A Vision For Clean Energy In Illinois By 2050

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Table of Contents

1 Study Description

The Coalition for Community Solar Access (CCSA) and Local Solar for All commissioned Vibrant Clean Energy (VCE®) to investigate scenarios that electrify and completely decarbonize the economy for the state of Illinois by 2050. The scenarios discussed in this report model the state of Illinois undergoing economy-wide electrification with decarbonization of the electricity sector. The modeling was performed using the WIS:dom®-P, a state-of-the-art model capable of performing detailed capacity expansion and production cost while co-optimizing utility-scale generation, storage, transmission, and distributed energy resources (DERs). The modeled scenarios use the National Renewable Energy Laboratory (NREL) Annual Technology Baseline (ATB) 2020 "advanced" cost projections for installed capital and Operation and Maintenance (O&M) costs. For fuel costs, forecasts from the Annual Energy Outlook (AEO) 2020 High Oil and Gas supply scenario are used.[1]

The scenarios modeled in this study are:

(1) **Electrify and decarbonize IL without distribution co-optimization ("noDER"):** In this scenario, the state of Illinois undergoes economy-wide electrification and decarbonization of the electricity sector without co-optimizing the distribution system with the utility-scale generation. In this scenario, the nuclear generation follow their current retirement schedules without license extension. This scenario serves as a counterfactual to compare changes in system costs and retail rates for customers as a result of co-optimizing the distribution system and utilizing distributed generation.

(2) **Electrify and decarbonize IL with distribution co-optimization with increased distributed generation buildout ("DER_wDG"):** In this scenario, WIS:dom-P co-optimizes the distribution system with utility-scale generation to decarbonize Illinois by 100% by 2050 while undergoing economy-wide electrification. In addition, this scenario assumes that a minimum of 5 GW of rooftop solar and 3.5 GW of community solar is installed in Illinois. The nuclear generation follows their current retirement schedules as in the "noDER" scenario.

The scenarios are initialized and calibrated with 2018 generator, generation, and transmission topology datasets. The scenarios then determine a pathway from 2020 through 2050 with results outputted every 5 years. As part of the optimal capacity expansion, WIS:dom-P must ensure each grid meets reliability constraints through enforcing the planning reserve margins specified by the North American Electric Reliability Corporation (NERC) and having a 7% load following reserve available at all times. Detailed technical documentation describes the mathematics and formulation of the WIS:dom-P software along with input datasets and assumptions.[2]

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[1] https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2020&region=1-0&cases=highogs&start=2018&end=2050&f=A&linechart=highogs-d112619a.3-3-AEO2020.1-0~highogs-d112619a.36-3-AEO2020.1-0~highogs-d112619a.37-3-AEO2020.1-0~highogs-d112619a.38-3-AEO2020.1-0~highogs-d112619a.39-3-AEO2020.1-0~highogs-d112619a.40-3-AEO2020.1-0&map=highogs-d112619a.4-3-AEO2020.1-0&sourcekey=0

[2] https://vibrantcleanenergy.com/wp-content/uploads/2020/08/WISdomP-Model_Description(August2020).pdf

1.1 WIS:dom®-P Model Setup

To model the capacity expansion pathway for a 100% decarbonized Illinois with economy-wide electrification of energy related activities, WIS:dom-P modeled Illinois with its existing generator topology, transmission, and weather inputs obtained from National Oceanic and Atmospheric Administration (NOAA) High Resolution Rapid Refresh (HRRR) model[3] at 3-km horizontal resolution and 5-minute time resolution. The initialized generator dataset is created by aligning the Energy Information Administration Form 860 (EIA-860) dataset[4] with the 3-km HRRR model grid. The existing generator topology in Illinois along with existing transmission at 3-km resolution is shown in Figure 1.1. The out-of-state transmission from Illinois to its neighbors is fixed at 2018 levels.

