Maximizing Cost Savings and Emission Reductions: Power Market Options for the Southeast United States

Prepared By:

Vibrant Clean Energy, LLC

Christopher T M Clack

Aditya Choukulkar

Brianna Coté

Sarah A McKee

Prepared For:

The American Council on Renewable Energy

Table of Contents

1 Summary .... - 3 -

2 Study Description .... - 6 -

2.1 WIS:dom®-P Model Setup .... - 8 -

3 Modeling Results .... - 12 -

3.1 System Costs, Retail Rates & Jobs .... - 12 -

3.2 Changes to Installed Capacity & Generation .... - 16 -

3.3 CO_2 Emissions & Pollutants .... - 20 -

3.4 Siting of Generators (3-km) .... - 23 -

1 Summary

Several utilities in the southeastern United States have proposed to form a framework named the Southeast Energy Exchange Market (SEEM) for trading energy among its members. This study uses the WIS:dom®-P optimization model to evaluate the SEEM framework against an optimal energy imbalance market (EIM) and regional transmission organization (RTO) over the proposed SEEM footprint. An additional scenario investigates the cost of decarbonizing the electricity sector in the SEEM footprint in the presence of an RTO. While the possible savings from the SEEM framework have been covered in other studies,[1] this study investigates the potential for further savings compared to the SEEM framework. The scenarios modeled in this study are listed below.

(1) **The Southeast Energy Exchange Market ("SEEM"):** In this scenario, SEEM is set up as described in the "Southeast Energy Exchange Market: Market Benefits and Non-Centralized Cost Evaluation" report.[1] Utilities within the SEEM footprint follow their capacity expansion plans as outlined in the latest Integrated Resource Plans (IRPs) released by the utilities.

(2) **An optimal Energy Imbalance Market over the SEEM footprint ("EIM"):** In this scenario, the utilities that are part of SEEM are modeled to create an optimal Energy Imbalance Market. WIS:dom-P models optimal capacity expansion through the least-cost combination of thermal and variable renewable energy generation, along with storage and transmission to meet load while maintaining recommended planning reserve margins and load-following reserves. While each of the balancing areas are required to meet their planning reserves individually within their footprint, they can use the energy transfers between the regions to count towards their planning reserve requirements.

(3) **Setting up a Regional Transmission Organization over the SEEM footprint ("RTO"):** In this scenario, the utilities that are part of SEEM set up an RTO among their members. Every balancing region undergoes optimal capacity expansion, ensuring the footprint as a whole meets their planning reserve requirements on their coincident load. Transmission costs are regionalized over the SEEM footprint.

(4) **Setting up a Regional Transmission Organization while decarbonizing the electricity sector ("RTO+Decarb"):** In this scenario, the utilities that are part of SEEM set up an RTO and have a goal to reduce electricity sector emissions by 98.5% by 2040. The remaining assumptions are similar to the previous scenario.

The "SEEM" scenario shows the lowest cost savings of all the scenarios modeled along with the lowest emission savings. The region would only reduce its emissions by 30% by 2040 if the capacity expansion plans outlined in the IRPs of the utilities in the SEEM footprint are followed. These modest emission reductions do not align with the announcements of 100% decarbonization by several major utilities in the region. For example, Duke Energy Carolinas and Duke Energy Progress reduce their emissions by 16.7% and 21% respectively by 2040,

[1] https://media.crai.com/wp-content/uploads/2020/12/23104641/CRA-SEEM-Report_Public-SNL.pdf

while Southern Company reduces its emissions by 15% by 2040. This is well short of their 100% decarbonization targets.

Results from the modeling show that the "RTO" scenario results in the largest cost savings, $119 billion, over the "SEEM" scenario cumulatively by 2040 (see Fig. 1.1 left panel). These savings come from optimal capacity expansion, which is coordinated by the member utilities with reserves planned over the coincident load in the region. Expanding transmission between the balancing regions and regionalizing the transmission costs (as a fraction of load) over each balancing region ensures that the installed generation is effectively utilized and costs are allocated fairly resulting in lower retail rates for customers.

The "RTO" scenario reduces annual emissions by 70% from 2020 levels. This is equivalent to a cumulative carbon dioxide emission reduction of 802 million metric tons (mmT) by 2040 (see Fig. 1.1 right panel). In this scenario, Duke Energy Carolinas and Duke Energy Progress reduce their emissions by 51.6% and 98.7% respectively, while Southern Company reduces its emissions by 85% by 2040. The formation of an RTO gives these utilities, which have pledged to 100% decarbonize by 2050, an economic pathway to achieve most of their goals. In addition, the "RTO" scenario creates about a million new jobs in the electricity sector by 2040.

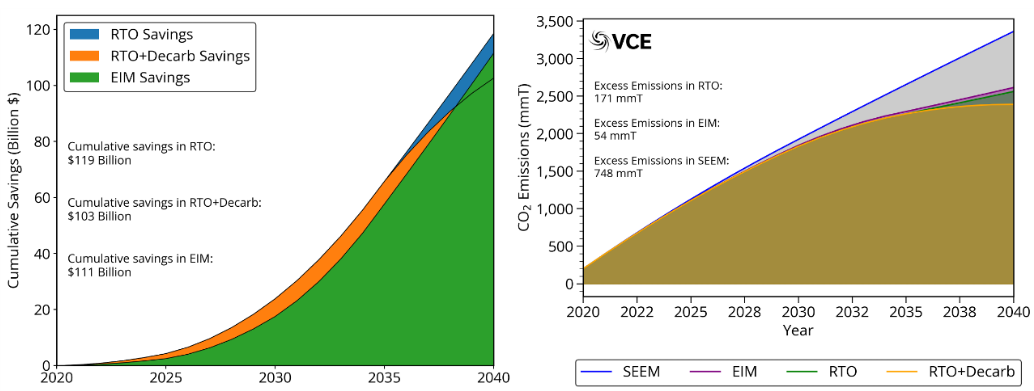

Figure 1.1: Cumulative savings in total system costs compared with the "SEEM" scenario (left) and cumulative carbon dioxide emissions in the scenarios modeled (right).

The "EIM" scenario results in cumulative cost savings of $111 billion by 2040 over the "SEEM" scenario. The savings in the "EIM" scenario come from optimal capacity expansion and utilizing the energy transfers between the balancing areas towards the planning reserve margin. The costs of new transmission build between the balancing areas is shared only between the connecting regions (similar to what is proposed in the Western EIM),[2] based on the ratio of their annual load. The "EIM" scenario also reduces emissions by 748 mmT cumulatively (or a 46.5% annual reduction) by 2040 compared to the "SEEM" scenario by replacing uneconomic fossil fuel generation with lower-cost, variable renewable energy (VRE) generation. In this scenario, Duke Energy Carolinas and Duke Energy Progress reduce their emissions by 36% and 63% respectively, while Southern Company reduces emissions by 85% by 2040. Therefore, while an optimal EIM helps reduce more emissions than the SEEM framework, it is not as effective as forming an RTO. In addition, the "EIM" scenario creates 819,000 new electric sector jobs by 2040.

[2] https://www.vibrantcleanenergy.com/wp-content/uploads/2020/10/CO-EIM-Options-Report.pdf

Setting up an RTO can present significant advantages when pursuing decarbonization goals. The coordinated capacity expansion aspect of RTOs and planning reserves over the whole RTO footprint enable the best sites for VRE generation to be developed irrespective of their location, ensuring utilities can share benefits of resources not in their territory. By contrast, an EIM limits balancing regions to resources available in their footprints to plan generation and reserves, leading to non-optimal capacity expansion decisions. In addition, RTOs facilitate transmission expansion through regionalizing the costs across the footprint. The coordinated transmission expansion in RTOs ensures that balancing regions can share energy effectively, reducing the need for excess capacity and optimally utilizing renewable generation by minimizing curtailment.

