Western Energy Imbalance Service and SPP Western RTO Participation Benefits

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Executive Summary

This study estimates the production cost benefits that would likely result from the creation of the WEIS Market and from extending the full Southwest Power Pool (SPP) Regional Transmission Organization (RTO) market to include the WEIS footprint. To assess these benefits, the Brattle team created a unified nodal production cost model of the WECC and most of the Eastern Interconnection, connecting the two models across the seven DC ties. The integrated Western Electricity Coordinating Council (WECC) and Eastern Interconnection model was developed in the Power System Optimizer (PSO) production cost simulation software. PSO is a state-of-the-art production cost simulation tool that simulates least-cost security-constrained unit commitment and economic dispatch with a full nodal representation of the transmission system, similar to actual RTO and Independent System Operator (ISO) market operations. PSO can generate hourly prices at every bus and generation output for each unit, which allow us to estimate changes in generation output, fuel use, production cost, or other metrics on a unit, state, utility, or regional level.

PSO is designed to mimic RTO and ISO operations: it commits and dispatches individual generating units to meet load and other system requirements. The model's objective function is set to minimize system-wide operating costs given a variety of assumptions on system conditions (e.g., load, fuel prices, etc.) and various operational and transmission constraints. One of PSO's most distinguishing features is its ability to evaluate system operations at different decision points, represented as "cycles," which would occur at different points in time and with different amounts of information about system conditions. PSO can simulate initial cycles to optimize unit commitment, calculate losses, and do an initial optimization of unit dispatch. Subsequent cycles can refine unit commitment decisions for fast-start resources and re-optimize unit dispatch based on the market design of real-time energy imbalance markets. As part of this cycle-based structure, PSO can also consider forecasting uncertainty and intra-hour real-time operations, although at this point this functionality has not been utilized in our analysis of WEIS and full SPP market benefits. Simulation of uncertainty and intra-hour operational challenges would further increase the magnitude of estimated market benefits.

We started with developing two separate models: a WECC model and a separate Eastern Interconnection model. These models were then connected across the seven existing DC ties. The WECC model reflects the 2028 WECC System Stability Planning Anchor Data Set (ADS), which was developed by WECC staff to operate for the GridView production cost simulation software. We converted the ADS model from GridView to operate in the PSO software, making the model compatible with our Eastern Interconnection model, which was developed from a database created by the Newton Energy Group (NEG), the company that licenses the PSO software. The NEG model includes SPP, Midcontinent ISO (MISO), and the neighboring areas, and was built using publically available data from FERC filings on the transmission topology, the generation resources, and load in these regions. We altered the NEG model to be consistent with the WECC ADS assumptions and updated the transmission topology to include additional transmission constraints identified in SPP's 2020 ITP. In our WECC model, the initial day-ahead commitment cycle is followed by cycles that simulate day-ahead economic dispatch, bilateral trading of power in the WECC, and a real-time economic dispatch cycle, reflecting the CAISO-administered Western Energy Imbalance Market (EIM) and the WEIS as they will be operated in the WECC by 2028.

The combined model of the WECC and Eastern Interconnection contains three cycles to simulate unit commitment and dispatch decisions along different timeframes and within different market structures. The model utilizes a day-ahead unit commitment cycle, in which the model optimizes unit commitment decisions for long lead-time resources based on the relative economics, operating characteristics and transmission constraints, and a day-ahead economic dispatch cycle, in which the model determines the optimal level of dispatch for all resources based on their relative economics subject to transmission constraints. The simulations then utilize a real-time cycle, in which the model re-optimizes unit commitment of fast-start resources (if market rules allow for it) and the dispatch of all committed resources. This real-time cycle also simulates the operation of imbalance markets, such as the EIM and WEIS.

To assess the benefits of participation in the WEIS Market and of extending the full SPP RTO market to the WEIS footprint, we simulated and compared three cases: (1) a Status Quo Case, (2) a WEIS Case, and (3) an RTO Case.

The **Status Quo Case** simulates operation of the Eastern Interconnection and WECC, including all the existing market structures with current and planned members in both interconnections. This includes the SPP, MISO, and CAISO RTO/ISO markets, and the CAISO-administered EIM. In the WEIS footprint, and in other non-market areas represented in the model, hurdle rates were applied between utilities to simulate bilateral trading frictions in all three cycles of the model. In the Status Quo Case, DC ties follow 2019 historical hourly flows in all cycles (shifted to align peak and off peak periods in 2028). Transmission capacity of WECC paths in the non-RTO areas of the WECC are derated by 10% to approximate the inefficiency with which bilateral contract-path transactions utilize the existing grid.

The **WEIS Case** is the same as the Status Quo Case, except that we implemented the proposed WEIS Market structure and allow for coordinated real-time trading over the four DC ties in the WEIS footprint. Hurdle rates between WEIS members are removed in the real-time cycle for transfers between WEIS members, and on flows over the four DC ties located within the WEIS footprint. The WECC path ratings in the WEIS footprint are returned to their full transmission capability (i.e., 10% derate is removed) in recognition that the WEIS Market is able to fully utilize the available grid capacity for real-time transactions.

The **RTO Case** simulates SPP's RTO market structure in the WEIS footprint. Hurdle rates are removed between the proposed WEIS member areas and the existing SPP market region in all cycles of the model, which implies day-ahead and real-time unit commitment and dispatch are optimized across the entire market footprint. Flows over the four DC ties that connect SPP to the WEIS are optimized in every cycle, and the WECC path ratings in the WEIS footprint are returned to their full transmission capability (i.e., 10% derate is removed) in recognition that nodal RTO markets are able to fully utilize the available grid capacity. We model a unified transmission tariff in the RTO Case across the SPP and the WEIS, implying that no hurdles exist in any cycle between WEIS participants and the current SPP footprint. The unified tariff implies a single regional through-and-out rate (RTOR) for sales from the WEIS footprint to other parts of the WECC, calculated as the average of the current wheeling rates for the WEIS members.

The study utilizes the Adjusted Production Cost (APC) metric, a simplified metric to estimate the cost of serving load for a utility or a group of utilities. In this study, the APC metric was calculated separately for the aggregate WEIS footprint and the SPP footprint. The APC metric allows us to estimate the production cost savings that the WEIS and SPP members would experience in the two market participation scenarios simulated in the study. The APC metric is calculated for each case, and the comparison across cases provides an estimate of how much the cost to serve load changes due to market participation. In the RTO Case, we also estimate the additional wheeling revenues that would be generated for the WEIS entities due to participation in the expanded SPP RTO.

We find that the creation of the WEIS is estimated to reduce APC by $16.1 million/year (0.3% of total APC) in the combined SPP and WEIS footprint. Of this benefit, $9 million/year (4.1% of APC) accrue to WEIS members and $7.1 million/year accrue to current SPP members (0.14% of APC). The production cost benefits experienced in the WEIS Market are due to the increased flows of low-cost power from SPP over the DC ties into the WEIS footprint. To accommodate this low-cost power, the WEIS members reduce production from higher-cost resources. This creates a benefit for SPP members, who are able to make more sales across the DC ties and for WEIS members that are able to substitute high-cost production for lower-cost purchases from SPP.

FIGURE 1: SUMMARY OF ESTIMATED MARKET PARTICIPATION BENEFITS ($ '000/YEAR)

Region	Reduction in APC	Wheeling Revenue	Total Benefit
WEIS Case	**-$16,174**		**$16,174**
WEIS Footprint	-$9,030		$9,030
SPP Footprint	-$7,144		$7,144
RTO Case	**-$32,648**		**$49,335**
WEIS Footprint	-$8,460	$16,687	$25,148
SPP Footprint	-$24,187		$24,187

We find that the extension of the SPP RTO to the WEIS footprint reduces APC for the study footprint by $33 million/year (0.6% of APC) and generates over $16 million/year of additional wheeling revenues; creating a total of over $49 million/year of benefits for the WEIS members and SPP. The WEIS members experience a reduction in APC of $8.5 million/year (3.9% of APC) and receive the $16 million/year of additional wheeling revenues. The current SPP members experience a reduction in APC of $24.2 million/year (1.3% of APC). The reduction in APC experienced in the RTO Case is primarily driven by an increase in market sales, which are mostly sold off-system to neighboring entities in the WECC. The expanded RTO market footprint allows entities in SPP to sell power into Arizona, New Mexico, Utah, and other areas of the WECC while only paying a single wheeling fee, which creates opportunity for increased market sales.