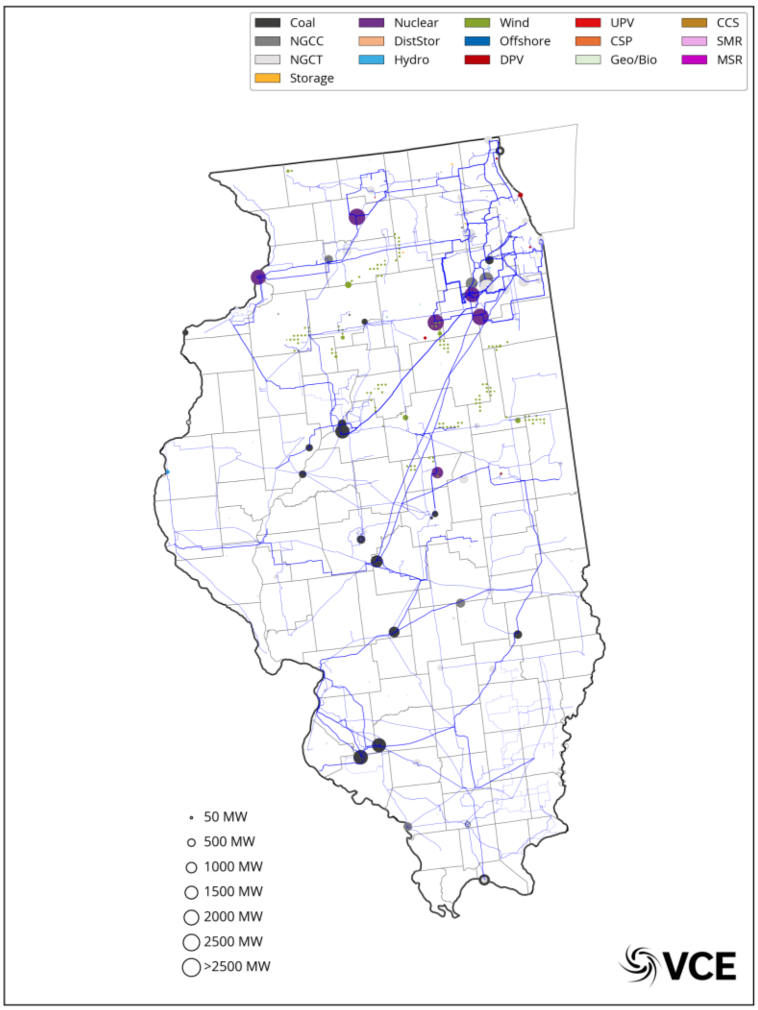

Figure 1.1: WIS:dom-P model domain and existing generators with transmission.

[3] https://rapidrefresh.noaa.gov/hrrr/

[4] https://www.eia.gov/electricity/data/eia860/

2 Modeling Results

2.1 System Costs, Retail Rates and Jobs

The total system costs and retail rates for the scenarios modeled in this study are shown in Figure 2.1. In both scenarios, the total system costs first reduce from 2020 to 2030 as the more expensive fossil fuel generation is retired and replaced with lower cost variable renewable energy (VRE) generation. After 2030, the load increases due to electrification of economy-wide energy related activities require investments in new generation which increases total system costs. In the "DER_wDG" scenario which co-optimizes the distribution grid with the utility-scale generation, the total system costs are lower than the non-co-optimized scenario ("noDER") in all investment periods except in 2040 and 2045, resulting in cumulative savings of $3.44 billion from 2018 to 2050.

The lower costs in the "DER_wDG" before 2040 are due to the distribution system co-optimization allowing more natural gas combined cycle (NGCC) generation to retire and better utilization of the remaining NGCC generation. This is achieved through the DERs shaving load peaks and shifting load such that the load factor is higher while peak load is lower. The result is less requirement for generation on the utility grid and utilization at higher capacity factors. The "DER_wDG" scenario results in additional spending in 2040 and 2045 as this scenario installs significant wind and storage along with natural gas turbine (NGGT) generation compared with the "noDER" scenario which mostly installs new NGCC generation. As a result, the "noDER" scenario results in significantly higher emissions compared with the "DER_wDG" scenario. In addition, the "noDER" scenario results in stranded NGCC generation that must be retired early because the carbon emission constraint results in these assets not being dispatched. The NGGT generation installed by the "DER_wDG" scenario, on the other hand, remains in place to provide capacity value and reliability, and runs during periods of high system stress.

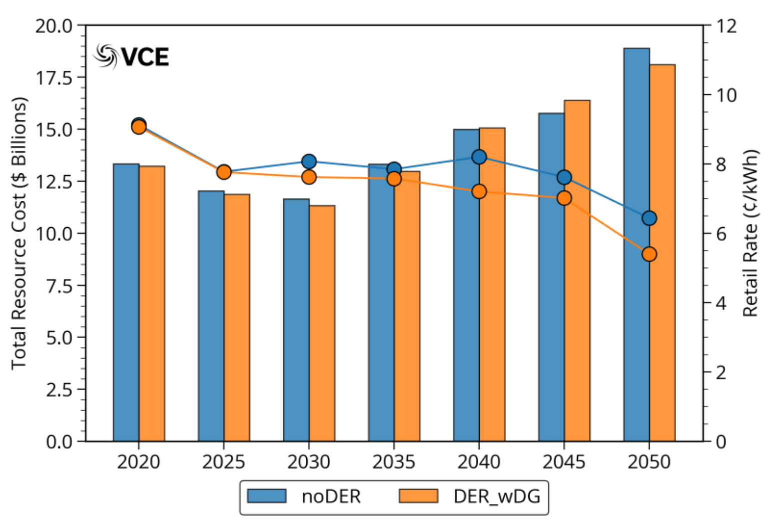

Figure 2.1: Total system cost (bars) and retail rates (solid lines) in Illinois for the two scenarios modeled.

The retail rates in the "DER_wDG" scenario are consistently lower compared with the "noDER" scenario due to savings in distribution system upgrades being directly passed on to customers. In addition, lower retail rates also result from the significantly more wind generation installed in the "DER_wDG" scenario which allows Illinois to export excess generation, yielding revenues that offset some of the costs of installed capacity and energy imports. By 2030, the "DER_wDG" scenario has an average retail rate of 7.9 ¢/kWh compared to 8.5 ¢/kWh in the "noDER" scenario, a 7% reduction. The reduction in retail rates in the "DER_wDG" scenario increases over the investment periods and by 2050, the average retail rate is 5.5 ¢/kWh compared to 6.5 ¢/kWh in the "noDER" scenario, a 16% reduction.

This reduction in retail rates occurs as economy-wide energy related activities are electrified, ensuring electrification remains attractive to customers. Figure 2.2 shows annual spending on electricity purchases in Illinois over the investment periods. The increased spending on electricity purchases after 2030 is due to the electrification of economy-wide energy related activities. The lower retail rates in the "DER_wDG" scenario mean that customers spend less on electricity purchases compared to the "noDER" scenario throughout the modeling period. The reduced spending on electricity purchases result in cumulative savings of $35.6 billion from 2018 to 2050 on expenditures for energy related activities which provide secondary economy-wide benefits for Illinois not captured in the modeling. It should be noted that the retail rates are calculated assuming all distributed generation is rate-based. Private investments by some customers will pay for a portion of the distributed generation installed, putting further downward pressure on retail rates.