The "RTO+Decarb" scenario, which decarbonizes the SEEM region by 98.5%, results in the largest emission savings of 973 mmT of CO_2 cumulatively by 2040 compared to the "SEEM" scenario. The "RTO+Decarb" scenario also results in $103 billion of cumulative savings in total resource costs due to the advantages of setting up an RTO. The savings are slightly lower compared to the "RTO" scenario as the decarbonization goal entails over-building of variable renewable energy (VRE) and storage generation to supply the region with clean reliable energy. The "RTO+Decarb" scenario decarbonizes the electricity sector using only VRE generation and existing nuclear generation, as novel clean technologies are not allowed to be installed in these scenarios. As a result, the "RTO+Decarb" scenario has to deploy large amounts of VRE generation between 2035 and 2040 to meet the decarbonization goal. The "RTO+Decarb" scenario creates about 1.5 million new jobs in the electricity sector by 2040. This scenario demonstrates the actions needed and their positive public health and economic outcomes if utilities such as Dominion, Southern Company, and Duke want to meet their 100% decarbonization goals.

2 Study Description

Several utilities in the southeastern United States have proposed to form a framework named the Southeast Energy Exchange Market (SEEM) for trading energy among its members. The utilities covered by the SEEM footprint serve a total load of about 674 terrawatt hours (TWh) with a peak load of about 123 gigawatts (GW), along with over 189 GW of installed capacity in 2020. If this region were a Regional Transmission Organization (RTO), it would be almost as large as the PJM Interconnection. The Charles River Associates' "Southeast Energy Exchange Market: Market Benefits and Non-Centralized Cost Evaluation" report[3] (henceforth referred to as the CRA SEEM study) studies the potential for possible savings from the SEEM framework. While the SEEM framework provides an opportunity for this region to form a real-time energy market, the SEEM framework does not explicitly propose to establish one. In this study, the SEEM framework is evaluated against an optimal energy imbalance market and an RTO, and its impacts on system costs, retail rates, and emissions compared to the SEEM framework are determined.

To evaluate the SEEM framework, the American Council on Renewable Energy (ACORE) commissioned Vibrant Clean Energy (VCE®) to perform a detailed analysis of SEEM and compare it to forming an optimal Energy Imbalance Market (EIM) and an RTO over the same footprint as SEEM. The modeling was performed using 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 "moderate" 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[4] are used, except for natural gas prices which came from the CRA SEEM study.

To evaluate the benefits of SEEM, four scenarios are modeled using WIS:dom-P as described below:

(1) **The Southeast Energy Exchange Market ("SEEM"):** In this scenario, SEEM is set up as described in the CRA SEEM. The various utilities that are part of SEEM are modeled to follow their capacity expansion as outlined in the latest Integrated Resource Plans (IRPs) released by the utilities. The utilities for which IRPs are not available are modeled to undergo optimal capacity expansion as determined by WIS:dom-P. The transmission between each balancing area is not allowed to expand (but transmission within each balancing area is allowed to expand), and WIS:dom-P does not co-optimize the distribution system with the utility grid. Each balancing area within the SEEM footprint is required to meet its planning reserve requirements individually.

(2) **An optimal Energy Imbalance Market over the SEEM footprint ("EIM"):** In this scenario, the utilities that are part of SEEM are modeled to create an optimal EIM. Each

[3] https://media.crai.com/wp-content/uploads/2020/12/23104641/CRA-SEEM-Report_Public-SNL.pdf

[4] 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

of the balancing areas within the SEEM undergo optimal capacity expansion. Transmission is allowed to expand between the balancing areas, and the new transmission costs between connected areas is divided based on their load ratio. While each of the balancing areas are required to meet their planning reserves individually, they can use the energy transfers between the regions to count towards their planning reserve requirements. For example, each utility will need to ensure that whatever generation it owns is able to meet its reserve requirements, but it can count the energy exchanges with its neighbors towards its planning reserves. The transmission between the balancing areas is allowed to expand and WIS:dom-P co-optimizes the distribution system with the utility-scale generation.

(3) **Setting up a Regional Transmission Organization over the SEEM footprint ("RTO"):** In this scenario, the utilities that are part of SEEM set up an RTO among its members. As a result of forming an RTO, the wheeling charges for energy transfers across the balancing areas are eliminated. Every balancing region undergoes optimal capacity expansion, ensuring the footprint as a whole meets their planning reserve requirements on their coincident load. Transmission between the balancing areas is allowed to expand and the transmission costs are regionalized among the members based on the ratio of the load to the total load in the footprint.

(4) **Setting up a Regional Transmission Organization while decarbonizing the electricity sector ("RTO+Decarb"):** In this scenario, the utilities that are part of SEEM set up an RTO and have a goal to decarbonize the electricity sector by 98.5% by 2040. Similar to the previous scenario, wheeling charges are eliminated, transmission costs are regionalized, and the region as a whole coordinates capacity expansion and meets planning reserves on the coincident load.

The scenarios are initialized and calibrated with 2020 generator, generation, and transmission topology datasets. The scenarios then determine a pathway from 2020 through 2040 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 has 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.[5]

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

2.1 WIS:dom®-P Model Setup

To investigate the various market options for the southeast United States, WIS:dom-P modeled the SEEM footprint with its existing generator topology, transmission, and weather inputs obtained from National Oceanic and Atmospheric Administration (NOAA) High Resolution Rapid Refresh (HRRR) model[6] at 3-km horizontal resolution and 5-minute time resolution. The average fixed latitude tilt solar capacity factors and 100-m hub-height wind capacity factors calculated from the HRRR model output over the model domain are shown in Fig. 2.1. Figure 2.1 (left panel) shows the consistently higher solar resource in Alabama, Georgia, North Carolina, and South Carolina. Higher solar capacity factors are also observed in the northwestern corner of Missouri and in the pockets of Oklahoma and Iowa that SEEM covers. The wind resource in parts of Missouri, Iowa, and Oklahoma is found to be superior to the rest of the SEEM footprint. Pockets along the Appalachian Mountains also show higher wind capacity factors. Wind capacity factors increase towards the Eastern Seaboard, offshore and closer to the Mississippi River Valley.

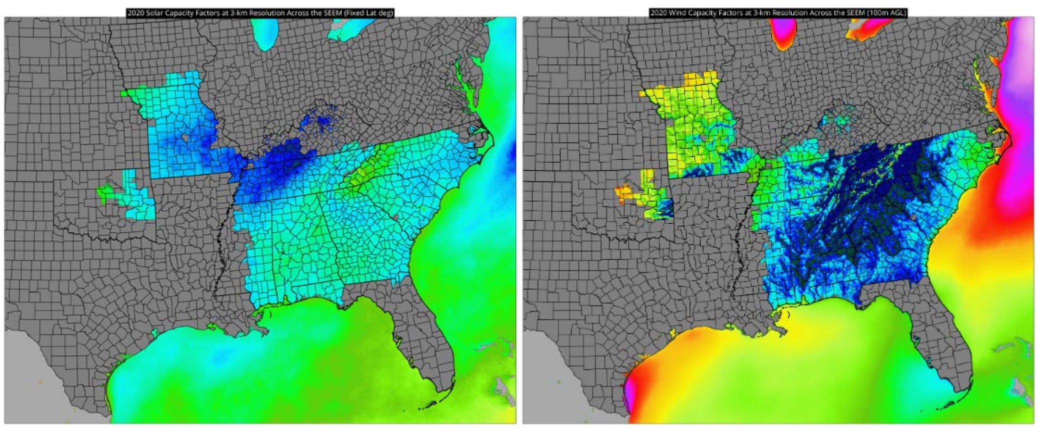

Figure 2.1: Average capacity factors for fixed latitude tilt solar (left) and 100m hub-height wind (right) over the SEEM footprint calculated from the HRRR model outputs.

The initialized generator dataset is created by aligning the Energy Information Administration Form 860 (EIA-860) dataset[7] with the 3-km HRRR model grid. The existing generator topology over the SEEM footprint in 2020, along with existing transmission at 3-km resolution, is shown in Figure 2.2. The SEEM market is divided into 9 balancing authorities which span 11 states. These are shown in Table 2.1. Each authority is simulated with all its generators, demands, and transmission pathways within its footprint and interconnections to the rest of the regions. The latest available Integrated Resource Plan (IRP) information for several major utilities in the Southeast states (where available) were incorporated as inputs into this study. Table 2.1 also summarizes where IRP information was used.