I. Scope of the Study

The Brattle Group was engaged by the SPP to develop an integrated model of the WECC and SPP footprints, and the areas neighboring SPP in the Eastern Interconnection. The objective of the study is to estimate the production cost benefits due to the creation of the Western Energy Imbalance Service (WEIS) Market and of extending the full SPP RTO market to the WEIS footprint. This analysis involved creating a unified nodal production cost model of the WECC and the Eastern Interconnection, and connecting the two models across the seven DC ties that bridge the two interconnections.

The Brattle team developed an integrated model of SPP and the WECC in the Power System Optimizer (PSO) production cost simulation software. The WECC portion of the model developed for this study is based on the 2028 WECC System Stability Planning Anchor Data Set (ADS), a model available to WECC members. The Eastern Interconnection portion of the model was developed based on a model of SPP, MISO, and neighboring areas licensed from the creators of PSO, the Newton Energy Group (NEG). The Brattle Group communicated with SPP and WEIS members (WAPA, Basin Electric Cooperative, and Tri-State Generation and Transmission Cooperative) to update the modeling assumptions to reflect the latest forecasts and projection for 2028 of generation resources, transmission, fuel prices and load into the model.

To assess the production cost benefits of the WEIS Market and the extension of the SPP RTO to the WEIS footprint, the Brattle team simulated three cases: a Status Quo Case, a WEIS Case, and an RTO Case. The Status Quo Case simulates operation of the Eastern Interconnection and WECC with the current market structures with current members (including members planning to join the EIM by 2028). The WEIS Case is the same as the Status Quo Case except that we implement the proposed WEIS Market structure coupled with coordinated real-time imbalance transactions between the WEIS members and the SPP members across the four DC ties in the WEIS footprint. The WEIS Market structure is implemented for the planned members in the WECC, and allows the model to coordinate real-time imbalance transactions between WEIS members and SPP members through optimal dispatch in the real-time, but without day-ahead optimization across the WEIS-SPP footprint. In the RTO Case, we implement an RTO market spanning the combined region of the prospective WEIS member areas and SPP.

The benefits estimated in this study center around the Adjusted Production Cost (APC) metric, which is a simplified metric to estimate the cost of serving load for a utility, or group of utilities. The APC metric calculates the cost of producing power as well as the cost of off-system purchases, while accounting for the revenues earned through off-system sales. The metric allows us to estimate the production cost savings that the WEIS members and the current SPP members would experience in the market participation scenarios simulated in the study. We calculate the APC metric for each case, and the comparison of the metric across cases provides an estimate of how much the cost to serve load changes due to market participation. In the RTO Case, we also determine the additional wheeling revenue that the WEIS members can expect to earn through additional off-system sales to the other areas of the WECC and include this as a benefit of market participation.

The Brattle team's simulations found that the creation of the WEIS real-time imbalance market with coordinated real-time imbalance transactions across the DC ties reduces APC by $9 million/year for WEIS members and by $7.1 million/year for the current SPP members. The WEIS Market produces benefits by allowing for increased flows of low-cost power from the western part of the SPP footprint across the DC ties into the WECC. Higher-cost generation backs down in the WEIS footprint to accommodate the inflows from SPP. This market transaction of power creates benefits on both sides of the DC ties.

The creation of the SPP West RTO creates benefits of $25 million/year for WEIS members and $24.2 million/year for current SPP members. The full integration of the WEIS footprint into the SPP RTO means power can flow from the current SPP footprint into Arizona, New Mexico, Utah, and other areas in the WECC while paying a single wheeling fee. As a result, the model shows increased power flows over the DC ties into the WECC that mostly pass through the WEIS footprint and are sold as off-system sales to other entities in the WECC. This creates benefits for WEIS members, through some purchases of lower-cost power from SPP and through additional wheeling revenues into the WECC, and creates benefits for SPP members that sell more power across the DC ties.

While the APC calculation captures system production costs caused by reduced hurdle rates, additional transmission availability, and dispatch optimization over a larger footprint, among others, the benefits we estimate in this study likely underestimate the true savings from the creation of the WEIS Market and expanding the SPP RTO. This production cost simulation will not capture market benefits associated with management of intra-hourly deviations for variable resources, uncertainty in load or renewables, generation or transmission outages, inefficiencies of bilateral trading, or operating reserves sharing, among others. The market benefits not captured by the APC metric are discussed further in Section III.B.

II. Modeling Approach and Assumptions

A. The Power System Optimizer (PSO)

For the simulations in this study, we used the Power Systems Optimizer (PSO) software developed by Polaris Systems Optimization, Inc. PSO is a state-of-the-art production cost modeling tool that simulates least-cost security-constrained unit commitment and economic dispatch with a full nodal representation of the transmission system, similar to actual RTO and ISO market operations.

A production cost model, like PSO, can be used as a tool to test system operations under varying assumptions, including but not limited to: generation and transmission additions or retirement, depancaked transmission and scheduling charges, changes in fuel costs, and jointly-optimized generating unit commitment and dispatch. PSO can be set up to produce hourly prices at every bus and generation output for each unit. The market operational results and prices produced by PSO can be used to estimate changes in generation output, fuel use, production cost, or other metrics on a unit, state, utility, or regional level.

PSO has certain advantages over traditional production cost models, which are designed primarily to model controllable thermal generation and to focus on wholesale energy markets only. PSO has the capability to capture the effects on thermal unit commitment of the increasing variability due to intermittent and largely uncontrollable renewable resources (both for the current and future developments of the system), as well as the decision-making processes employed by operators to adjust other operations in order to handle that variability. PSO simultaneously optimizes energy and multiple ancillary services markets, and it can do so on an hourly or sub-hourly timeframe (though only an hourly timeframe was used in this study).

PSO uses mixed-integer programming to solve for optimized system-wide commitment and dispatch of generating units. Unit commitment decisions are particularly difficult to optimize due to the non-linear nature of the problem. With mixed-integer programming, the PSO model closely mimics actual market operations software and market outcomes in jointly optimized competitive energy and ancillary services markets.

Like other production cost models, PSO is designed to mimic ISO operations: it commits and dispatches individual generating units to meet load and other system requirements. The model's objective function is set to minimize system-wide operating costs given a variety of assumptions on system conditions (e.g., load, fuel prices, etc.) and various operational and transmission constraints. One of PSO's most distinguishing features is its ability to evaluate system operations at different decision points, represented as "cycles," which would occur at different points in time and with different amounts of information about system conditions. Unlike some production cost models, PSO simulates trading between balancing areas based on contract-path transmission rights, which allows for a more realistic and more accurate representation of actual trading opportunities and transactions costs.

PSO can simulate initial cycles to optimize unit commitment, calculate losses, and do an initial optimization of unit dispatch. Subsequent cycles can refine unit commitment decisions for fast-start resources and re-optimize unit dispatch based on the market design of real-time energy imbalance markets. The market structure can be built into sequential cycles in the model to mimic actual system operation for utilities that conduct utility-specific unit commitment in the day-ahead period but participate in real-time energy imbalance markets that allow for re-optimization of dispatch and some limited re-optimization of unit commitment. Explicit commitment and dispatch cycle modeling allows more accurate representation of individual utility preference to commit local resources for reliability, but share the provision of energy around a given commitment. This is how we represent bilateral trading and the Western Energy Imbalance Market (EIM) and WEIS Market in the model.

B. Model Development

The integrated SPP-WECC model used in this study was developed initially as two separate models: a WECC model and an Eastern Interconnection model. Updates were made to these models separately in parallel work streams to control model-processing time and calibrate the individual models before introducing complications of combining the models. The two models were then combined across the seven DC ties to create an integrated model of both interconnections.