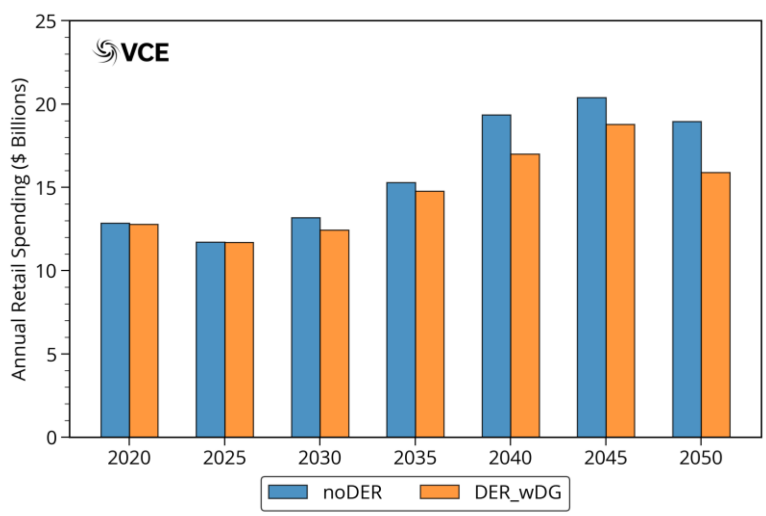

Figure 2.2: Annual retail in Illinois for electricity purchases in the scenarios modeled.

The contribution of the various sectors to total system costs per kWh of served load is shown in Figure 2.3. In 2020, about 40% of the total system costs come from fossil fuel generation, with nuclear and the distribution system making up the majority of the remaining costs. The retirement of the fossil fuel generation is the major driver in reduction of total system costs and retail rates to 2030. After 2030, more generation is added to the grid to serve the increasing load due to electrification. However, as the new generation installed is lower-cost variable renewable energy generation (VREs) and the costs are spread over a larger load, the cost per kWh of load served continues declining until 2050. The increase in 2050 is due to the large investments in utility-scale solar and storage needed in Illinois to meet the 100% decarbonization goal.

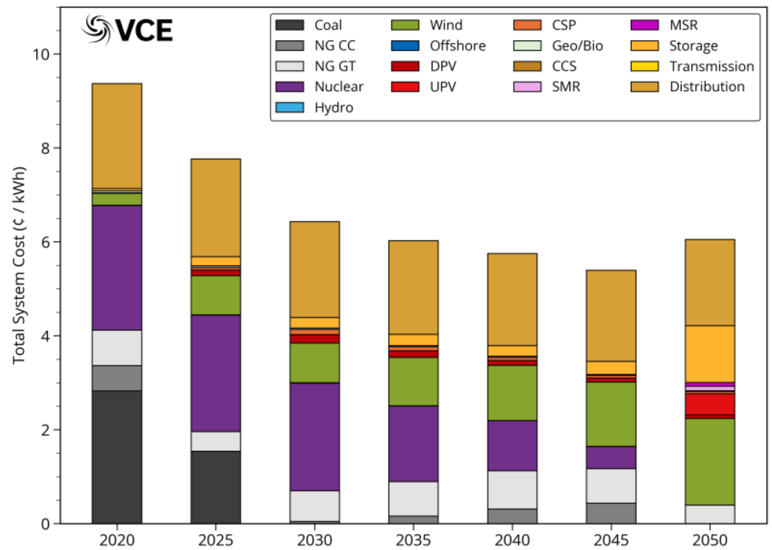

Figure 2.3: Contribution to total system cost per kWh load from each energy system sector in the "DER_wDG" scenario.

The direct full-time equivalent jobs supported by the electricity sector in Illinois for the "DER_wDG" scenario is shown in Figure 2.4. As the electricity sector transitions from fossil fuel generation to VREs, the number of jobs supported by the electricity sector increases from about 50,000 in 2020 to about 212,400 by 2045. The largest growth in jobs is seen in the wind and solar industries followed by the storage industry. The large increase in jobs in the utility-scale solar and storage industries between 2045 and 2050 is due to the large installation of solar and storage required between those investment periods to meet the carbon reduction constraint. The economic benefits of the "DER_wDG" scenario show up in job creation as well with the "DER_wDG" scenario resulting in about 63,000 more jobs in the electricity sector compared to the "noDER" scenario by 2030. The additional jobs in the "DER_wDG" scenario come from the distributed solar industry which adds about 60,000 more jobs by 2030 compared to the "noDER" scenario. By 2050, the "DER_wDG" scenario results in about 27,000 more total electric sector jobs compared to the "noDER" scenario with the distributed solar industry being the main contributor to the additional jobs.

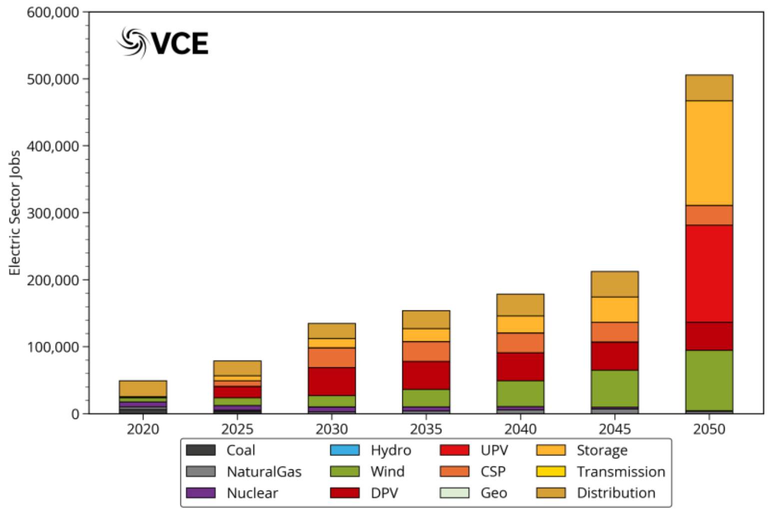

Figure 2.4: Direct full-time equivalent jobs created in the electricity sector by industry.