[6] https://rapidrefresh.noaa.gov/hrrr/
[7] https://www.eia.gov/electricity/data/eia860/

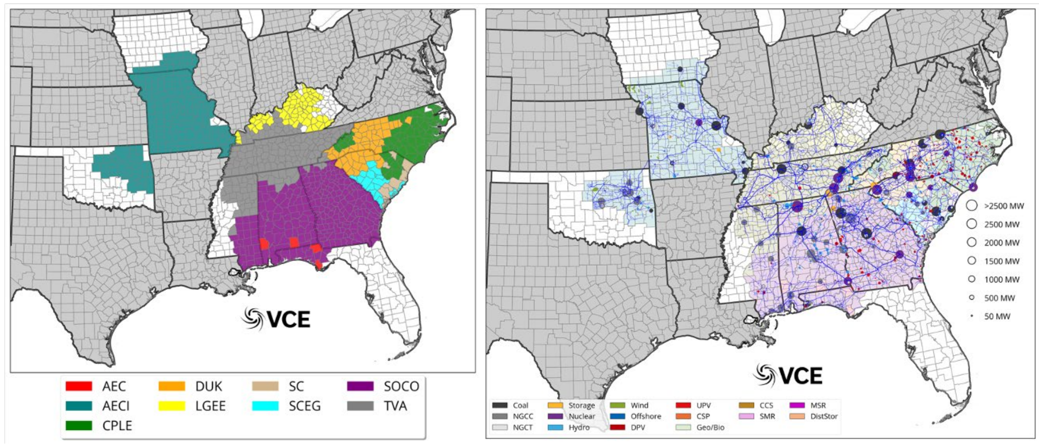

Figure 2.2: The various balancing areas within the SEEM footprint modeled by WIS:dom-P.

The inputs incorporated from the IRP data included capacity changes (generator resource buildouts or specific generator retirements), load growth expectations and forecasts, peak loads, DSM, and energy efficiency programs. These inputs remained the same for all scenarios modeled in this study. The IRP data provided a balancing authority-level granularity input dataset across the Southeast. The footprint of that balancing authority may extend across states' boundaries. Where IRP information was not available, the EIA 861 data was utilized to create the existing generator dataset.

Balancing Authority	CRA Study Entity	Acronym	WIS:dom Code	States Covered	IRP Used
PowerSouth Energy Cooperative		AEC	57	Alabama, Florida	No
Associated Electric Cooperative, Inc.	Associated Electric Cooperative Inc., Central Electric Power Cooperative	AECI	58	Iowa, Missouri, Oklahoma	No
Duke Energy Progress	Duke Energy Progress, NC Electric Membership Corporation	CPLE	59	North Carolina, South Carolina, Tennessee	Yes
Duke Energy Carolinas	ElectriCities of North Carolina, Inc., Duke Energy Carolinas, NC Electric Membership Corporation	DUK	60	Georgia, North Carolina, South Carolina	Yes
Louisville Gas and Electric Company and Kentucky Utilities	LG&E and KU Energy	LGEE	61	Kentucky, Tennessee	No
South Carolina Public Service Authority	Santee Cooper	SC	62	South Carolina	Yes
South Carolina Electric & Gas Company	Dominion Energy South Carolina	SCEG	63	South Carolina	Yes
Southern Company Services, Inc.	Dalton Utilities, Georgia System Operations Corporation, Georgia Transmission Corporation, MEAG Power, Oglethorpe Power Corporation, Southern Company	SOCO	64	Alabama, Florida, Georgia, Mississippi	Yes
Tennessee Valley Authority	Tennessee Valley Authority	TVA	65	Alabama, Georgia, Kentucky, Mississippi, North Carolina, Tennessee	Yes

Table 2.1: WIS:dom-P Balancing authority list modeled for SEEM. The WIS:dom-P acronym and ID is provided.

The CRA SEEM study was also utilized to prepare and compare the VCE inputs. VCE used this study to define the balancing authorities modeled. A few of the entities modeled in the CRA study have both ownership and spatial overlap that VCE combined into one entity. An example of this is MEAG Power and Southern Company (Georgia Power, in particular) which co-own several generating assets. These were modeled under Southern Company in the

VCE study. For a complete list of utility comparison, please see Table 2.1. Further, the natural gas fuel forecasts were utilized from this study in the VCE data as well.

WIS:dom-P resolves the transmission topology of the modeled grid down to each 69-kV substation resolution. The transmission topology can be aggregated to create a reduced-form (county- or state- level) as required for each model simulation, as shown in Fig. 2.3. WIS:dom-P utilizes the state- and county- level reduced-form transmission systems. The county-level is for the spur lines connections to generation sites, while the state-level is for the bulk transmission.

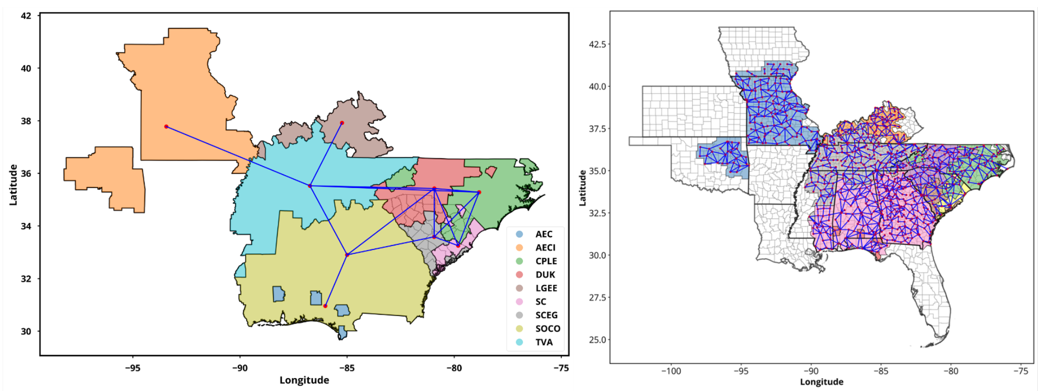

Figure 2.3: Inter-region bulk transmission and county level transmission topology for the SEEM region.

A unique feature of WIS:dom-P is its ability to resolve the utility-scale electricity grid with detailed granularity over large spatial domains. This unique feature has recently been expanded to allow for the model to co-optimize and coordinate the utility grid with the distribution grid. The tractability of such a co-optimization requires parameterization of all the distribution-level grid topology and infrastructure. Therefore, WIS:dom-P disaggregates the DER technologies, but aggregates the distribution lines and other infrastructure as an interface (or "*grid edge*") that electricity must pass across. The model does assign costs and can compute inferred capacities and distances from the solutions, but cannot (with current computation power) resolve explicitly all the infrastructure in a disaggregated manner.

The main components of deriving the utility-distribution (U-D) interface are:

a. Utility-observed peak distribution demand;
b. Utility-observed peak distribution generation;
c. Utility-observed distribution electricity consumption.

The definition of "*Utility-observed*" is the appearance of the metric at 69-kV transmission substation or above. Below the 69-kV, the model is implicitly solving with combinations of DERs, and what remains is exposed to the utility-scale grid at the substation. Figure 2.4 is a schematic of how WIS:dom-P represents the U-D interface and Fig. 2.5 displays an illustration of how the distribution co-optimization results in two distinct concerts playing out: DERs coordinating to reshape the demand exposed to the utility-scale (*load shifting to supply*) and utility-scale generation and transmission coordinating to serve the demand that appears at the 69-kV substation (*supply shifting to load*). Further details of the distribution co-optimization are available in Section 1.9 of the WIS:dom-P technical documentation.