1. The WECC Model

The modeling assumptions used in this study are based off the 2028 WECC System Stability Planning Anchor Data Set (ADS) developed by WECC staff to conduct regional transmissions studies in the western U.S. The WECC ADS model assumptions are developed from data contributed by WECC members. The database includes an assumed generation portfolio for 2028 in the WECC, peak load and energy demand forecasts for 2028, a transmission topology reflective of expected 2028 transmission upgrades, wind and solar production templates based on historical hourly production profiles from NREL's 2009 database, and hydro profiles for normal hydrological conditions.

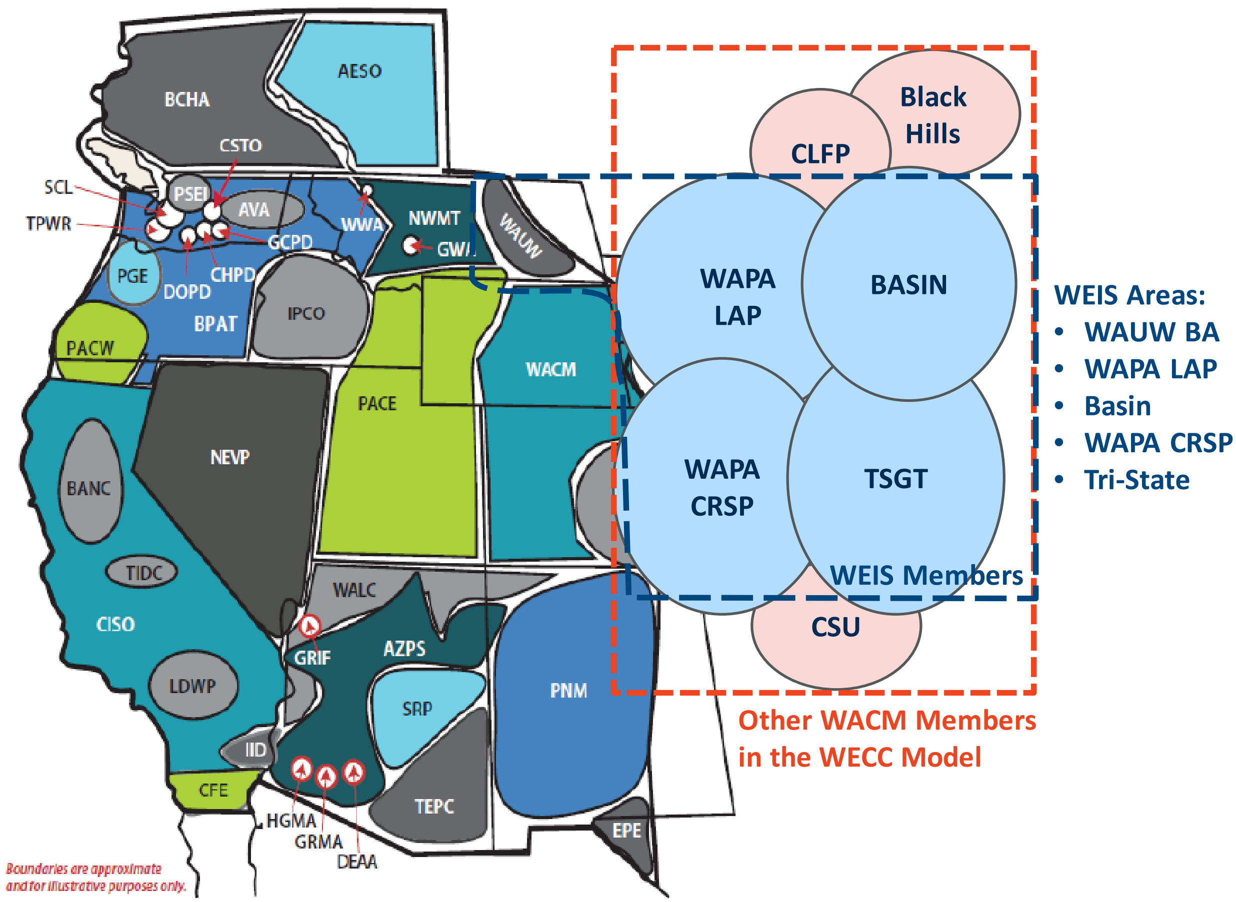
The WECC ADS model represents each Balancing Area (BA) in the WECC, implying that the WECC model has all the generation, load, and transmission mapped to one of the BAs in the WECC. Multiple members of the WEIS Market are located within the Western Area Power Administration (WAPA) Colorado Missouri (WACM) BA, along with some other non-WEIS entities. Therefore, simulating the impact of creating a market in the WEIS footprint on the individual WEIS members required a more granular representation of the WACM BA. We separated the generation, load, and transmission located in the WACM BA into sub-areas representing all the utilities that make up the WACM BA. We developed this more detailed representation of the WACM BA with the help and input of the WEIS members - WAPA, Tri-State, and Basin.

The WEIS entities provided us with the information to map the generation and transmission buses to their respective systems and with the updated data on their generation resources, fuel prices, and load to inform our 2028 modeling assumptions. We created a WECC model that contained all the BAs in the other parts of the WECC, and a utility-specific representation of the WACM BA footprint. The utility-specific representation of the WACM BA contained individual areas for WAPA's Loveland Area Projects (LAP) system, WAPA's Colorado River Storage Project (CRSP) system, Basin's Western Interconnection system, and Tri-State's system.[1] The proposed WEIS members include three other entities within the

[1] Tri-State has generation, transmission, and load within the Public Service Company of Colorado (PSCO) BA and within the Public Service Company of New Mexico (PNM) BA. Since both of these areas have announced plans to join the EIM, Tri-State provided us with the information and data to separate their system between the parts going into the WEIS and the parts with the PSCO and PNM BAs.

WACM BA, the Wyoming Municipal Power Agency (WMPA), Deseret Power Electric Cooperative (Deseret), and the Municipal Energy Agency of Nebraska (MEAN).[2] The load and generation that these entities plan to bring into the WEIS are included in the model, within the Basin zones (WMPA), LAP zone (MEAN), and the CRSP zone (Deseret). The proposed WEIS footprint also includes the portion of the WAPA Upper Great Plains system that is in the WECC (the WAUW BA).[3] Figure 2 indicates the WECC balancing areas represented in the model, identifies the WEIS member areas modeled in our study, and illustrates the separation of the WACM BA into the WEIS members and other utilities.

FIGURE 2: WECC BALANCING AREAS AND MODELED AREAS IN THE WEIS FOOTPRINT



The WEIS ADS model was developed to operate in GridView, another nodal production cost simulation software. To conduct the simulations for this study, we converted the ADS model to operate in the PSO software. This conversion made the model compatible with our Eastern Interconnection model, and allowed us to represent day-ahead operations and real-time operations in one simulation. The PSO

2 The WACM BA includes other utilities that are not planning to join the WEIS, such as Black Hills Power, Cheyenne Light Fuel and Power, and Colorado Springs Utilities (Colorado Springs Utilities has moved to the PSCO BA, but at the time the WECC ADS model was developed it was part of the WACM BA). In the model used for this study, we represent these areas as their own zones within the WECC.

