Detailed Siting Enhancement of MISO High Penetration Wind, Solar and Storage

Prepared By:

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Prepared For:

Midcontinent Independent System Operator

Background

Vibrant Clean Energy, LLC (VCE) is a Colorado company that has positioned itself as a world-class provider of renewable energy assessment and energy optimization studies. VCE, since its beginnings, has focused on providing the analytical underpinning for the energy transition underway across the world. The team at VCE have provided support to the private and public sectors enabling more intelligent implementation of energy resources onto the electricity grid.

The primary mission of VCE is to provide clients with the least-cost pathways to fulfill their particular needs. The least-cost pathways can be benchmarked against sensitivities to assess the impacts of alternative options. VCE has expertise on Renewable Energy (RE), Energy Efficiency (EE), electric/thermal energy storage, system integration, Electric Vehicles (EVs,) economics, software development, policies and regulations, and big-data analytics.

VCE is led by founder and CEO Dr Christopher T M Clack, who has a background in mathematics, statistics and plasma physics. He has been building energy grid integration models for the past half-decade with a strong interest in agnostic cost co-optimization. All the models that Dr Clack has created are constructed from the ground up to incorporate high-resolution weather and load data. In a nutshell, the models are designed to deal with big data.

The flagship model is known as WIS:dom [Weather Informed Systems: design, operation, markets]. It is the successor to the C-OEM suite. It is the first, and only, commercially available capacity expansion, production cost model that can solve for the entire North American grid, while considering variable generation, at hourly 3-km resolution, transmission power flow, generator physical limitations, retirements, yearly investment periods, and more.

The Midcontinent Independent System Operator (MISO) that provides open-access transmission service and monitoring of the high-voltage transmission system in the Midwest US, central southern US, and Manitoba, Canada. MISO also operates one of the world's largest real-time energy markets. MISO employees more than 900 staff.

As part of MISO commitment to its stakeholders from its Value Proposition, MISO continually strives to create further value and strengthen reliability within its footprint. Part of that responsibility is to assess the impacts of changing landscapes within the industry with regards to technologies, economics, regulation and social behavior. To that end, MISO regularly performs transmission expansion planning (MTEP) studies where it will investigate changes in the needs of its stakeholder.

Recently, dramatic shifts have occurred primarily driven by the innovation of variable generation, such as wind and solar photovoltaics, and storage technologies. These shifts have altered the needs within MISO (and elsewhere) for siting decisions, transmission upgrades, congestion probabilities, demand growth, and emissions. With all these dynamic impulses to the system, MISO seeks new ways to evaluate the future system under various scenarios, using a unified platform, that can transect the various pathways and determine enhancements to their planning that will continue to assist the evolution of the MISO footprint for decades to come.

Description of Work

Study Objectives:

The study has numerous objectives. The most critical is to determine the effects of high penetrations of wind and solar PV on the MISO grid. The purpose of driving high renewable scenarios is to determine the siting requirements and changes to those requirements as the amount of wind and solar increase. In addition, the impact of EVs, storage, and DERs on the siting of generation and transmission will also be evaluated.

By investigating the increase in variable generation various other metrics can be computed and evaluated. For example, when other RTOs are considered along with MISO, does the resulting future siting needs change? If they do change, what is the primary driving factors of that change? Is there a pathway that allows siting behavior to be minimally altered?

The WIS:dom optimization model was created to research such questions in a high-resolution, big-data framework. WIS:dom allows the objectives to be evaluated in a co-optimized environment so that comparisons can be drawn between scenarios in a holistic manner.

MISO already has sufficient detail for low penetration level siting of variable generation and all thermal generation resource, but the assumptions for variable generation may need to be adapted as higher levels of renewables enter the footprint. In addition, external changes could alter the siting of variable generation within MISO. The factors affecting the MISO footprint with higher penetration of variable generation resources are: siting requirements of the VREs, transmission expansion constraints within MISO, impact of weather variability, external grid dynamics and interconnections, and distributed resources. Below we detail the enhancements and factors that will be considered in the study.