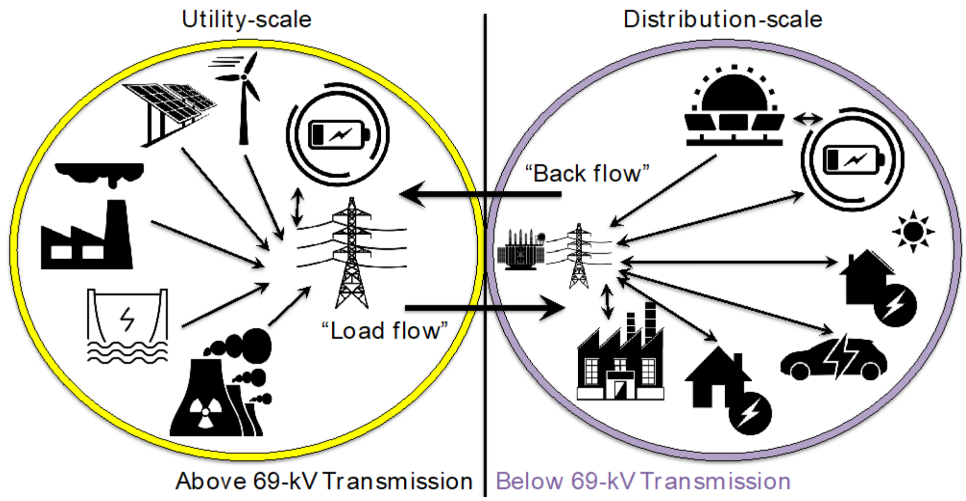

Figure 2.4: A schematic picture of the U-D interface within the WIS:dom-P modeling platform.

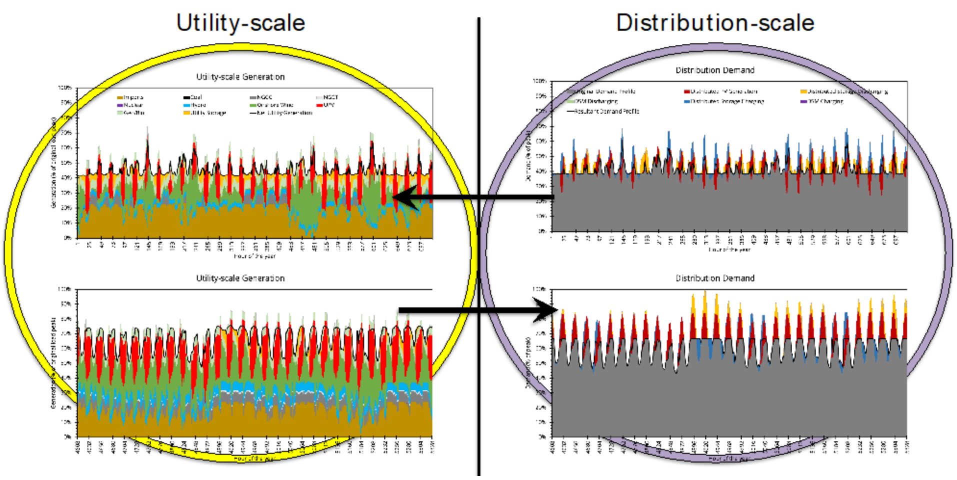

Figure 2.5: Example coordination at the utility- and distribution-scale within the WIS:dom-P model.

3 Modeling Results

3.1 System Costs, Retail Rates & Jobs

The evolution of the total resource cost in the four scenarios modeled along with the average retail rates over the SEEM region is shown in Fig. 3.1. The total resource cost in the "SEEM" scenario reduces from approximately $64.7 billion in 2020 to $53.1 billion in 2040. The "EIM" scenario, which performs optimal capacity expansion and counts the energy transfers between the balancing areas towards the planning reserve, reduces its total resource cost to $42.1 billion by 2040 as a result of the more efficient capacity planning. In the "RTO" scenario, where all the balancing regions within the SEEM footprint form an RTO and coordinate their capacity expansion and transmission planning, costs reduce faster than the "EIM" scenario until 2030, after which the "EIM" scenario catches up in terms of annual cost savings. Finally, the "RTO+Decarb" scenario follows a similar path in terms of total resource costs as the "RTO" scenario until 2035, after which the "RTO+Decarb" scenario sees an increase in costs as it races to nearly decarbonize the electricity sector by 2040.

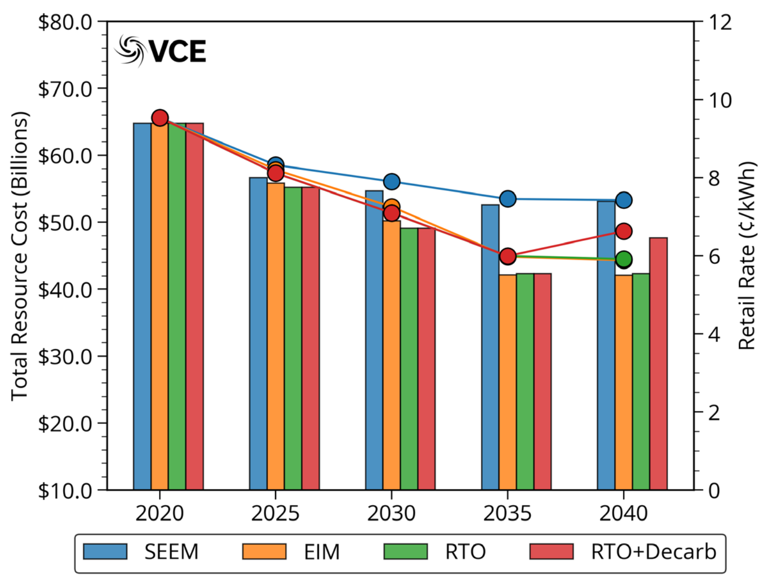

Figure 3.1: Total system cost (bars) and retail rates (solid lines) over the SEEM region for the scenarios modeled.

The cumulative savings in total resource costs with respect to the "SEEM" scenario is shown in Fig. 3.2. The "EIM" scenario accumulates savings at a slightly slower pace between 2020 and 2030 compared to the "RTO" and "RTO+Decarb" scenarios, as it retires the fossil generation slower than the "RTO" scenario and therefore results in higher system costs. After 2030, the "EIM" scenario speeds up retirements of fossil generation to catch up to the "RTO" and "RTO+Decarb" scenarios and hence accumulates savings at a faster rate to reach $111 billion in cumulative savings by 2040.

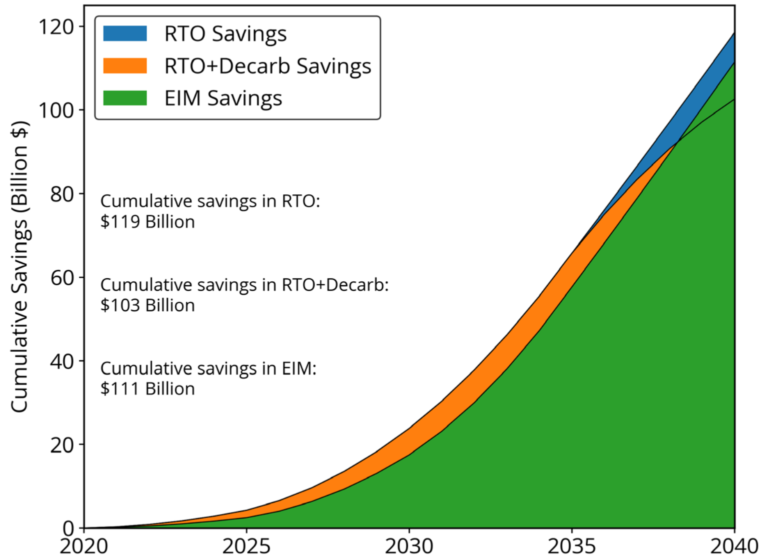

Figure 3.2: Cumulative savings for the "EIM", "RTO", and "RTO+Decarb" scenarios compared to the "SEEM" scenario.