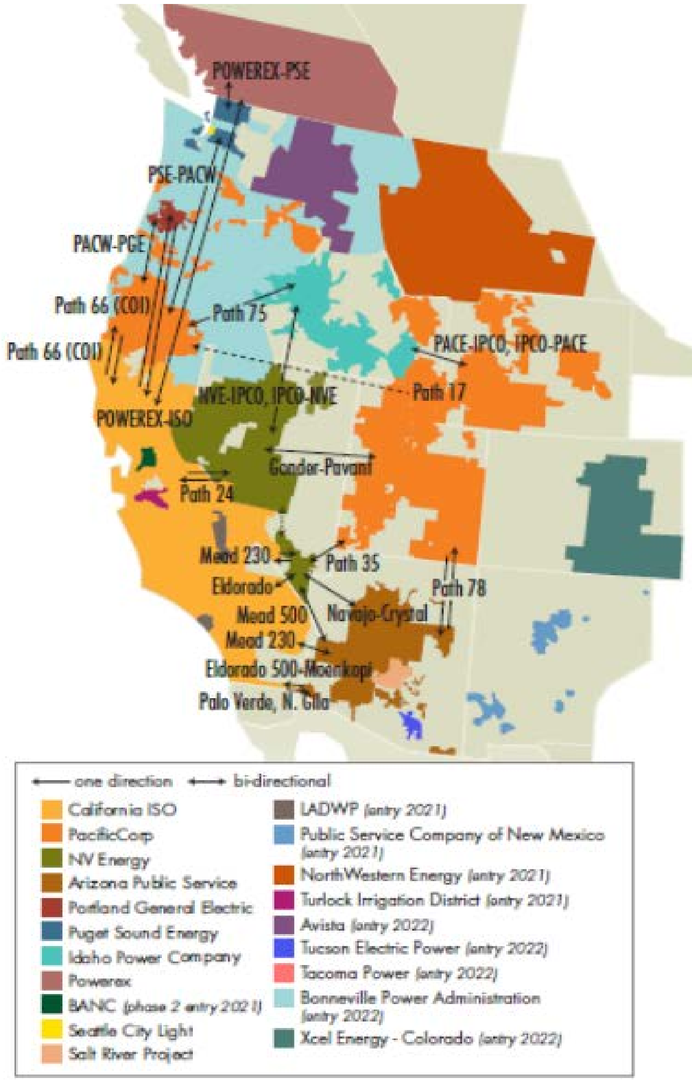
3 The majority of the WAPA Upper Great Plains system is in the Eastern Interconnection and is already a member of the SPP RTO market.

model is equipped with the ability to simulate optimization decisions in different cycles, with each cycle representing the market structures and information at different decision-marking timeframes. For example, in PSO we can simulate an initial cycle that determines day-ahead unit commitment decisions that reflects the constraints faced by, and decisions made by, individual utilities when committing their resources in the day-ahead timeframe. The initial day-ahead commitment cycle is followed by cycles that simulate day-ahead economic dispatch, including bilateral trading of power in the WECC, and a real-time economic dispatch, reflecting the energy imbalance markets in the WECC.

The combined day-ahead and real-time model of the WECC includes a representation of the CAISO-administered Western Energy Imbalance Market (EIM) that includes all the utilities that are currently members and the utilities that have announced their intention to join prior to 2028.[4] The representation of the EIM in the WECC model ensures the portion of the WECC that does not intend to join the WEIS is properly simulated by the model. To simulate market transactions in the EIM, our team developed modeling assumptions to represent the transmission capability between EIM members. For the existing EIM members, we utilized information provided in the quarterly Western EIM Benefits Report, shown in Figure 3, to approximate the transfer capability between the existing members. For the prospective members of the EIM, we estimated the transfer capability between the members using the WECC 2019 Path Rating Catalog, which is available to WECC members, and other publicly available sources.

4 All active EIM members were modeled as EIM participants, and pending members: Los Angeles Department of Water and Power (LADWP), Public Service Company of New Mexico (PNM), Avista (AVA), Tucson Electric Power (TEPC), Bonneville Power Administration (BPA), Balancing Authority of Northern California (BANC), Turlock Irrigation District (TIDC), Public Service Company of Colorado (PSCO), Platte River Power Authority (PRPA), Black Hills Colorado Electric (BHCE), and Colorado Springs Utilities (CSU) were also modeled as EIM participants.
https://www.westerneim.com/Pages/About/default.aspx

FIGURE 3: TRANSFER PATHS BETWEEN CURRENT EIM PARTICIPANTS



The WECC ADS model assumptions reflect the physical limits of the transmission system in the WECC, as shown in the WECC Path Ratings Catalog. To reflect the inefficiencies of bilateral transmission scheduling we apply a 10% de-rate to all the transmission paths in the model that are not part of an RTO market (all paths external to the CAISO footprint). This includes the transmission paths in and around the WEIS footprint, such as TOT 2A, TOT 3, and TOT 5.

The last modeling assumption update made to the WECC ADS model is to adjust prices for inflation. The cost data in the ADS model are expressed in 2018 dollars, which were inflated to 2020 dollars using an assumed inflation rate of 2% consistent with the inflation rate used by SPP to adjust their modeling assumptions. Therefore, all results presented in this report are in 2020 dollars.

2. The Eastern Interconnection Model

The Eastern Interconnection model was developed based on a database created by the Newton Energy Group (NEG), which is the same company that developed and licenses the PSO software. The NEG model includes SPP, MISO, and the neighboring areas,[5] and was built using publically available data from FERC filings on the transmission topology, the generation resources, and load in these regions.

The Brattle team altered the NEG model to be consistent with the WECC ADS assumptions. We updated the modeling assumptions to include the retirement and addition of generation resources as planned for 2028 (in the SPP and MISO footprints, as provided by SPP). We also altered the transmission topology to include major transmission constraints identified in SPP's 2020 ITP, and adjusting the hourly solar and wind production profiles to match the same historical year used in the WECC model (2009 from NREL's database).

We updated the fuel prices in the model to reflect assumptions provided by SPP. All the fuel prices in the model, except for natural gas prices, were updated to match the prices in SPP's 2020 ITP. The natural gas prices used in the model were developed from SPP's 2028 Henry Hub forecast and the corresponding forecasts for SPP-internal locations. As explained in the next section, the SPP natural gas price forecasts were used to develop prices used in the WECC as well.

The model simulates unit commitment and dispatch across all the regions represented in the model based on the relative economics and operating characteristics of the generation resources in each region. The model also simulates the optimal transfer of power across the SPP-MISO seam, based on the cost of power on each side of the seam, the transmission capability between the regions, and subject to a hurdle rate. Power transfers between all the other regions in the Eastern Interconnection model are set at fixed levels in each hour based on the historical flow data from the NEG model (shifted to align peak and off peak periods with 2028).

3. The Integrated Eastern Interconnection-WECC Model

Our team developed the two models independently and then combined them across the seven DC ties that connect the Western and Eastern Interconnections. In the Status Quo Case, the flows across the DC ties are modeled as fixed hourly schedules, which cannot be adjusted by the model to take advantage of price differences across the ties. The flows across the DC ties are based on the historical flows from 2019 (shifted to alight peak and off peak periods with 2028) provided by SPP.

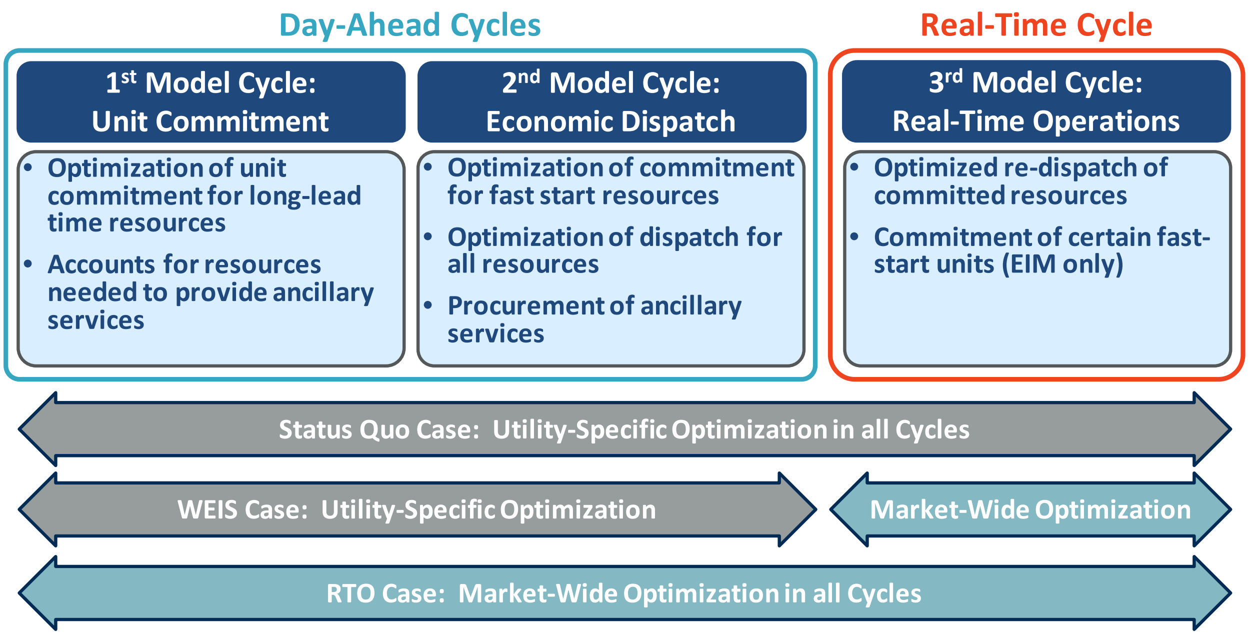
The combined model contains three cycles to simulate unit commitment and dispatch decisions along different timeframes and within different market structures. The three cycles simulated in the model are:

[5] Neighboring areas include SPA, EEI, SPC, IESO, SERC, LG&E, PS, SOCO, TVA, AEP, COMED, DEOK, MH, and AECI.