The percentage change in jobs in each county in Illinois in the "DER_wDG" scenario is shown in Figure 2.5. The total jobs in each county for each investment period is shown in Table A at the end of the document. In almost all counties, jobs increase by significant margins as compared to 2020 values. The counties with the largest job increases are ones which see large deployments of solar. The counties that lose jobs (colored in grey) are those where fossil fuel generation existed in 2020 and was retired by WIS:dom-P. Only a few of the counties that lose fossil fuel generation see it replaced by VRE installations. Therefore, figuring out ways to replace the loss of jobs and economic activity in these regions will be an important consideration to ensure an equitable and just transition for all communities.

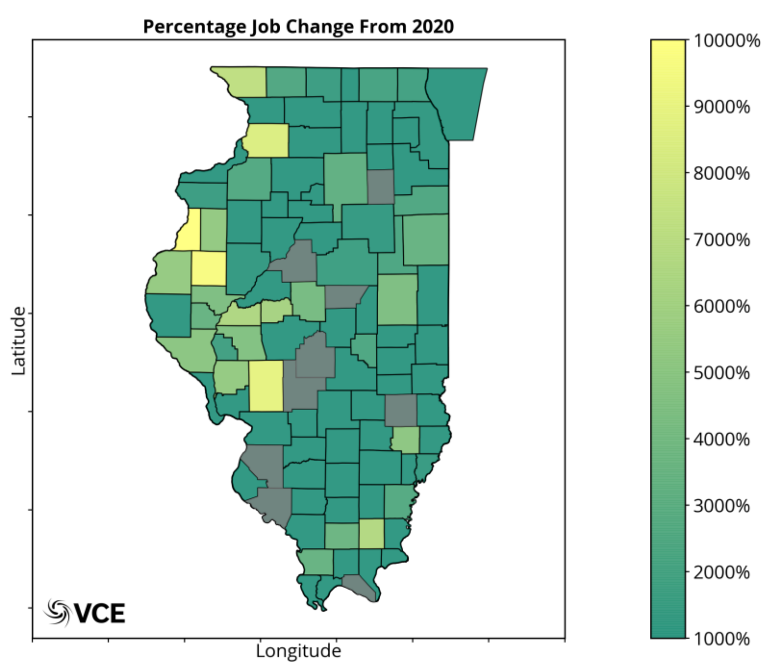

Figure 2.5: Percentage change in jobs compared to 2020 in the "DER_wDG" scenario. Counties that lose jobs are colored in grey.

2.2 Changes to Installed Capacity and Generation

The installed capacities and generation mix in Illinois for the "DER_wDG" scenario is shown in Figure 2.6 (top and bottom panels respectively). Until 2030, nuclear generation is the largest source of clean energy in Illinois, contributing more than 50% of the total energy generated in the state. In the "DER_wDG" scenario, all the coal and NGCC generation is retired by 2030 resulting in about 90% of the energy being carbon free. After 2030, some new NGCC generation is added along with an increase in imports to help meet the increased demand due to electrification resulting in a temporary increase in emissions between 2035 and 2045, before dropping to zero by 2050. Illinois also becomes a net exporter of energy by 2050 due to the overbuild of VREs required to meet the emission constraints which help offset some of the costs resulting in lower retail rates.

