | 29 | 21 | 86 |
| AZ | 1 | 10 | 66 | 4 | 1 | 60 | 40 | 186 |
| CA | 2 | 14 | 114 | 9 | 2 | 126 | 34 | 316 |
| CO | 1 | 5 | 33 | 2 | 1 | 31 | 31 | 105 |
| CT | 1 | 3 | 13 | 3 | 0 | 42 | 19 | 81 |
| DE | 0 | 1 | 4 | 1 | 0 | 13 | 16 | 35 |
| FL | 2 | 12 | 162 | 9 | 3 | 128 | 21 | 336 |
| GA | 1 | 6 | 73 | 5 | 2 | 70 | 67 | 224 |
| IA | 0 | 4 | 21 | 2 | 0 | 22 | 27 | 76 |
| ID | 0 | 2 | 7 | 1 | 0 | 11 | 7 | 28 |
| IL | 2 | 20 | 62 | 9 | 2 | 132 | 55 | 284 |
| IN | 1 | 9 | 44 | 6 | 1 | 79 | 53 | 193 |
| KS | 0 | 4 | 30 | 2 | 1 | 27 | 34 | 99 |
| KY | 1 | 10 | 42 | 6 | 1 | 80 | 89 | 229 |
| LA | 1 | 4 | 51 | 3 | 1 | 47 | 12 | 120 |
| MA | 1 | 4 | 19 | 4 | 1 | 60 | 27 | 117 |
| MD | 1 | 5 | 19 | 4 | 1 | 54 | 36 | 120 |
| ME | 0 | 1 | 6 | 1 | 0 | 18 | 10 | 37 |
| MI | 1 | 9 | 42 | 5 | 1 | 76 | 52 | 187 |
| MN | 0 | 3 | 21 | 1 | 0 | 21 | 13 | 60 |
| MO | 1 | 12 | 33 | 5 | 1 | 74 | 83 | 209 |
| MS | 1 | 3 | 33 | 2 | 1 | 31 | 15 | 85 |
| MT | 0 | 3 | 11 | 1 | 0 | 18 | 17 | 52 |
| NC | 1 | 5 | 60 | 4 | 1 | 55 | 15 | 141 |
| ND | 0 | 2 | 10 | 1 | 0 | 10 | 13 | 35 |
| NE | 0 | 2 | 11 | 1 | 0 | 12 | 16 | 43 |
| NH | 0 | 1 | 7 | 2 | 0 | 23 | 12 | 45 |
| NJ | 1 | 6 | 22 | 4 | 1 | 65 | 27 | 126 |
| NM | 0 | 3 | 21 | 1 | 0 | 19 | 20 | 66 |
| NV | 1 | 5 | 20 | 2 | 0 | 30 | 26 | 87 |
| NY | 3 | 11 | 46 | 9 | 2 | 135 | 97 | 302 |
| OH | 2 | 11 | 53 | 7 | 2 | 96 | 56 | 227 |
| OK | 1 | 7 | 48 | 3 | 1 | 42 | 42 | 143 |
| OR | 1 | 6 | 24 | 2 | 1 | 36 | 11 | 82 |
| PA | 3 | 17 | 63 | 13 | 3 | 186 | 110 | 395 |
| RI | 0 | 1 | 3 | 1 | 0 | 10 | 6 | 21 |
| SC | 1 | 4 | 44 | 3 | 1 | 41 | 21 | 114 |
| SD | 0 | 1 | 5 | 0 | 0 | 6 | 7 | 20 |
| TN | 1 | 4 | 43 | 3 | 1 | 42 | 50 | 144 |
| TX | 0 | 3 | 255 | 1 | 2 | 25 | 17 | 304 |
| UT | 0 | 4 | 13 | 1 | 0 | 21 | 13 | 54 |
| VA | 1 | 4 | 46 | 3 | 1 | 42 | 12 | 107 |
| VT | 0 | 0 | 2 | 0 | 0 | 7 | 7 | 17 |
| WA | 2 | 15 | 62 | 6 | 1 | 91 | 12 | 193 |
| WI | 1 | 8 | 25 | 4 | 1 | 54 | 44 | 137 |
| WV | 1 | 6 | 27 | 4 | 1 | 49 | 38 | 125 |
| WY | 0 | 3 | 20 | 1 | 0 | 19 | 20 | 65 |
| US Total | 43 | 283 | 1937 | 169 | 44 | 2425 | 1490 | 6426 |

## Supplementary Note 13. INPUT TEMPERATURE DATA UNCERTAINTY




*Supplementary Figure 16: Uncertainty in temperature input data used in this study. The temperature projections plotted in this figure correspond to RCP8.5. The blue line corresponds to annual average of temperature estimates by state from the CCSM4 model which is the temperature input data used in this study (the original data is in hourly resolution). The red range corresponds to the maximum and minimum temperatures in each year from the CCSM4 model within each state. The black line corresponds to the annual average of temperature estimates by state across CMIP5 ensemble models (the original data is in monthly resolution). The grey range corresponds to maximum and minimum temperatures across models. Note that the temperature variability represented in the red range is captured in our analysis. It is noteworthy that the variability is within the bounds of the CMIP5 cross-model uncertainty range.*

## Supplementary Note 14. MODEL DEVELOPMENT DETAILS

*Supplementary Table 13: Details of model developments compared with previous version of model (Wise et al. 2019 [8])*

| Modeling detail | Wise et. al. 2019 | Current model |
|---|---|---|
| Intra-annual electricity demand profile | 1. Combined single profile for total electricity;<br>2. Modeled only at the supply-side to capture intra-annual supply-side dynamics;<br>3. Demand-side economic response is modeled at the annual scale;<br>4. Subannual demand profile is fixed and does not change over time or across experiments. | 1. Disaggregated profile with twenty-five segments for each end-use sector;<br>2. Modeled at supply and demand-side;<br>3. Hence there are twenty five new market (supply/demand) equations being solved in each model period;<br>4. Profile is dynamic and might change over time and across experiments depending on the assumed temperature (degree hour) inputs. |
| Building energy demand | Annual | 25 segments |
| Transport Energy demand | Annual | 25 segments |
| Industry Energy Demand | Annual | 25 segments |
| Response of building energy to exogenous assumptions about temperature/ degree days | None | Endogenous |
| Building energy demand response profile disaggregated by service (heating/cooling/other) | None | Disaggregated |
| Separate decisions for investment and dispatch | Yes | Yes |

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