- **Day-Ahead Unit Commitment Cycle:** the model optimizes the unit commitment decisions for long-lead time resources, such as coal and nuclear plants, based on the relative economics and operating characteristics of the resources (e.g., minimum run time, ramping rate, maintenance schedules, etc.) and the transmission constraints reflected in the model. The model will also ensure that enough resources are committed to serve load, accounting for average transmission losses and the need for ancillary services.
- **Day-Ahead Economic Dispatch Cycle:** the model solves for unit commitment for fast start resources and the optimal level of dispatch for all resources in the model based on the relative economics of the resources. In this cycle, the model will solve for the provision of ancillary services for each area in the WECC and each market footprint in the Eastern Interconnection.
- **Real-Time Cycle:** this cycle allows us to simulate the operation of the real-time imbalance markets, such as the EIM and the WEIS. In this cycle, the model can re-optimize dispatch levels and unit commitment decisions for certain fast-start resources if the real-time market rules allow for re-commitment.

These three cycles will take on different assumptions depending on the market structure in place. For example, in a bilateral setting as currently exists in the WEIS footprint, all three of these cycles would be set up to analyze utility-specific unit commitment and dispatch decisions. In the Status Quo Case, each of these three cycles would include hurdle rates and transmission wheeling fees between the utility areas to limit the amount of power transactions that can take place between the utilities. In this way, we replicate the operation of the bilateral market, where utilities demonstrate a strong preference to commitment and dispatch their own resources instead of relying upon the resources of a neighboring entity. In an RTO market, all three of the cycles would be set up to simulate market-wide optimization of unit commitment and dispatch. In the RTO setting, there would be no hurdle rates between market members in any cycle, allowing the model to perfectly optimize unit operation in the market footprint. In the WEIS Case, the day-ahead cycles would operate like the bilateral setting and the real-time cycle would operate like the market. Figure 4 describes the three cycles simulated in the model and how they are set up to reflect the operation of different market structures.

FIGURE 4: MODELED CYCLES IN PSO



The natural gas prices in the unified model were developed to ensure consistency between fuel prices in the Western and the Eastern Interconnections. We developed locational fuel prices for points in the Eastern Interconnection model based on the 2028 Henry Hub forecast provided by SPP, and information given by SPP on the differentials between locational prices and the Henry Hub. The natural gas prices in the WECC region were developed using historical differential between each gas pricing location in WECC and the Henry Hub, which were applied to the 2028 Henry Hub forecast provided by SPP. Table 1 shows the average annual 2028 price (in 2020 dollars) of natural gas in selected regions of the model.

TABLE 1: AVERAGE ANNUAL NATURAL GAS PRICE MODELING ASSUMPTIONS (2020 $/MMBTU)

WECC Model Locations		Eastern Interconnection Model Locations	
Arizona North	$3.5	Louisiana	$3.5
Arizona South	$3.3	Henry Hub	$2.5
British Columbia	$3.1	Minnesota	$4.4
California PG&E	$4.6	Oklahoma	$3.6
California SDGE	$4.5	Southeast	$3.8
Colorado	$2.3	Texas Southeast	$3.4
Idaho South	$2.7	West SPP	$3.3
Malin	$2.9	Wisconsin	$3.8
Montana	$2.3		
Nevada North	$2.6		
Nevada South	$3.4		
New Mexico North	$2.6		
New Mexico South	$2.5		
SoCal Border	$3.4		
SoCal Gas	$4.5		
Texas West	$2.6		
Utah	$2.5		
Washington	$3.1		
Wyoming	$2.3		

C. Description of the Cases Simulated

The three cases simulated in this study allow us to estimate the production cost benefit of creating the WEIS and of extending the SPP RTO market to the WEIS footprint. The three cases simulated are: 1) the Status Quo Case, 2) the WEIS Case, and 3) the RTO Case. These cases differ only by the market structure (scope of optimization, hurdle rates in each cycle, and derates on transmission paths to approximate inefficiencies under the Status Quo Case). Therefore, a comparison of the production costs and system operation across the cases allows us estimate the impact of the two potential market structures.

The Status Quo Case simulates operation of the Eastern Interconnection and WECC with the current market structures with the current/planned members. These includes the SPP, MISO, and CAISO market footprints as currently constituted, and the EIM footprint with all current members and the utilities that have announced they will join before 2028.

As described in the previous section, the model simulates unit commitment and dispatch decisions in three sequential optimization cycles (see Figure 4). The Status Quo Case contains several different market structures, depending on the region, such as RTO markets in SPP, MISO, and CAISO, and an energy imbalance market in the EIM. Therefore, the modeling assumptions in each cycle of the model vary for the different regions of the model. The assumptions in all areas of the model, except the WEIS footprint, are the same in all three cases. Therefore, we focus on highlighting the differences between the modeling assumptions in the WEIS footprint.

TABLE 2: MODELING ASSUMPTIONS FOR THE WEIS FOOTPRINT ACROSS CASES

Market Design Assumption	Status Quo Case	WEIS Case	RTO Case
Hurdle Rate between WEIS Members	• $8/MWh Unit Commitment • $4/MWh Dispatch	• $8/MWh Unit Commitment • $4/MWh Dispatch • $0/MWh in real-time WEIS Market	• $0/MWh for all commitment and dispatch
Transmission Capacity	• All paths around the WEIS derated 10%	• Transmission in the WEIS rated at physical limits	• Transmission in the WEIS rated at physical limits
DC Ties	• DC ties flows fixed to historical 2019 levels in all day-ahead and real-time	• DC ties flows fixed to historical 2019 levels in all day-ahead • Model optimizes DC ties flows based on price in real-time	• Model optimizes DC ties flows based on price in day-ahead and real-time

III. Study Results

This section of the report summarizes results of the simulations described above. The first part of this section focuses on two computed metrics, which we estimate using the results of the simulations as inputs. These two metrics estimate the market participation benefit for the SPP and prospective WEIS members for the two market structures considered. The two benefits we focus on are (1) the Adjusted Production Cost (APC) metric, which approximates of the cost to serve load, and (2) in the RTO Case only, the additional wheeling revenues that the WEIS members can expect to collect due to increased wheel-through transactions from SPP to the rest of the WECC.

We also describe a list of market participation benefits that are not analyzed in this study. Like all production cost simulations, this study does not capture all the operational details and nuances experienced during actual operation of the power system. Therefore, some of the benefits of participation in a regional energy imbalance market or RTO market are not accounted for in this study.

A. Market Benefits Estimated in this Study

1. Adjusted Production Cost Benefits

The study calculates the Adjusted Production Cost (APC) metric, which is a simplified metric to estimate the cost of serving load for a utility or a group of utilities (in this study the metric was calculated for the aggregate WEIS footprint and the SPP footprint). The APC metric calculates the cost of producing power as well as the cost of off-system purchases, while accounting for the revenues earned through off-system sales. The APC metric does not account for all the costs incurred to serve load. For example, the metric does not account for cost-based contracts for generation, marginal loss refunds, revenues from financial transmission rights, and other costs and revenues that may accrue to market participants.