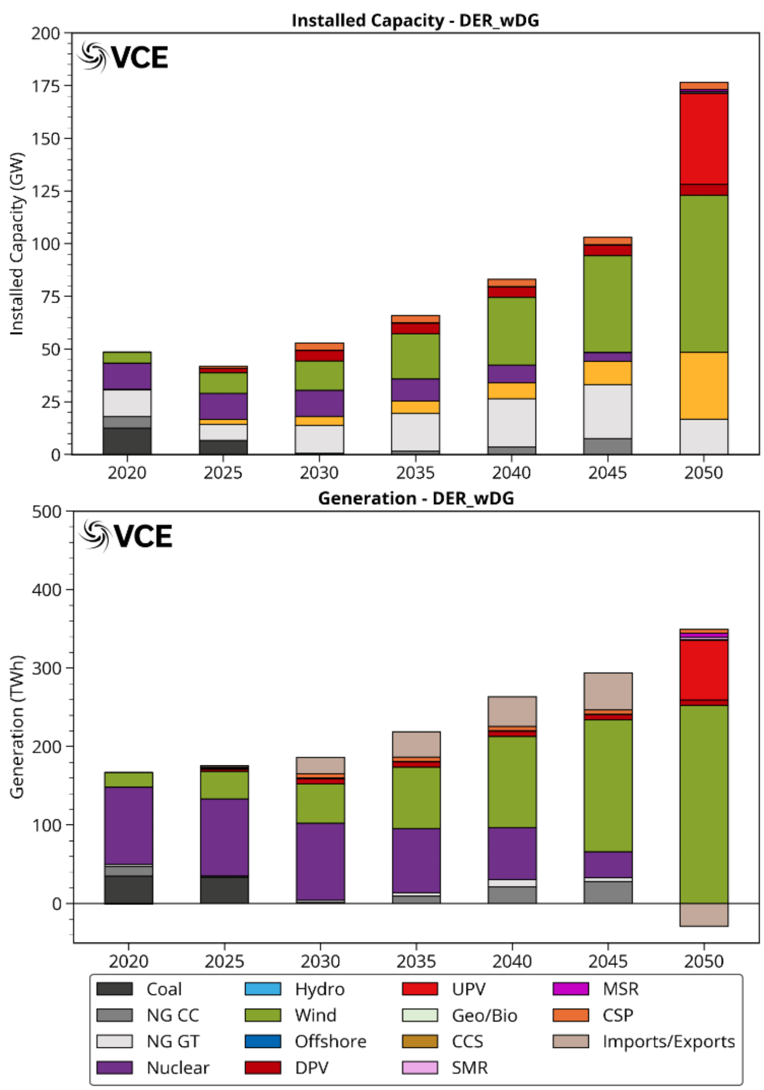

Figure 2.6: WIS:dom-P installed capacities (top) and generation (bottom) for the "DER_wDG" scenario in Illinois.

The utility-scale and distribution scale storage installed in Illinois for the "DER_wDG" scenario is shown in Figure 2.7. Until 2040, almost all the new storage added is on the distribution grid to absorb the distributed solar generation, shave demand peaks, and shift load to ensure lower costs for customers. As shown in Figure 2.8, between 2045 and 2050, a large amount of utility-scale storage is added to absorb the excess generation from the utility-scale solar added on to the grid during this time.

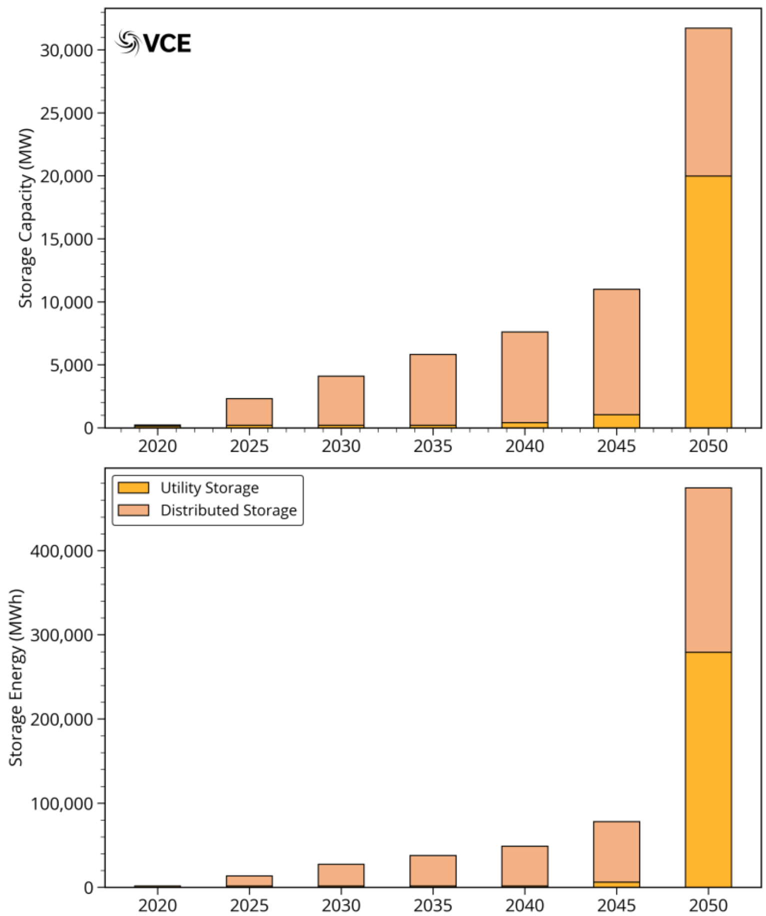

Figure 2.7: Utility storage and distributed storage installed in each investment period for the "Consumers Plan).

As with storage, Figure 2.8 shows that most of the solar added in Illinois is on the distribution grid until the 2045-2050 period. This reduces transmission losses and the amount of energy moved between the transmission-distribution interface, lowering operating and upgrade costs. The model builds 5 GW of rooftop solar and 3.5 GW of community solar as required by the assumptions. This solar added to the distribution grid is used effectively with distributed storage resulting in minimal curtailment.

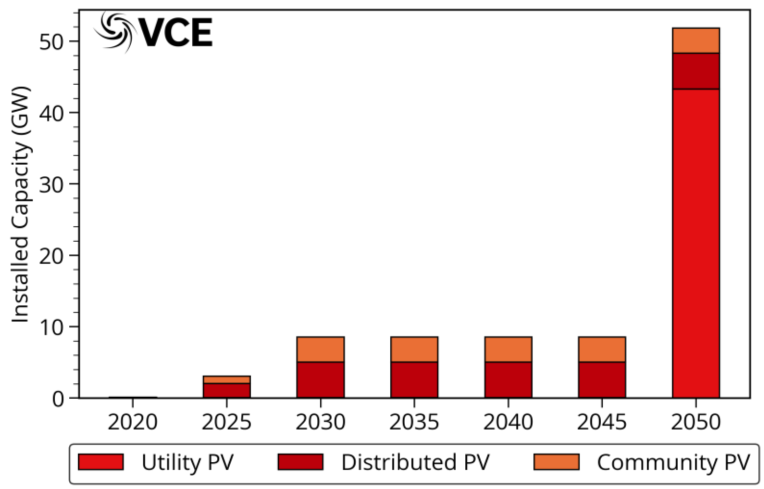

Figure 2.8: Utility PV and Distributed PV installed over the investment periods in Illinois.