The "RTO" and the "RTO+Decarb" scenarios accumulate savings with respect to the "SEEM" scenario at similar rates until 2035, as forming an RTO brings not only economic benefits through more efficient capacity expansion and transmission planning, but also brings about significant emission savings (about 802 million metric tons cumulatively by 2050). In the "RTO" scenario, the cumulative cost savings add up to $119 billion by 2040. Most of these savings are passed on to customers through lower retail rates. In the "EIM" scenario, the cumulative savings in retail spending is $105 billion, while in the "RTO" scenario it is $111 billion cumulatively by 2040. These cost savings from forming an RTO are found to be of similar order of magnitude to a previous study of the southeast region.[8]

After 2035, the "RTO+Decarb" scenario deploys a large amount of variable renewable generation (VRE) in order to decarbonize the electricity sector by 98.5% by 2040. In all scenarios modeled, novel technologies such as carbon capture and sequestration (CCS), Molten Salt Reactors, and Small Modular Reactors are not allowed to be installed. As a result, the "RTO+Decarb" scenario has to completely rely on VRE generation and storage to decarbonize the electricity sector resulting in overbuilding of VRE generation between 2035 and 2040. Therefore, the cost savings in the "RTO+Decarb" scenario slow down after 2035 and result in cumulative savings of $103 billion by 2040. The cumulative savings in retail spending in the "RTO+Decarb" scenario due to the reduced retail rates is $97 billion by 2040.

The cost per kWh of delivered energy broken out by industry in the electricity sector is shown in Fig. 3.3. In 2020, fossil generation makes the largest contribution to the cost of electricity followed by the distribution system costs. Over the investment periods, the various scenarios retire fossil generation at different rates. The "SEEM" scenario, which keeps the most amount of fossil generation on the grid, has the highest cost of electricity with 35% of the cost coming from fossil generation. The "EIM" and "RTO" scenarios are able

[8] https://vibrantcleanenergy.com/wp-content/uploads/2020/08/SERTO_WISdomP_VCE-EI.pdf

to reduce costs faster by retiring the uneconomic fossil fuel generation and replacing it with lower cost VRE generation. In the "RTO+Decarb" scenario, there is an increase in the cost of electricity after 2035 due to because of the large installation of VRE generation to decarbonize the electricity sector. However, even with the increase in costs in 2040, the cost of energy in the "RTO+Decarb" scenario remains lower than the "SEEM" scenario in 2040 due to the savings from more efficient use of the installed capacity.

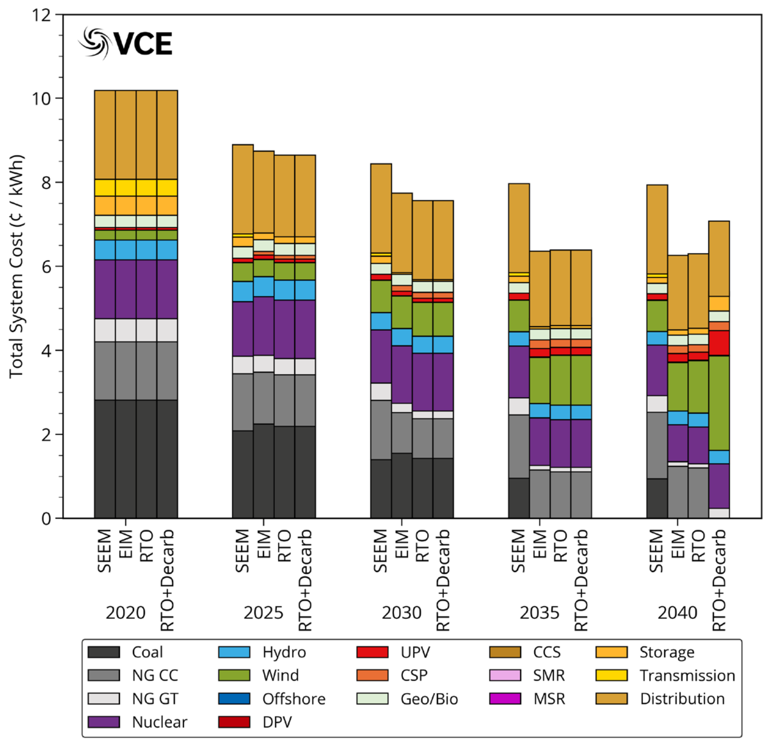

Figure 3.3: Contribution to total system cost per kWh load from each energy system sector in the "scenarios modeled for the SEEM footprint.

The full-time equivalent electricity sector jobs supported by the installed capacities over the investment periods for the various scenarios modeled is shown in Fig. 3.4. The transmission industry is the largest employer in all scenarios modeled. The thermal generators make up the smallest fraction of the total electricity sector jobs. The "SEEM" scenario creates the smallest number of new jobs as it maintains a large portion of its thermal generation and creates very little new VRE generation or storage. In the "EIM" scenario, by 2040, more than 50% of the jobs come from VRE and storage industries.

The "EIM" scenario almost doubles the total number of electricity sector jobs, with 664,000 jobs in 2020 growing to 1.5 million full-time jobs by 2040. The "RTO" scenario creates about 200,000 additional jobs compared to the "EIM" scenario with 1.7 million jobs in 2040. The "RTO+Decarb" scenario creates the most jobs with 2.14 million jobs by 2040 due to the significantly higher VRE installations in this scenario to meet the electric sector decarbonization constraint.

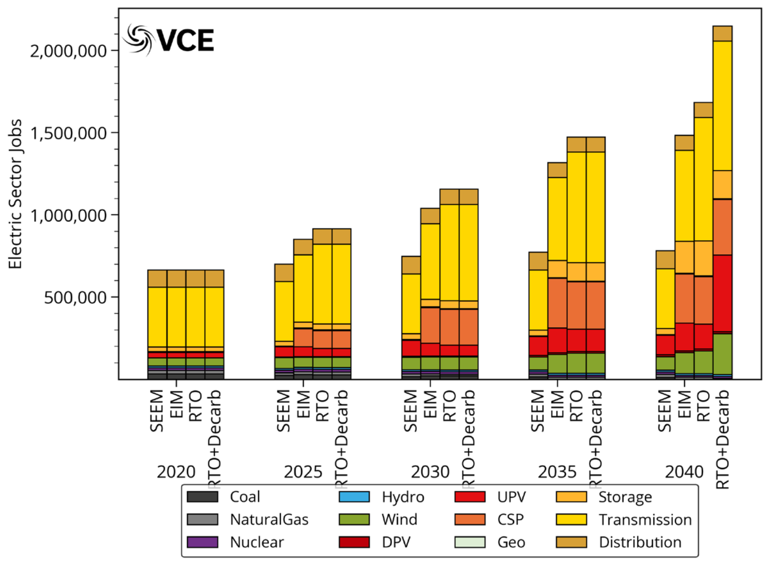

Figure 3.4: Full-time equivalent jobs created in the electricity sector by industry in the scenarios modeled.

3.2 Changes to Installed Capacity & Generation

The evolution of the installed capacities and generation in the various scenarios over the investment periods is shown in Fig. 3.5. As seen from Fig. 3.5, in all scenarios except the "SEEM" scenario, coal generation is retired by 2035 due to it being uneconomic compared to the new, lowest-cost VRE generation. In addition to the coal retirements, all scenarios except the "SEEM" scenario also retire a significant amount of their older natural gas combined cycle generation for economic reasons.