The metric allows us to estimate the production cost savings that the WEIS and SPP members would experience in the market participation scenarios simulated in the study. The APC reflects the net costs associated with production, purchases, and sales of wholesale power, and is calculated as:

Adjusted Production Cost =

(+) Generator costs (fuel, start-up, and variable operation and maintenance (O&M)) for generation owned or contracted by the SPP and WEIS entities;

(+) Costs of market purchases by the SPP and WEIS entities from other generators and imports from neighboring regions; and

(−) Revenues from market sales and exports by the SPP and WEIS entities.

The APC metric is calculated for each case, and the comparison of the metric across cases provides an estimate of how much the cost to serve load changes due to market participation. For example, the APC metric for the SPP footprint in the Status Quo Case minus the APC metric in the RTO Case indicates how much the cost of serving load will decrease for the SPP members if the WEIS entities join the RTO market.

2. Additional Wheeling Revenue (RTO Case Only)

In the RTO Case, we estimate the additional wheeling revenue that would be generated for the WEIS entities due to participation in an expanded SPP RTO. The expanded RTO in the WEIS footprint would imply a unified transmission tariff in the WEIS and hurdle-free transferring of power over the DC ties between the WEIS and SPP footprints. The unified transmission tariff in the RTO Case can create additional wheeling revenues in two ways. First, the WEIS members will be able to utilize each other's transmission systems without incurring any wheeling fees to sell power to other entities in the WECC, which would create additional wheel-out revenues for the entire WEIS footprint. Second, under the expanded RTO power would be able to flow from the eastern side of the DC ties in SPP across the ties, through the WEIS footprint, and be sold to other entities in the WECC that share a transmission connection with the WEIS while only paying a single wheeling fee. These wheel-through transactions may not necessarily reduce production costs for WEIS members, as the power flows through and out of the footprint, but it will generate wheeling revenues for the WEIS members.

We calculate the additional wheeling revenue for the WEIS members by comparing the MWh of exports from the WEIS entities to the rest of the WECC in the Status Quo Case against the exports in the RTO Case. The additional MWh of export flows are multiplied by an estimate of the WEIS RTOR. The WEIS RTOR is estimated as the load-weighted average of the individual utility wheeling rates. The actual RTOR for a unified WEIS footprint will be determined in discussions between the prospective members, and will change over time as transmission costs in the region change. Based on the information on wheeling fees provided by the WEIS members and the relative loads of each member, we estimated a RTOR for the unified WEIS at $5.75/MWh. Therefore, we applied this rate to difference between the WEIS exports in the RTO Case and the Status Quo Case.

B. Market Benefits Not Estimated in this Study

Production cost simulations, such as those conducted in this study, are helpful for understanding the benefits of participating in a regional market, but there are limitations of such simulations as tools for understanding all the benefits created from market participation. Production cost models are powerful tools: they jointly simulate generation dispatch and power flows to capture the actual physical characteristics of both generating plants and the transmission grid, including the complex dynamics between generation and transmission availability, energy production and operation, and ancillary services requirements. These types of simulations provide valuable insights to both the operations and economics of the wholesale electric system in the entire interconnected region. For that reason, production cost models are used by every ISO and RTO, and most utilities, for transmission planning purposes.

However, similar to most other production cost simulations, the simulations undertaken for this study have their limitations and likely yield conservatively low estimates of the benefits for SPP and the WEIS members. The specific limitations include:

- This study does not assess the benefits of **improved management of load and generation uncertainties** provided by a regional energy imbalance market or RTO market, particularly as it relates to the **integration and balancing of increasing amounts of renewable generation**. The study simulates unit commitment and dispatch deterministically based on perfect foresight of all loads and available generation, including hourly renewable generation output, for both day-ahead and real-time operations. The simulations do not consider uncertainties in loads, generation outages, or the level of wind and solar generation that exist between the time utility-specific unit commitment and dispatch decisions are finalized (on a day-ahead and intra-day basis) and when the real-time energy imbalance markets would make their unit commitment (in the EIM) and dispatch decisions. Therefore, the simulations do not capture the benefit of the markets in managing this uncertainty. Having a regional market provides the system operator with a larger pool of resources and optimization tools to manage unexpected changes of generation and load between day-ahead and real-time operations, thereby reducing costs, reducing the need for reserves and ramping capability, and increasing reliability, particularly when integrating large amounts of variable resources, such as wind and solar generation.

- The simulations have been performed on an hourly basis and thus do not capture the additional benefits the WEIS and RTO would provide by balancing loads and generation (and the related uncertainties) on an **intra-hour** basis.
- The simulations are based on **normal weather, average hydrology, normal monthly energy and peak load, and normal generation outages** without considering additional benefits realized during unusually challenging operational conditions. For example, atypical weather patterns (such as extreme cold temperatures or very hot and humid conditions) could create large swings of power flows across a system or other operational challenges. Challenging conditions such as these tend to increase the benefit of regional energy imbalance markets.
- The study does not account for the **reliability benefits** of belonging to a larger regional market footprint resulting from a **reduction in reserves** needed to meet operational and flexibility requirements.
- The simulations do not consider the additional transmission constraints and operational challenges on the power grid during **transmission-related outages**. Transmission limits are reflected in the simulations, but the modeling does not account for transmission outages and the additional unexpected operational challenges they create. The greater flexibility provided by integrated regional market operations yields higher cost savings and improved reliability during transmission outages.
- We do not assume that the improved incentives of operating in a price-transparent and competitive regional market would improve **generator efficiency and availability**, as has been documented by the experience in other regional markets.
- The Status Quo Case in the WEIS footprint **does not fully capture inefficiencies of bilateral trading practices** in terms of less flexible bilateral trading blocks (*e.g.*, 16-hour blocks at 25 MW increments) and congestion caused by unscheduled power flows.
- The simulations do not capture any benefits achievable through **improved regional coordination and optimization of hydropower resources**. We have left hydro dispatch unchanged between the Status Quo Case and the two market participation cases, leaving out benefits associated with allowing the flexible portion of hydro resources to be dispatched more optimally by the regional market (subject to their operating constraints).
- The study does not include savings from more **efficient planning for transmission projects** nor economic **retirement of generation** under market cases.
- Finally, the study does not capture any **changes in transmission cost allocation** as a result of WEIS entities joining the WEIS Market or SPP RTO.

The benefits estimated in this study, as well as the benefits described above that are not accounted for in the study, would need to be weighed against the administrative costs associated with participating in the respective regional energy imbalance markets.

C. Market Benefit Results

In this section, we present the estimated market participation benefits for two possible future market structures that include the prospective WEIS members. First, we present the production cost savings created by the formation of the WEIS Market for real-time energy imbalance transactions. Next, we present the production cost savings created by extending the SPP RTO market to the WEIS footprint, and the increased wheeling revenues that would be generated in the RTO market.

1. WEIS Market Benefits

The creation of the WEIS reduces APC for the entire study footprint (the WEIS and SPP) by $16.1 million/year (0.3% of APC). This benefit is recognized as $9 million/year (4.1% of APC) for the WEIS members and $7.1 million/year for the SPP members (0.14% of APC). In this case, benefits are driven by increased transfers of low-cost power over the DC ties from SPP to WEIS. The creation of the WEIS allows for an increase in profitable trading across the DC ties, resulting in increased flows into the WEIS in real-time. The inflow of power from SPP allows WEIS members to ramp down expensive generation and save on fuel costs.

Figure 5 shows the reduction in APC for the WEIS members due to the creation of the imbalance market. The table displays the aggregate reduction in APC in the bottom right hand corner of the table, which indicates a reduction of just over $9 million/year. The remainder of the table provides additional insight into the results, and shows how system operations and costs in the WEIS footprint change due to the creation of the WEIS. The columns Figure 5 are divided into three sections labeled “GWh,” “$/MWh,” and “Total ($1000s/Year).” The "GWh” section details the quantity of production within the WEIS in both cases, and the quantity of off-system market purchases and sales in both cases. The section labeled “$/MWh” indicates the average cost of production within the WEIS and the price of off-system purchases and sales, in both the Status Quo and WEIS Cases. The final section of the table, labeled "Total ($1000s/Year),” shows the overall production costs, purchase costs, and sales revenues under both cases. The comparison of the final costs of production and purchases and the revenues from sales under both cases illustrates how much the APC for the WEIS entities will change in the WEIS Case versus the Status Quo Case.