2.3 Emissions and Pollutants

The annual emissions change with respect to 2005 levels and the cumulative electricity sector emissions in the "DER_wDG" scenario compared to the reference case of emissions staying at the same levels as 2020 is shown in Figure 2.9. The model shows a rapid reduction in annual emissions as fossil fuel generation is either retired or used to a lesser extent and is replaced with clean VRE generation. The annual emissions decline by 97.5% from 2005 values as all NGCC and coal generation is retired, and as Illinois uses nuclear and wind to meet most of its load. A small amount of imports accounts for all emissions in 2030. After 2030, as load increases due to electrification, new NGCC generation is added. This results in an increase in annual emissions until 2045, after which all carbon emissions are eliminated.

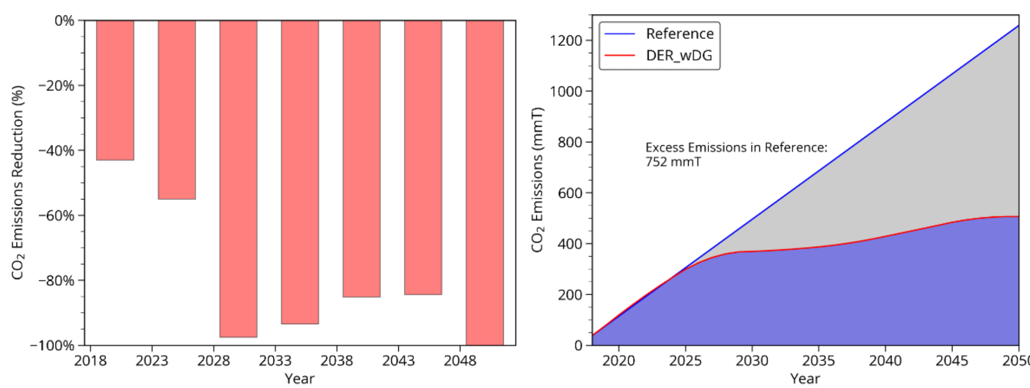

Figure 2.9: Annual emissions change with respect to 2005 (left) and cumulative carbon dioxide emission in the electric sector.

Between 2018 and 2030, as fossil generation is ramped down, Illinois adds 369 million metric tons (mmT) of CO_2 emissions from the electricity sector. From 2030 to 2050 only 137 mmT of CO_2 is added as Illinois uses only a small amount of gas generation to help meet the growing load. Cumulatively by 2050, the "DER_wDG" scenario saves 752 mmT of CO_2 emissions compared to continuing as today[5] without a carbon elimination goal. Compared with the "noDER" scenario, the "DER_wDG" scenario reduces cumulative carbon emissions by 88 mmT by 2050, a 15% reduction.

The economy-wide emissions levels in Illinois in the "DER_wDG" scenario are shown in Figure 2.10. Electrification alone is responsible for a considerable reduction in economy-wide emissions, as cumulative CO_2 emissions in Illinois are lower by 2,112 mmT by 2050. The "DER_wDG" scenario further reduces emissions by decarbonizing the electricity sector resulting in an additional savings to 752 mmT of carbon dioxide cumulatively by 2050. Therefore, the cumulative economy-wide emission savings from the "DER_wDG" scenario is 2,864 mmT of carbon dioxide compared with continuing as today without emission reductions or electrification.

[5] "Continuing as today" refers to an assumption that carbon emissions in sectors (including the electricity sector) remain at 2018 levels. The 2018 EIA emissions can be found here: https://www.eia.gov/environment/emissions/state/excel/table4.xlsx

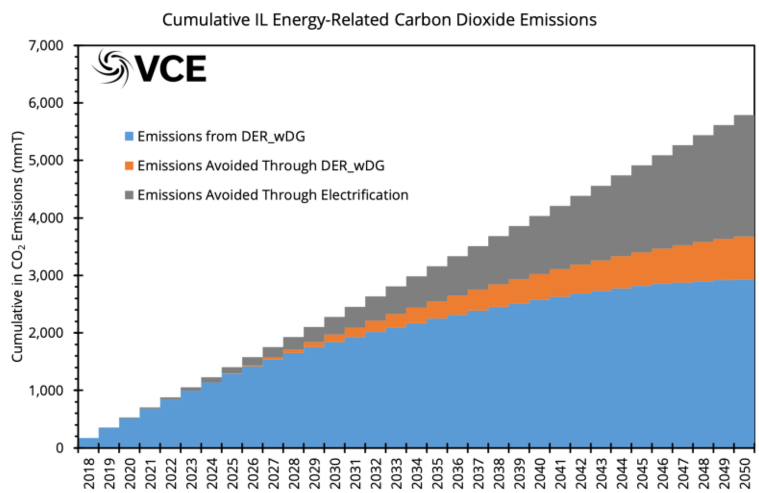

Figure 2.10: Economy-wide carbon dioxide emissions in Illinois

In addition to eliminating carbon emissions, the "DER_wDG" scenario also completely eliminates other criteria air pollutants from the electricity sector. Figure 2.11 shows the emissions levels for criteria air pollutants tracked by WIS:dom-P in the electricity sector. Emissions of all pollutants drop sharply between 2020 and 2030 as all fossil fuel use is eliminated. After 2030, as gas generation is installed to meet the growing load, NO_x and methane emissions increase slightly before going back down to zero by 2050.