Resource Siting Enhancements:

- Wind tiers 4+ ~30% up to 100% penetration levels;
- Solar tiers 4+ ~10% up to 100% penetration levels;
- Grid tied storage (determining the level of need within the MISO mix);
- Distributed Energy Resources (rooftop solar PV, storage, EVs);
- The above resources procured outside MISO's footprint;

- Wind/solar placement under variation of technology (hub heights, rotor diameters, axis-tracking, optimized for energy vs value to grid).

Transmission Expansion Constraints:

- MISO footprint transmission expansion, via reduced form (county level or high-voltage level), required for siting enhancement scenarios shown above. Impacts of constraining those expansions on the siting;
- Storage and transmission considered together as grid assets and determine the benefits of such a scenario;
- Sensitivity to costs (for underground or lower losses).

Inter- and Intra- Annual Weather Variability:

- Assess the impact of multi-year weather dataset on siting compared with a “typical” weather year;
- Determine the benefits of higher geographic resolution on the results of the study (3-km);
- Compute the impact of weather variability on the requirements for natural gas combined cycle (NG CCGT) plants, natural gas combustion turbines (NG CT) and demand response (DR) within MISO’s footprint;
- Capacity credit evaluation based upon various penetrations and weather variability.

Interconnection Influences of External RTOs:

- Model different geographic scales to determine the adjustment to MISOs planning by outside influences;
- Geographic extent to be considered: MISO only; MISO, PJM and SPP; MISO, SPP, PJM, NYISO, TVA and SERC; whole Eastern Interconnect;
- Employ sensitivities with regards to capacity, energy, reserve cooperation between scales to evaluate the possible benefits.

Distributed Resources and Other Considerations:

- Electric vehicle adoption within MISO;
- Residential storage;
- Rooftop solar PV impacts;
- Demand response/management;
- Role of charging/discharging vehicles on grid;
- Planning and following reserve requirements in a changing mix on MISO’s footprint.

Technologies That Will Be Considered:

The WIS:dom optimization model includes the following possible technology options:

1. Solar Photovoltaics
    a. Fixed axis,
    b. 1-axis tracking,
    c. 2-axis tracking,
    d. Optimal direction to face panels [energy vs value],
    e. Rooftop solar PV;
2. Grid tied energy storage
    a. Li-Ion,
    b. Flow batteries,
    c. Constraints on efficiency, cycling, power, or energy;
3. Wind Turbines
    a. 80 m hub height,
    b. 100 m hub height,
    c. 120 m hub height,
    d. Turbine designs,
    e. Rotor diameter;
4. Electric Vehicles
    a. Charging/discharging behavior,
    b. Amount and location of EVs,
    c. V2G, G2V, etc.;
5. Distributed Energy Resources
    a. Storage,
    b. Heat pumps,
    c. Other demand management;
6. Large scale demand management.

WIS:dom Optimization Model

The WIS:dom (Weather-Informed Systems: design, operation, markets) optimization model is the flagship, state-of-the-art, product created by VCE. A precursor to WIS:dom was the seminal C-OEM (the Co-Optimized Energy Model) which was the first commercial model to be able to co-optimize variable generation, conventional generation, transmission, storage and power flow at a granularity of 13-km and 60-minute for the entire continental United States for a full year.

WIS:dom contains numerous improvements from C-OEM in its description of power flow, investment time periods, pollutant tracking, dispatch, reserve requirements, and technology descriptions. Further, WIS:dom has been designed to work at all geographic scales as well as include a wide range of technologies that are more appropriate for a wide range of studies (see previous page description of technologies considered). The WIS:dom region for MISO contains 166,719 resource sites as depicted in Figure 1.