FIGURE 5: DETAILED MARKET PARTICIPATION BENEFITS FOR THE WEIS FOOTPRINT STATUS QUO CASE VS. WEIS CASE

	GWh			$/MWh			Total ($1000s/Year)		
Cost Components	**Status Quo**	**WEIS in SPP**	**Difference**	**Status Quo**	**WEIS in SPP**	**Difference**	**Status Quo**	**WEIS in SPP**	**Difference**
Production	29,011	28,150	**-861**	$8.78	$8.54	**-$0.24**	$254,803	$240,386	**-$14,417**
Purchases									
DA & Bilateral Market	2,540	2,531	**-9**	$35.61	$34.95	**-$0.65**	$90,458	$88,464	**-$1,994**
Real-Time Market	0	1,433	**1,433**	$40.50	$12.49	**-$28.00**	$9	$17,903	**$17,894**
Sales									
DA & Bilateral Market	4,358	4,405	**47**	$28.75	$28.50	**-$0.25**	$125,281	$125,543	**$262**
Real-Time Market	0	515	**514**	$9.50	$19.92	**$10.42**	$5	$10,255	**$10,250**
Total	**27,193**	**27,193**	**0**	**$8.09**	**$7.76**	**-$0.33**	**$219,984**	**$210,954**	**-$9,030**

Figure 5 illustrates how the WEIS lowers the APC of its members. Given the ability to purchase and trade in the real-time market, the WEIS members make 1,433 GWh of market purchases in the imbalance market compared to almost no purchases in the real-time in the Status Quo. The WEIS members also make about 514 GWh of real-time market sales in the WEIS Case. To accommodate these additional market purchases and sales, the WEIS entities reduce their own production by about 860 GWh, saving over $14.4 million/year in production costs. Taken together, these impacts result in over $9 million/year in APC savings.

FIGURE 6: DETAILED MARKET PARTICIPATION BENEFITS FOR THE SPP FOOTPRINT STATUS QUO CASE VS. WEIS CASE

	GWh			$/MWh			Total ($1000s/Year)		
Cost Components	**Status Quo**	**WEIS in SPP**	**Difference**	**Status Quo**	**WEIS in SPP**	**Difference**	**Status Quo**	**WEIS in SPP**	**Difference**
Production	247,911	249,127	**1,217**	$16.34	$16.28	**-$0.06**	$4,050,725	$4,055,057	**$4,332**
Purchases									
DA & Bilateral Market	70,553	70,399	**-154**	$28.85	$28.81	**-$0.04**	$2,035,487	$2,028,220	**-$7,267**
Real-Time Market	925	1,316	**391**	$16.53	$26.00	**$9.47**	$15,294	$34,224	**$18,930**
Sales									
DA & Bilateral Market	29,671	29,743	**72**	$28.90	$28.78	**-$0.12**	$857,396	$855,877	**-$1,519**
Real-Time Market	957	2,339	**1,382**	$10.58	$14.87	**$4.29**	$10,121	$34,780	**$24,658**
Total	**288,760**	**288,760**	**0**	**$18.13**	**$18.10**	**-$0.02**	**$5,233,989**	**$5,226,845**	**-$7,144**

Figure 6 demonstrates the overall reduction of $7.1 million/year in APC for the SPP footprint, in the bottom right hand corner. The table shows that the SPP footprint has an increase of real-time market sales of almost 1,400 GWh between the WEIS and Status Quo Cases (from 957 GWh in Status Quo to 2,339 GWh). SPP members are able to make these sales at an average price of $14.87/MWh, resulting in an increase in real-time market sales revenue of $25 million/year. This increase in sales revenue is offset by an increase in purchasing costs in the real-time market in the WEIS Case (an increase of $18.9 million/year). However, the overall increase in sales revenue between the two cases is large enough to drive an overall net reduction in APC of $7.1 million for the SPP footprint between the WEIS Case and Status Quo Cases.

2. RTO Market Benefits

The expansion of the SPP RTO market to the WEIS members creates benefits for the combined study footprint (the WEIS and SPP) of over $49 million/year (0.6% of APC), including over $25 million/year (11.4% of APC) for WEIS members and $24 million/year (1.3%) for current SPP members. The $25 million/year of the benefit for the WEIS members includes $8.5 million/year in reduced APC and $16.7 million/year in the additional wheeling revenues. The APC savings in the RTO Case are generated by additional off-system sales to neighboring areas in the WECC enabled by the joint transmission tariff created in the RTO. In this case, both the WEIS and the SPP members increase production to make profitable sales to neighboring entities, creating increased sales revenues and overall benefits.

Figure 7 illustrates the benefits for WEIS members in the RTO Case. The table shows an increase in day-ahead sales of 728 GWh between the two cases, creating an increase in sales revenue of $17.8 million/year. To accommodate the additional off-system sales, the WEIS members increase production by 720 GWh, increasing their production costs by $19 million/year. In the RTO Case, the WEIS members are able to make market purchases at a lower cost ($31.74/MWh vs. $35.61/MWh), which creates a benefit of $9.8 million/year. Taken together, the increase in production costs is more than offset by the decrease in purchase costs and increase in sales revenues. Overall, the WEIS members experience $8.5 million/year of adjusted production cost savings. The WEIS members also benefit from the increased wheeling fee generated by the additional off-system sales that occur in the RTO Case. The additional wheeling fees amount to almost $16.7 million/year.

FIGURE 7: DETAILED MARKET PARTICIPATION BENEFITS FOR THE WEIS FOOTPRINT STATUS QUO CASE VS. RTO CASE

	GWh			$/MWh			Total ($1000s/Year)		
Cost Components	**Status Quo**	**RTO**	**Difference**	**Status Quo**	**RTO**	**Difference**	**Status Quo**	**RTO**	**Difference**
Production	29,011	29,731	**720**	$8.78	$9.21	**$0.43**	$254,803	$273,820	**$19,017**
Purchases									
DA and Bilateral Market	2,540	2,540	**0**	$35.61	$31.74	**-$3.87**	$90,458	$80,611	**-$9,848**
Real-Time Market	0	24	**24**	$40.50	$16.24	**-$24.25**	$9	$395	**$386**
Sales									
DA and Bilateral Market	4,358	5,086	**728**	$28.75	$28.13	**-$0.62**	$125,281	$143,065	**$17,784**
Real-Time Market	0	16	**16**	$9.50	$14.45	**$4.95**	$5	$237	**$232**
Adtnl. Wheeling-Out Revenue									**$16,687**
Total	**27,193**	**27,193**	**0**	**$8.09**	**$7.78**	**-$0.31**	**$219,984**	**$211,524**	**-$25,148**

Figure 8 demonstrates the $24.2 million/year reduction in APC for the SPP footprint under the RTO Case. This reduction is driven primarily by an increase in market sales into the WECC, resulting in a $20.6 million increase in day-ahead off-system sales revenue compared to the Status Quo Case. This increase in sales, combined with a 1,061 GWh decrease in day-ahead market purchases, means an increase in production of 2,049 GWh within the SPP footprint compared to the Status Quo Case. The increase in sales revenues drives an overall APC reduction of $24 million/years.