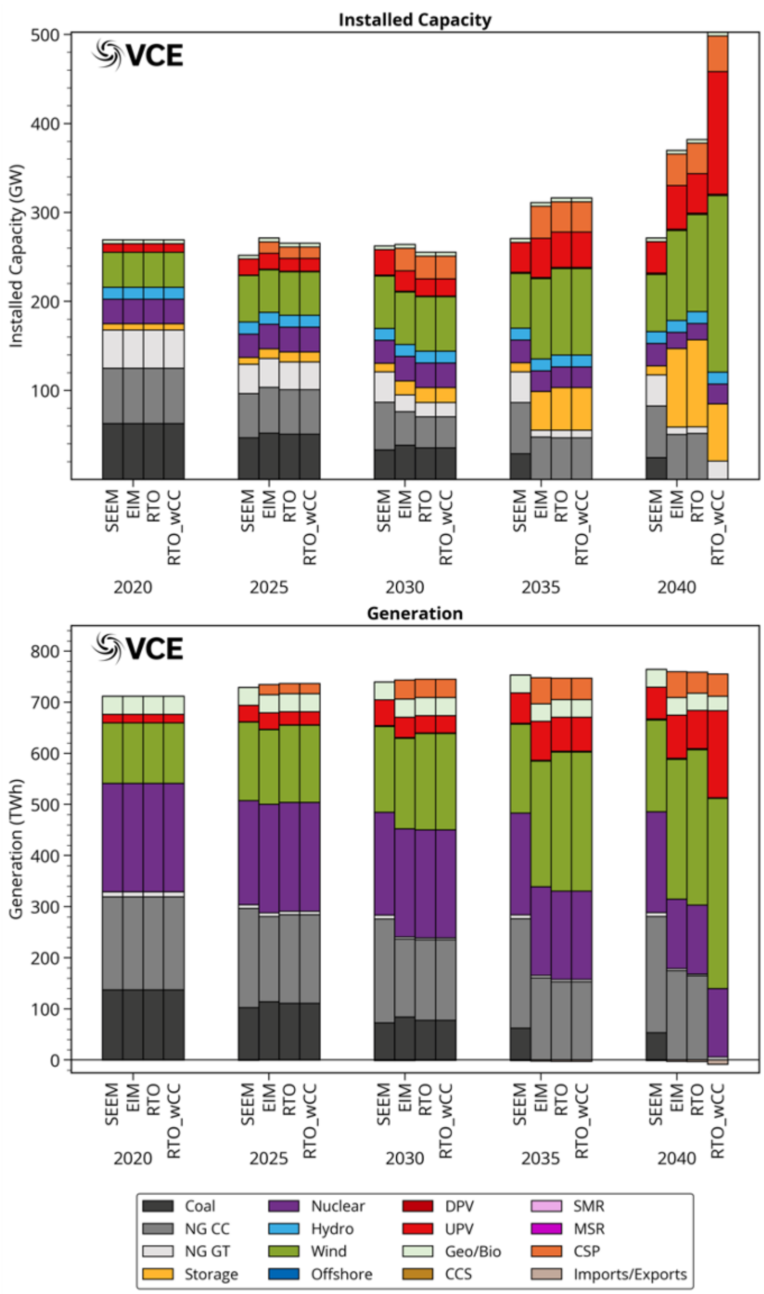

Figure 3.5: WIS:dom-P installed capacities (top) and generation (bottom) for the scenarios modeled.

As a result of the retirement of the coal and gas generation and replacement with VRE generation, all scenarios apart from the "SEEM" scenario significantly reduce emissions and costs. Another way the "EIM" and "RTO" scenarios reduce costs is by planning the capacity expansion efficiently, such that the installed generation is effectively utilized and there is minimal excess capacity on the grid. One way to quantify the excess capacity on the grid is through a reserve margin as a percentage of coincident load in the region. The reserve margin as a fraction of the coincident load in 2020 is 85% and drops to 40% by 2040 in the "SEEM" scenario. This high reserve margin is due to each balancing area planning their reserves independently without considering the available transmission capacity.

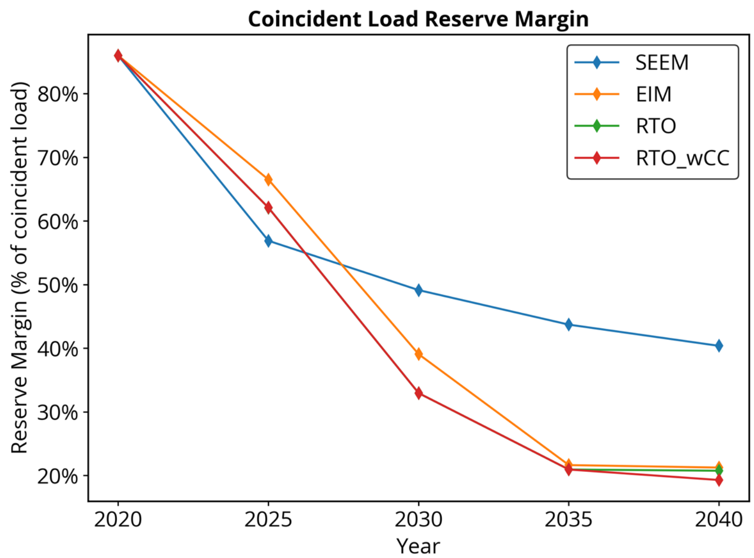

Figure 3.6: Reserve margin calculated as a fraction of coincident load over the SEEM footprint for the various scenarios modeled.

In the "EIM" scenario, where the individual balancing regions plan their capacity to ensure they meet their planning reserve margins individually but count the energy transfers between the regions towards their planning reserve, they are able to more efficiently utilize installed capacity and have a reserve margin of 21% of the coincident load by 2040. Counting energy transfers towards planning reserves (similar to that proposed for the Western EIM[9]) ensures that the advantage of the EIM framework is fully utilized.

In the "RTO" scenario, the reserve margins drop faster than the "EIM" scenario as the balancing areas in the SEEM footprint coordinate their capacity expansion to ensure the best site for VRE generation is developed irrespective of which balancing area territory it is located in. By 2040, the "EIM" and the two RTO scenarios end up with very similar reserve margins, but the RTO scenarios are able to bring in greater efficiencies earlier resulting in more savings.

In all scenarios, except the "SEEM" scenario, WIS:dom-P co-optimizes the distribution system with the utility grid. As a result, in the co-optimized scenarios, the model installs distributed storage to ensure more effective use of the DER resources. Figure 3.7 shows the

[9] https://www.westerneim.com/Documents/Briefing-Policy-Initiatives-Roadmap-Annual-Plan-Presentation-Jan20_2021.pdf

utility-scale and distributed storage installed in the various scenarios modeled. In the "EIM" and "RTO" scenarios, most of the storage installed is in the distribution system to more effectively utilize the distributed PV and community solar installed in these scenarios. The storage installed on the distribution system is of a shorter duration, while storage installed on the utility grid is of longer duration. This is due to the fact that in the distribution system the generation is all solar, and higher capacity and shorter duration storage is more effective at absorbing the excess solar generation and discharging during periods of peak demand to shave load peaks. While on the utility grid, longer duration storage is more effective to absorb the excess wind generation and to help meet load during the longer lulls observed in wind generation.

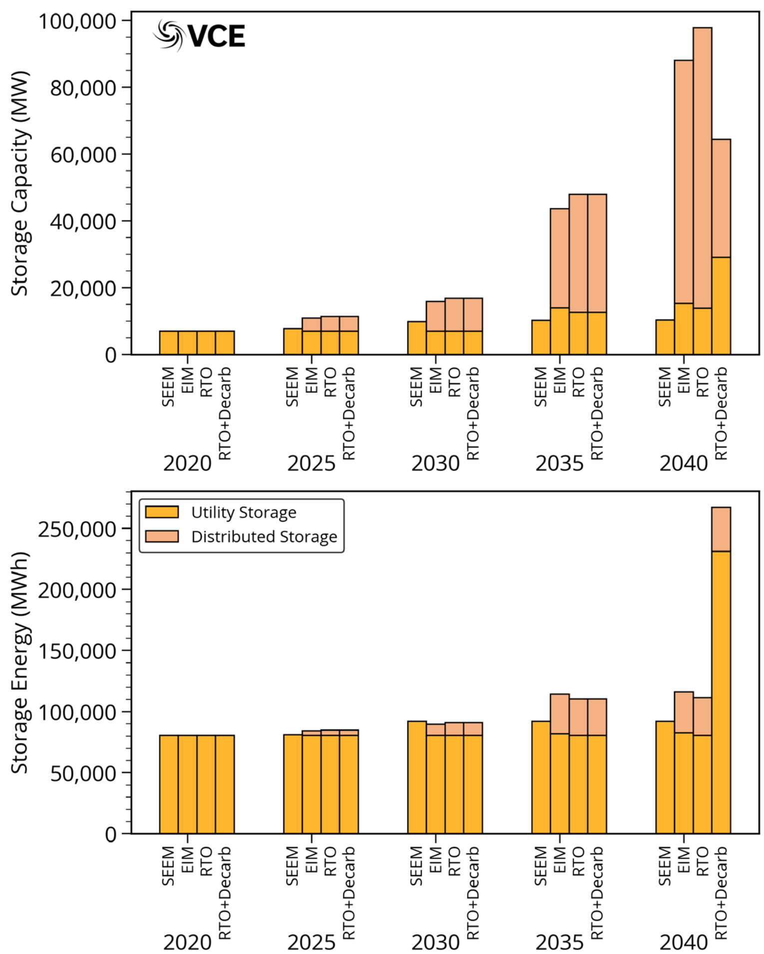

Figure 3.7: Utility storage and distributed storage installed in each investment period for the scenarios modeled.