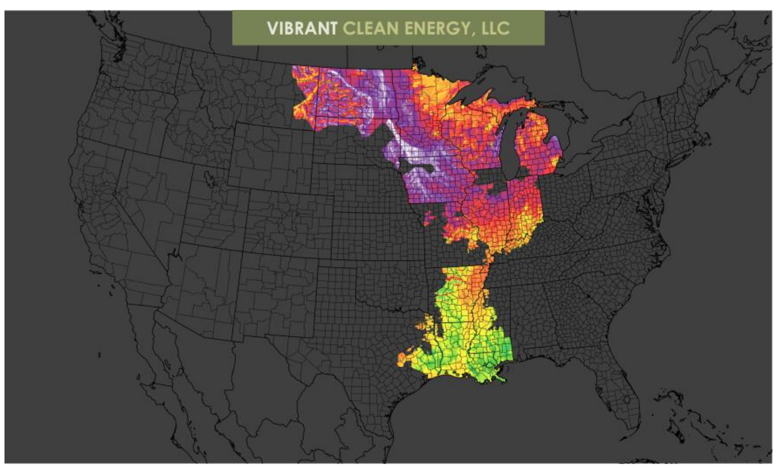

Figure 1: The geographic extent of MISO showing the wind capacity factors at 80m AGL. The MISO footprint will be the core focus of the study.

However, for some of the sensitivities, WIS:dom will be utilized over the entire Eastern Interconnect. It will incorporate existing generation, transmission and retirement dates. The Eastern Interconnect has large geographic extent (shown in Figure 2) and contains numerous generators (shown in Figure 3). WIS:dom has the ability to solve over such scales at hourly resolution for several years chronologically.

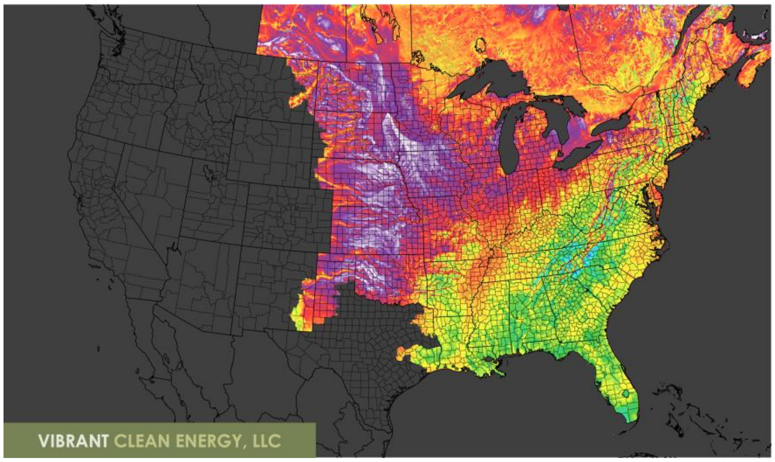

Figure 2: The geographic extent of the Eastern Interconnect and its associated wind capacity factors. The WIS:dom optimization model will represent the whole of the Eastern Interconnect for some sensitivities to determine its impact on MISO siting enhancements.

WIS:dom provides dispatch values for each hour of each year for each asset over the domain studied. These are usually aggregated in reports to county or state or Local Resource Zone (see Figure 4), but the data is available on a generator-level basis. The furthest time horizon that WIS:dom currently resolves to is 2055, and does so in two to five-year investment periods. Each investment period has cost estimates (see Figure 5), resource estimates, electricity pricing estimates, and utility grid upgrades / retirements.