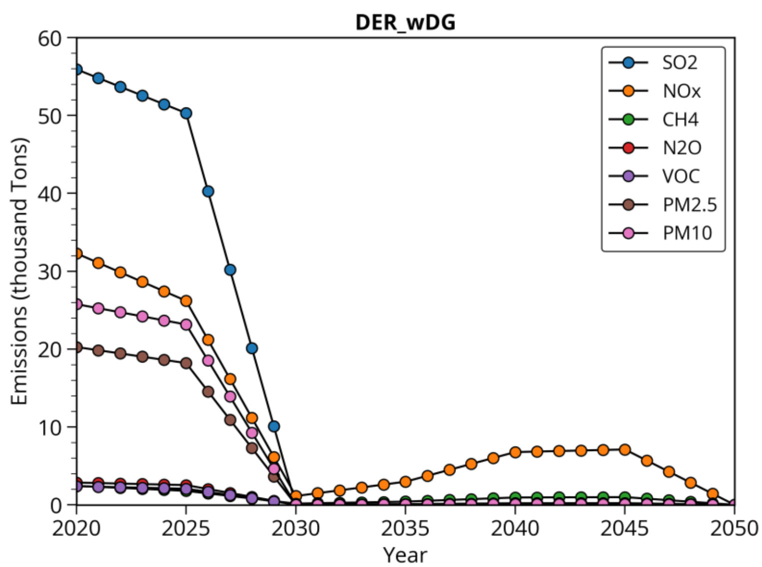

Figure 2.11: Emissions from other criteria pollutants tracked by WIS:dom-P.

2.4 Siting of Generators (3-km)

WIS:dom-P uses weather datasets spanning multiple years at 3-km spatial resolution and 5-min temporal intervals over the contiguous United States. WIS:dom-P performs an optimal siting of generators on the 3-km HRRR model grid. The WIS:dom-P installed capacity layout at 3-km resolution along with the transmission paths above 115 kV for 2035 is shown in Figure 2.12 (left panel), while the WIS:dom-P installed capacity by 2050 is shown in Figure 2.12 (right panel). The grid is largely composed of fossil fuel generation in 2018, which is transforms to VRE dominated by 2035 and almost all VRE generation by 2050. Apart from significant wind generation, Illinois also deploys significant levels of solar generation both at utility-scale and distribution-scale.

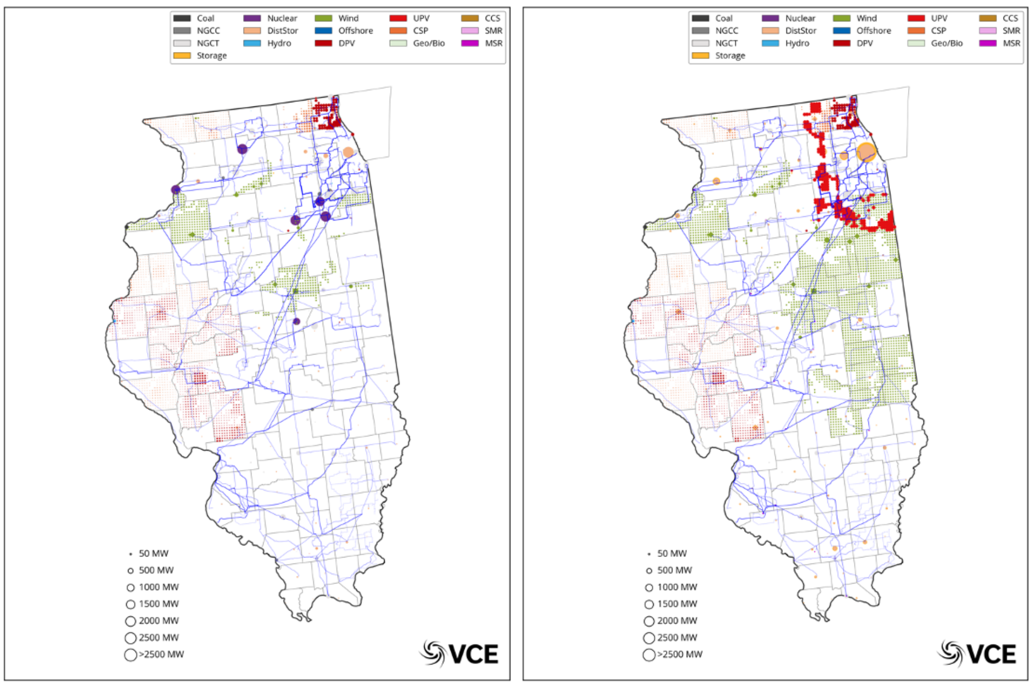

Figure 2.12: Installed generation layout in 2035 (left) and 2050 (right) at 3-km resolution along with transmission paths above 115 kV.

In 2035, almost all the solar on the grid is on the distribution grid with utility scale solar showing up in the last investment period. The community solar installations are sited in the northeast portion of the states in counties north of Cook county and in the northwest part of the state. While rooftop PV is installed in and around Cook county as they are the most populous parts of the state.

When making the siting decisions, the model takes into account several criteria to determine the optimal siting for generators. In addition to accounting for expected generation and distance from the load, the model ensures that generation is not sited in unsuitable locations. The model also ensures that the technical potential of each grid 3-km grid cell is not exceeded. The technical potential for the various VRE technologies in each grid cell is determined according to factors such as population, land cover, terrain slope, and others. In addition, each technology is limited by a maximum packing density to ensure that generators do not hamper performance of other generators in the grid cell, such as through wakes for wind turbines and excessive shading for solar panels.