In the "RTO+Decarb" scenario, less distributed storage capacity is installed at very low duration, while a higher capacity and longer duration storage is installed on the utility grid compared to the other scenarios. The higher storage capacity on the utility grid is to absorb the excess utility solar generation, while the longer duration ensures that load is met during the long periods of lulls observed in the wind generation.

The solar generation installed in the scenarios modeled is shown in Fig. 3.8. As seen from Fig. 3.8, the "SEEM" scenario installs very little distributed solar and all the new solar installed is on the utility grid. In the "EIM" and "RTO" scenarios, similar levels of utility-scale solar is installed, but there is a significant (32 GW) amount of community solar added to the grid as well. The community solar generation works along with the distributed storage to shave load peaks within the distribution system, ensuring that the load seen by the utility grid has a higher load factor which leads to a more efficient operation. In the "RTO+Decarb" scenario, significantly more utility-scale solar is installed with similar levels of community solar as in the "EIM" and "RTO" scenarios. The "RTO+Decarb" scenario installs more utility-scale generation to ensure efficient energy transfers between the balancing areas, leading to more optimal use of the installed VRE generation.

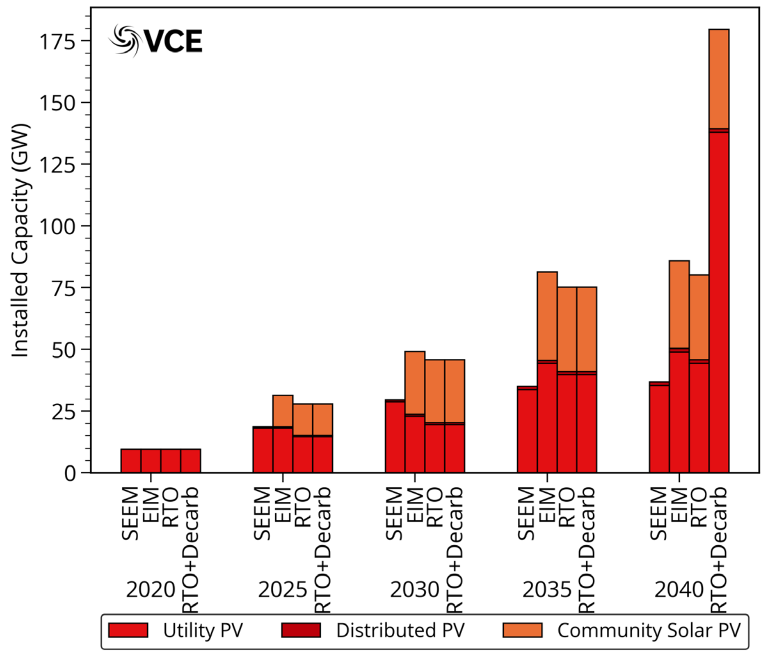

Figure 3.8: Utility PV, Distributed PV and Community PV installed over the investment periods in the scenarios modeled.

3.3 CO_2 Emissions & Pollutants

The cumulative carbon dioxide emissions from the electricity sector for the scenarios modeled is shown in Fig. 3.9. In the "SEEM" scenario, the carbon dioxide emissions are seen to accumulate almost linearly as a result of keeping a significant amount of fossil fuel generation on the grid. By 2030, the "SEEM" scenario reduces emissions by only 25% compared to 2020 levels, and by 2040 the emissions are reduced by 30% compared to 2020 levels. As a result, between 2020 and 2040, the "SEEM" scenario emits 3,362 million metric tons (mmT) of CO_2 from the electricity sector alone.

The results from the "SEEM" scenario show that the current IRPs of utilities such as Southern Company, Dominion and Duke will not enable achievement of their 100% decarbonization announcements by a significant margin. For example, Duke Energy Carolinas and Duke Energy Progress reduce their emissions by 16.7% and 21% respectively by 2040 in the "SEEM" scenario, while Southern Company reduces its emissions by 15% by 2040.

The "EIM" scenario significantly reduces emissions compared to the "SEEM" scenario, with 34% emissions reduction by 2030 and 67% by 2040 compared to 2020 levels. In this scenario, Duke Energy Carolinas and Duke Energy Progress reduce their emissions by 36% and 63% respectively, while Southern Company reduces emissions 85% by 2040. Over the modeled region, the "EIM" scenario results in reducing CO_2 emissions by 748 mmT cumulatively by 2040. The "EIM" scenario brings about this emission reduction while saving $111 billion in total system costs compared to the "SEEM" scenario.

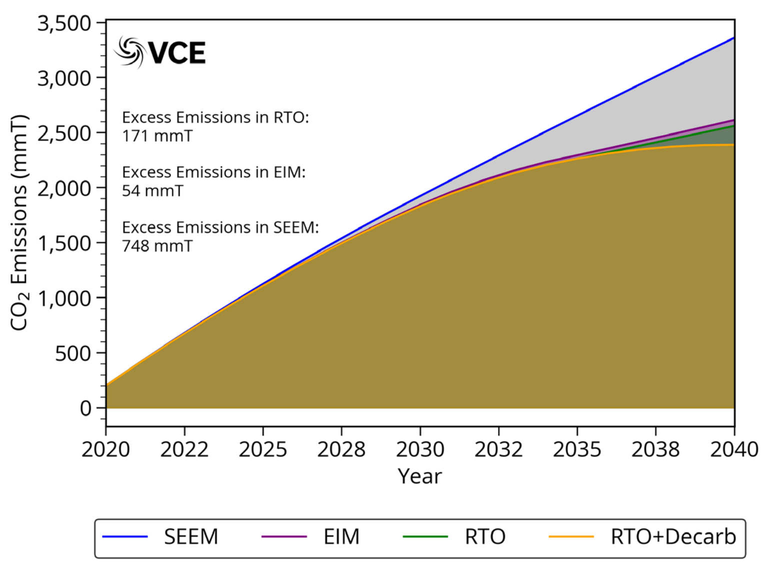

Figure 3.9: Cumulative electric sector emissions in the scenarios modeled.

The "RTO" scenario brings about additional emission reductions, resulting in a 70% reduction in CO_2 emissions by 2040 compared to 2020 levels. This reduction is an additional 54 mmT of CO_2 emissions compared to the "EIM" scenario. Therefore, the "RTO" scenario reduces CO_2 emissions by 802 mmT while saving $119 billion in total system costs. In this scenario, Duke Energy Carolinas and Duke Energy Progress reduce their emissions by 51.6% and 98.7% respectively, while Southern Company reduces its emissions 85% by 2040. This shows that setting up an RTO pays off financially, as well as resulting in reduced climate impacts, improved local air quality, and greater progress toward decarbonization goals. It is to be noted these emission reductions come about without any emission constraints, showing that setting up an RTO is the most economical way to maximize emission reductions. Therefore, it is economic to make significant reductions in greenhouse gas emissions in the electricity sector in the southeast United States.

The "RTO+Decarb" scenario, which aims to decarbonize the electricity sector by 98.5% by 2040, results in a further CO_2 savings of 171 mmT compared to the "RTO" scenario. The "RTO+Decarb" scenario thus has a cumulative CO_2 savings of 973 mmT compared to the "SEEM" scenario by 2040, which comes with cost savings of $103 billion cumulatively by 2040. Therefore, the best way for utilities in the SEEM footprint to decarbonize the electricity sector while saving customers money is through forming an RTO.