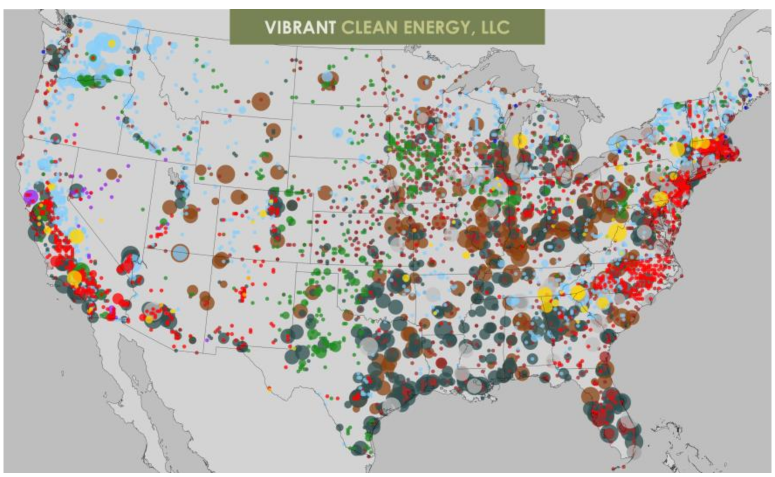

Figure 3: WIS:dom representation of existing (and proposed) Generation across the contiguous United States. Currently there is over 1,100 GW of installed capacity and another 120 GW in queue for construction.

WIS:dom utilizes high-resolution (spatially and temporally) weather data to determine resource properties over vast spatial-temporal horizons. Thus, WIS:dom can be used on scales as small as campuses, cities, counties or states/provinces; but uniquely can also be used for sovereign entities and continents. Moreover, these scales can be nested, allowing high-fidelity local modeling accompanied with lower-fidelity larger areas to create feedbacks within the model that simulate outside influences on local markets.

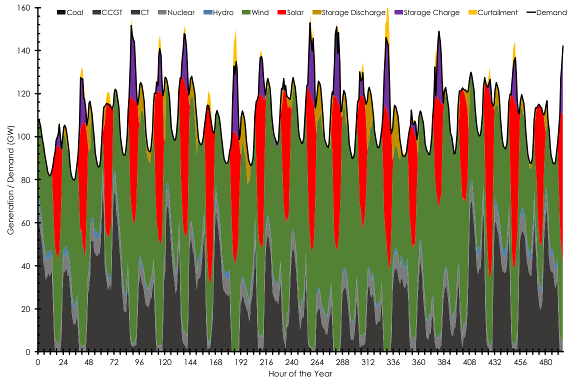

Figure 4: The hourly dispatch output from the WIS:dom optimization model for a deep decarbonization scenario within MISO. It shows a month period.

The WIS:dom optimization model relies on publically available data where possible, and contains default values for generators, transmission, storage, production cost and resource siting. However, WIS:dom was designed from the beginning to allow "plug-and-play" capability, whereby it can take advantage of customized datasets required for detailed modeling of specific questions, markets or balancing areas. For example, higher-resolution weather data over a utility or ISO; or proprietary heat rates for generators within a utility; or localized demand profiles.

The WIS:dom optimization model was designed, and built with big-data in mind. It includes GIS data, economic inputs, political and regulatory inputs, transmission constraints, technology data, high resolution weather data and forecasts, siting constraint datasets for generation and much more.

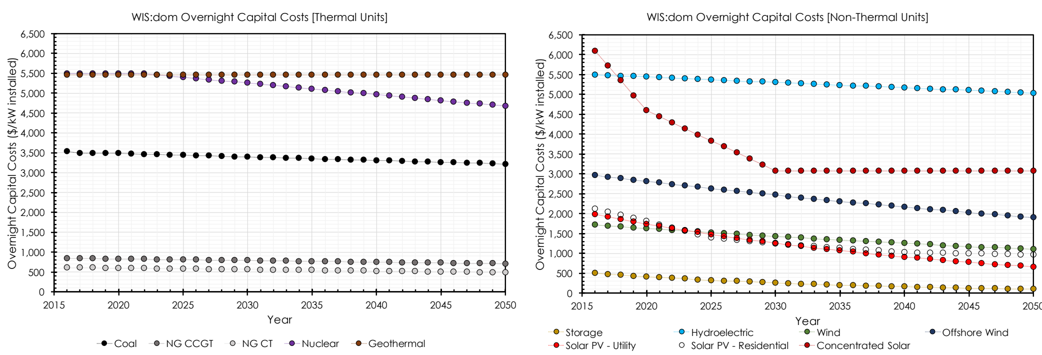

Figure 4: Example capital costs of weather-driven renewables and storage with time. All inputs within WIS:dom are customizable for specific localities.