Table A: Total jobs by county in Illinois over the investment periods in the "DER_wDG" scenario.

County	2020	2025	2030	2035	2040	2045	2050
Adams	102	112	166	214	271	359	972
Alexander	11	13	19	25	31	42	117
Bond	33	35	49	63	80	104	267
Boone	128	133	177	224	281	363	858
Brown	16	18	1173	489	496	506	569
Bureau	847	1295	1029	1131	1117	1141	1582
Calhoun	8	8	13	16	21	27	74
Carroll	23	25	38	49	62	82	222
Cass	17	19	3277	967	977	994	1119
Champaign	488	502	659	832	1044	1349	22111
Christian	675	394	95	121	153	201	519
Clark	28	28	44	57	72	95	239
Clay	117	65	139	186	240	292	300
Clinton	81	82	116	149	188	243	582
Coles	99	105	149	190	240	315	807
Cook	8850	9399	13719	17626	22294	29378	105907
Crawford	31	34	50	64	81	108	289
Cumberland	19	21	30	38	48	63	164
De Kalb	618	1330	773	859	935	1087	2277
De Witt	1050	1263	1139	1081	967	757	823
Douglas	36	38	53	68	86	115	297
Dupage	2150	2636	3026	3823	4803	6202	14467
Edgar	35	38	53	67	85	111	280
Edwards	12	13	18	23	29	39	100
Effingham	63	66	95	122	154	202	513
Fayette	54	49	76	98	125	160	345
Ford	316	495	435	492	963	3203	7452
Franklin	70	75	107	137	173	227	589
Fulton	282	190	10855	3211	3248	3301	3640
Gallatin	8	8	13	17	21	28	79
Greene	28	30	3350	1376	1389	1409	1536
Grundy	1341	1319	1343	1208	1089	798	1001
Hamilton	17	17	25	32	41	53	128
Hancock	35	38	4222	1736	1753	1780	1955
Hardin	6	7	11	14	17	23	62
Henderson	11	12	4075	1182	1189	1198	1265
Henry	621	943	772	6040	10756	10527	16246

Iroquois	451	759	616	681	680	13419	15742
Jackson	252	184	179	244	334	475	1011
Jasper	301	169	24	31	39	51	140
Jefferson	74	78	110	140	177	231	586
Jersey	51	53	72	91	115	149	359
Jo Daviess	32	36	54	2116	2134	2164	2371
Johnson	23	24	35	44	56	73	188
Kane	1348	1286	1844	2358	2979	3825	8440
Kankakee	451	661	652	767	858	1008	11226
Kendall	734	586	579	747	983	1310	2336
Knox	102	108	151	192	242	317	800
La Salle	2099	3147	2254	2108	1966	1680	68030
Lake Michigan	524	12552	1170	486	494	510	663
Lake	1896	5845	2540	28035	28764	29804	36050
Lawrence	44	49	78	102	130	175	503
Lee	678	1146	986	1142	3194	4947	5684
Livingston	870	1552	1226	1341	1315	1328	11189
Logan	41	453	448	528	575	684	1730
Macon	395	306	248	307	381	475	913
Macoupin	83	142	10715	4629	4774	5053	7475
Madison	623	522	653	810	1011	1205	1405
Marion	114	82	129	166	211	255	304
Marshall	23	25	37	47	60	80	213
Mason	245	142	2923	1199	1211	1230	1371
Massac	595	328	122	164	211	269	492
McDonough	59	129	5332	2502	2661	2975	5768
McHenry	906	1967	1046	16618	16849	17190	19113
McLean	1069	2171	9619	10423	12004	11768	18083
Menard	22	24	2838	1169	1182	1203	1353
Mercer	28	34	60	80	102	140	441
Monroe	69	68	97	124	156	202	469
Montgomery	522	309	88	114	144	191	513
Morgan	69	68	7487	3062	3086	3116	3253
Moultrie	29	37	83	113	146	205	686
Ogle	1503	1537	1685	1557	1442	1174	3542
Peoria	647	486	355	427	526	627	829
Perry	117	74	139	183	234	286	345
Piatt	175	97	202	269	347	419	399

Pike	35	33	5878	1716	1727	1739	1775
Pope	10	11	16	21	26	35	91
Pulaski	8	9	14	18	23	31	85
Putnam	156	97	47	65	84	120	424
Randolph	944	532	78	98	122	153	298
Richland	35	69	184	256	334	486	1828
Rock Island	1559	1529	1702	4457	5690	5569	8251
Saint Clair	1342	930	522	626	769	910	1145
Saline	36	81	236	330	431	632	2428
Sangamon	699	521	405	490	604	708	738
Schuyler	20	20	2096	859	867	877	926
Scott	43	28	1276	576	604	640	801
Shelby	277	140	151	216	306	413	334
Stark	208	333	296	338	350	391	857
Stephenson	213	317	374	3921	3996	4142	5394
Tazewell	1215	893	418	484	547	616	805
Union	30	48	111	153	198	285	1028
Vermilion	586	799	680	763	792	831	962
Wabash	17	20	34	45	58	79	240
Warren	33	34	5467	1607	1622	1644	1779
Washington	30	32	46	58	74	97	250
Wayne	32	33	46	59	74	96	228
White	27	38	86	118	153	216	745
Whiteside	98	257	795	1118	1463	2158	8403
Will	4502	4178	3961	4359	8027	9631	21459
Williamson	267	261	445	608	787	1111	9962
Winnebago	628	546	651	797	989	1177	9906
Woodford	350	497	399	439	444	453	497