The criteria air pollutants tracked by WIS:dom-P in the electricity sector for the scenarios modeled is shown in Fig. 3.10. In the "SEEM" scenario, due to the presence of fossil fuel generation on the grid, significant SO_2, NO_x, CH_4 emissions remain. In the "EIM" and "RTO" scenarios, the SO_2 emissions are completely eliminated by 2035 as a result of retiring all the coal generation, while some NO_x emissions remain due to presence of some gas generation on the grid. However, these scenarios result in significant improvements to local air quality. In the "RTO+Decarb" scenario, the remaining NO_x emissions are also eliminated as the electricity sector almost completely decarbonizes. Therefore, creating an EIM or an RTO can also improve health outcomes for residents in the SEEM footprint through improved local air quality.

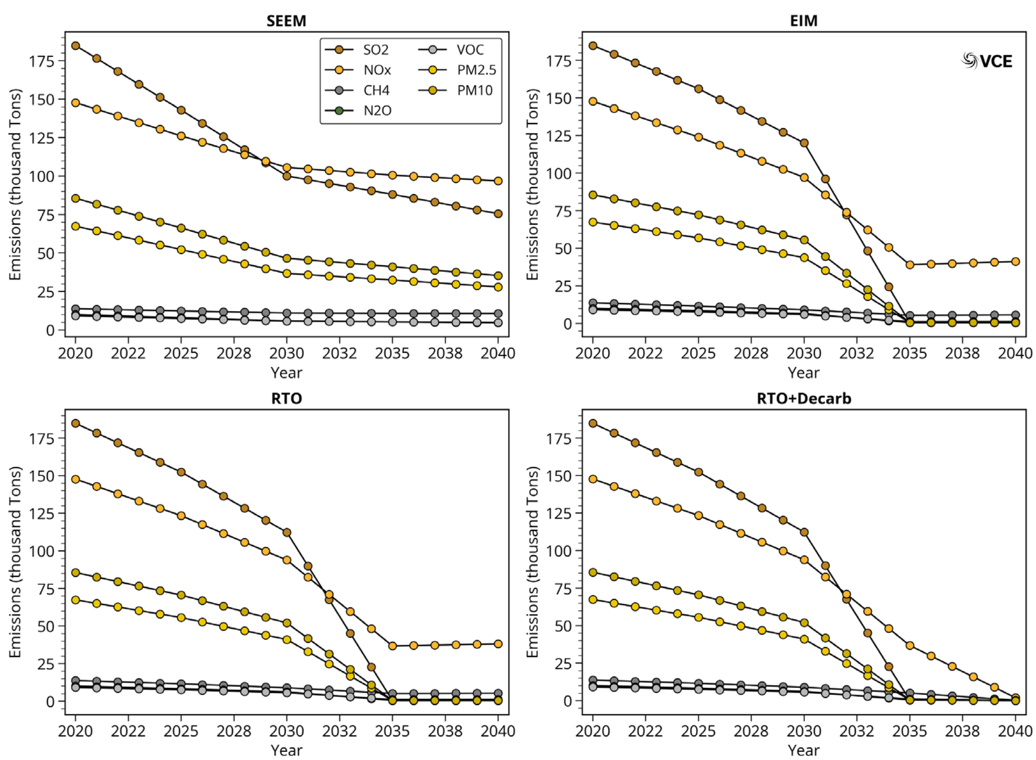

Figure 3.10: Emissions from other criteria pollutants tracked by WIS:dom-P.

3.4 Siting of Generators (3-km)

WIS:dom-P uses weather datasets spanning multiple years at 3-km spatial resolution 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 in 2040 for the scenarios modeled, is shown in Figure 3.11. The “SEEM” scenario, which does not install significant VRE generation, only has some wind generation in the AECI region around Missouri, Oklahoma, and Iowa. Solar generation is spread over the rest of the balancing areas. In the “EIM” and “RTO” scenarios significantly more wind generation is installed in the AECI region, along with significant wind installation in the CPLE (predominantly Duke Energy Progress) and SOCO (Southern Company) regions. This shows up, in particular, with wind installations in North Carolina and along the southern portions of Alabama and Georgia. Solar generation, including community solar, is spread across almost all regions which provides complementary production to the wind generation. There was no offshore wind selected in these scenarios which speaks to the cost of the offshore technology versus what is available on land to install and optimize.

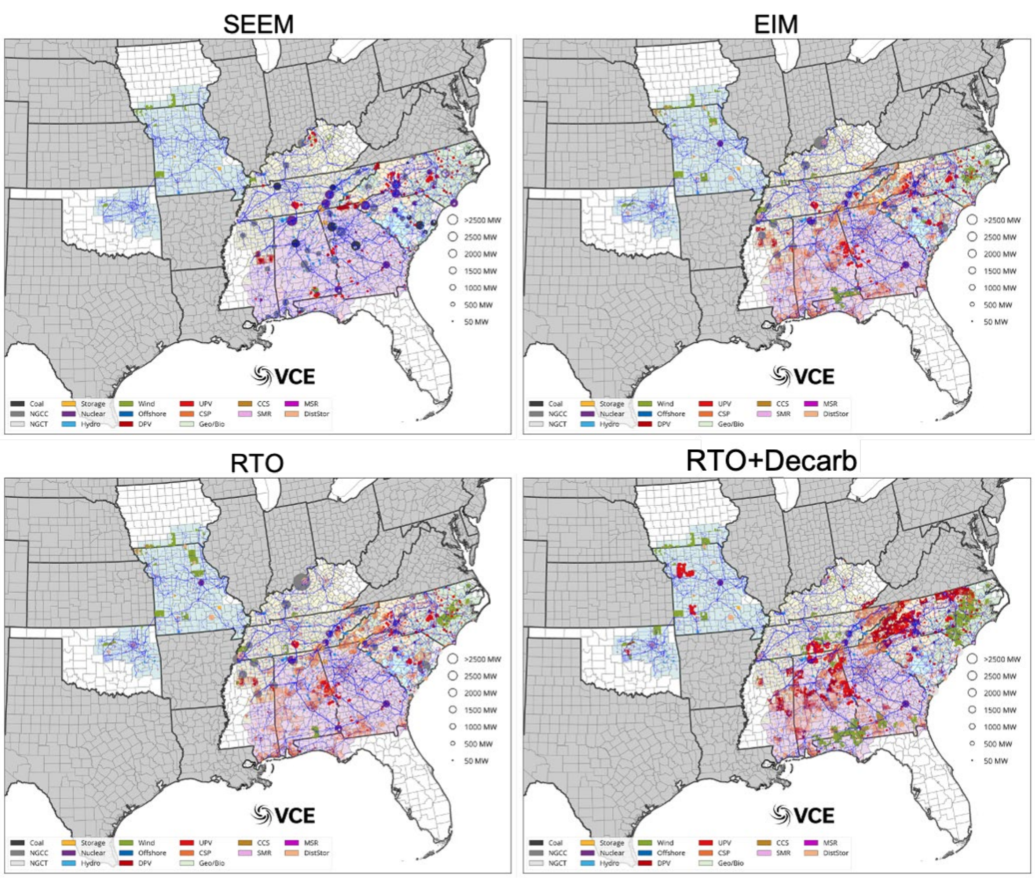

Figure 3.11: Installed generation layout in 2040 for the “SEEM” scenario (top left), “EIM” scenario (top right), “RTO” scenario (bottom left) and “RTO+Decarb” scenario (bottom right” along with transmission paths above 115 kV.

The “RTO+Decarb” scenario has the largest deployment of VRE generation, with utility-scale solar installed even in the AECI region. The rest of the regions also see more solar generation installed throughout. In the SOCO and CPLE regions, significantly more wind generation is installed as these regions have the best wind resource within their territories.

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 (for transmission considerations), the model ensures that generation is not sited in unsuitable locations, such as permanent wetlands, national parks or military zones. 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.