Study Approach

1. VCE will customize and deploy the WIS:dom optimization model for MISO and the Eastern Interconnect. The customization must include:
   - Hour-by-hour demand for MISO and external regions that are optimized upon. The extent of the data will be 3 calendar years;
   - Transmission limitations and constraints between MISO regions and external RTOs. The external RTOs will be depicted with lower transmission fidelity;
   - Current and in-queue generation assets for MISO and the EI;
   - Spatial availability and locations for new generation. The WIS:dom optimization model will respect protected areas;
   - Current policies, incentives, regulations, and salient data unique to MISO and EI;
   - Hourly weather and power data for variable generation at 3-km hourly and 5-minutely. Total number of years is 3 years;
   - Cost projections in keeping with MISO's other studies;
   - Optimal clustering and integer corrections proceeding each investment period with re-dispatch to correct for linear relaxation within WIS:dom.
2. The WIS:dom optimization model will be used to run each of the sensitivities described below. A total of twenty (20) sensitivities are expected. WIS:dom will be tested and benchmarked for 1 historical year.
3. All data required for the WIS:dom optimization model will be collected by VCE in collaboration/consultation with MISO where necessary. In particular VCE will provide generators, transmission, costs, retirement dates, load, power data, and all software to perform the study. MISO will provide data deemed necessary to customize WIS:dom for their purposes from the study, i.e. generator specific heat rates, retirement schedule, operating schedule, load data, etc.
4. .

Minimum WIS:dom Optimization Model Constraints (Blank cell indicates no limit)

Purpose	Scenario	Trading	Tx. Exp.	Wind %	PV %	Storage %	DPV %	DS %	EV %
Optimal expansion EI	1								
Optimal MISO expansion	2	Current	Current						
Optimal MISO expansion	3	None							
Optimal wind siting	4	None		100					
Optimal solar siting	5	None			100				
Optimal storage siting	6	None				10			
Optimal DPV siting	7	None					10		
Optimal DS siting	8	None						10	
Optimal EV siting	9	None							10
50/50 Wind Solar	10	None		50	50				
100% Wind and Solar	11	None		combined	100				
Optimal W+S Siting	12-13	Current / Expand	Current / Expand	combined	50	10	10	10	10
Optimal W+S Siting	14-15	Current / Expand	Current / Expand	combined	75	20	20	20	20
Optimal W+S Siting	16-17	Current / Expand	Current / Expand	combined	90	30	30	30	30
Optimal W+S Siting	18-19	Current / Expand	Current / Expand	combined	100	30	30	30	50
Free / TBD	20								

Table 1: The anticipated WIS:dom optimization model runs to be performed for the study. Blank cells indicate that variable is free in the optimization. Model runs will be adjusted with consultation with MISO depending upon the results of the baseline cases (scenarios 1-3). Scenarios 12+ facilitate the discovery of outside influences on MISO as those grids try to increase wind and solar, and if that alters MISO pathways.

Related Studies Performed By VCE

Vibrant Clean Energy has performed two extensive studies within the MISO footprint that relate to the current proposal.

The first was a study commissioned by MISO to determine the effect of reducing emissions within its footprint. The study only considered a single wind turbine height and solar PV technology. It also used a single year of 13-km weather data and did not consider outside impacts on its footprint. The study report can be found on the MISO MTEP site.

The second study was funded by the energy foundation and sought out solutions for Minnesota with respect to storage. The study used WIS:dom to model MISO with Minnesota having various levels of storage. The study pushed the boundaries of the ability to model storage and variable generation in large-scale grids. The study was limited in scope and funding, and therefore was limited in its ability to model many sensitivities in terms of technologies, years of data and geographic extent.

The present study would remove all the limitations from the previous studies and enable a strong foundation and platform for insight into the possible futures to the MISO grid. It allows for several years of high-resolution weather and load data, vast geographic extent (the whole Eastern Interconnect), numerous technology types, distributed generation, electric vehicles, and the interplay of all of these factors.