FIGURE 8: DETAILED MARKET PARTICIPATION BENEFITS FOR THE SPP FOOTPRINT STATUS QUO CASE VS. RTO CASE

	GWh			$/MWh			Total ($1000s/Year)		
Cost Components	**Status Quo**	**RTO**	**Difference**	**Status Quo**	**RTO**	**Difference**	**Status Quo**	**RTO**	**Difference**
Production	247,911	249,960	**2,049**	$16.34	$16.17	**-$0.17**	$4,050,725	$4,042,855	**-$7,870**
Purchases									
DA and Bilateral Market	70,553	69,491	**-1,061**	$28.85	$29.36	**$0.51**	$2,035,487	$2,040,084	**$4,596**
Real-Time Market	925	867	**-59**	$16.53	$17.12	**$0.59**	$15,294	$14,837	**-$457**
Sales									
DA and Bilateral Market	29,671	30,651	**980**	$28.90	$28.64	**-$0.25**	$857,396	$878,009	**$20,613**
Real-Time Market	957	906	**-51**	$10.58	$11.00	**$0.42**	$10,121	$9,965	**-$157**
Total	**288,760**	**288,760**	**0**	**$18.13**	**$18.04**	**-$0.08**	**$5,233,989**	**$5,209,802**	**-$24,187**

D. System Operation Results

In addition to providing us with the information to calculate the APC and wheeling revenue benefits, the simulations provide operational results for the SPP and WEIS footprints, including generation mix by fuel type and transmission flows. We present the generation by fuel type in the Status Quo Case to illustrate the fuel mix assumed for 2028 in SPP and the WEIS footprints. Given the importance of the DC ties in the WEIS Market and the expanded SPP RTO, we also present the flows across the four DC ties that are within the WEIS footprint in all the cases simulated.

1. Generation by Fuel Type

This section presents the generation mix by fuel type for the SPP and WEIS footprints simulated in our model. The generation mix is assumed to change considerably by 2028 (the year simulated in this study) compared to the current resource mix. In the WEIS region, additional renewable sources are expected to come online and some coal-fired resource as planned for retirement. We worked with the WEIS members to develop these modeling assumptions based on the latest plans for generation additions and retirements. Figure 9 illustrates the 2028 supply mix in the WEIS footprint. The 2028 generation mix in the WEIS is made up of over 15 TWh of coal generation (51% of the total generation), 9.1 TWh of hydro (30%), 3.4 TWh of wind (11%), 1.5 TWh from solar (5%), and less than 1 TWh from natural gas.

FIGURE 9: WEIS FOOTPRINT 2028 GENERATION SUPPLY MIX (TWH)

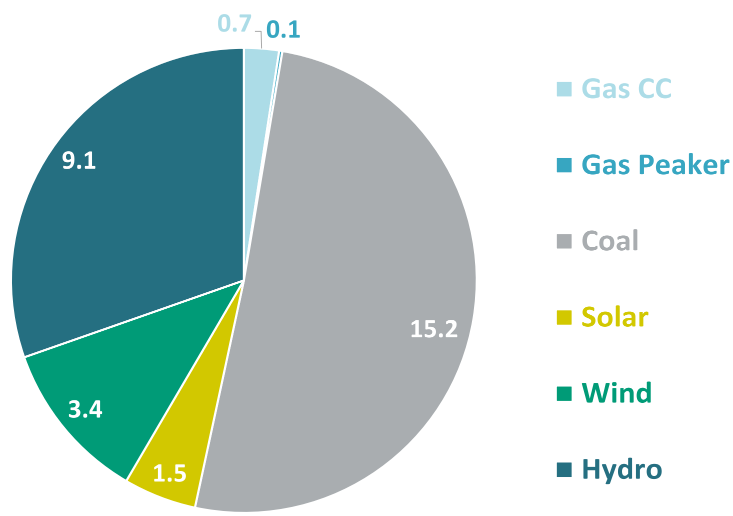
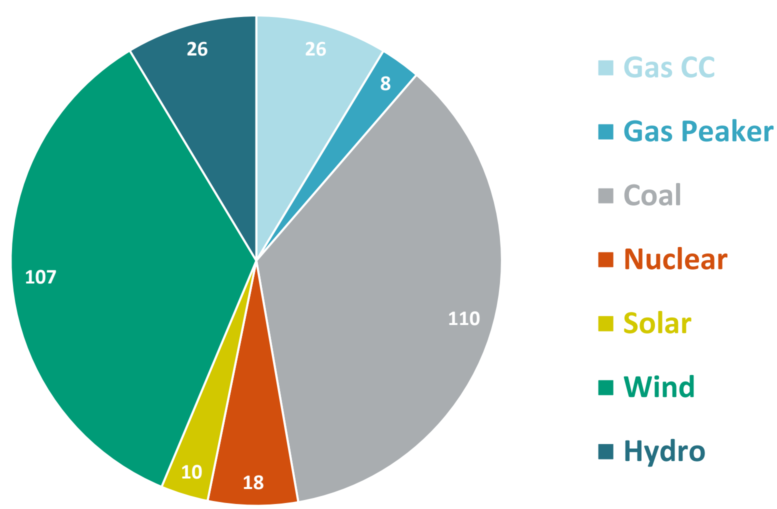


Figure 10 illustrates the generation supply mix in the SPP footprint for 2028, which is made up of 110 TWh of coal-fired generation (36% of the total generation), 107 TWh of wind (35%), 34 TWh from natural gas (11%), 26 TWh from hydro (9%), 18 TWh from nuclear (6%), and 10 TWh from solar (3%).

FIGURE 10: SPP FOOTPRINT 2028 GENERATION SUPPLY MIX (TWH)

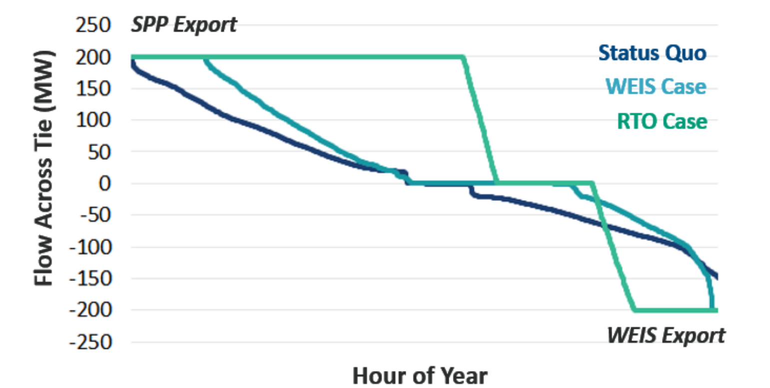


2. DC Tie Flows

This study finds that the ability to optimize flows over the DC ties is a major contributor to creating the benefits of market participation. Therefore, in this section, we illustrate how the flows over the four DC ties that connect SPP to the WEIS change between the three simulated cases. Figure 11 through Figure

14 show the flows at the Miles City tie, the Stegall tie, the Rapid City tie,[6] and the Sidney tie. In the Status Quo Case, the flows are fixed at 2019 historical hourly amounts (shifted to align peak and off peak periods with the 2028 calendar year). Therefore, the dark blue line on each of the four figures shows the flow duration curve based on those historical 2019 flows. In the WEIS Case, the four DC ties are modeled at the fixed 2019 hourly flows in the day-ahead unit commitment and dispatch cycles of the model, but we allow optimization to occur in the real-time cycle of the model. Therefore, the model has some limited ability to adjust flows in response to prices on either side of the tie in the WEIS Case, but not complete ability to optimize based on price. The teal line on each figure shows the flows in the WEIS Case, which demonstrate some movement away from the historical flows to better reflect price signals. Lastly, in the RTO Case, the model is able to fully optimize flows over the DC ties in all cycles of the model. Therefore, the green lines in the figures demonstrate a fully optimized flow duration curve at each of the four DC ties.

FIGURE 11: MILES CITY TIE FLOWS



On the Miles City DC tie, we see that flows under the Status Quo Case are approximately evenly split between importing and exporting from SPP. In almost no hours of the year is the full capacity of the Miles City tie utilized, and in about 10%-15% of the hours of the year, there are no flows over the tie in the Status Quo Case. In the WEIS Case, flows over the Miles City tie shift more in the direction of exporting from SPP to the WEIS. Although there are still many hours of the year when the tie's capacity is not fully utilized (or utilized at all). In RTO Case, SPP becomes a large exporter to the WEIS, which implies completely flipping the direction of flows in many hours of the year.

[6] The rights on the Rapid City tie are shared between Basin and Black Hills Power. Since Black Hills Power is not a prospective member of the WEIS, only the portion of the Rapid City tie that is controlled by Basin is modeled as part of the two simulated market structures. The portion of the Rapid City tie that is controlled by Black Hill Power is modeled at the 2019 fixed hourly flows in all three cases.

FIGURE 12: STEGALL TIE FLOWS

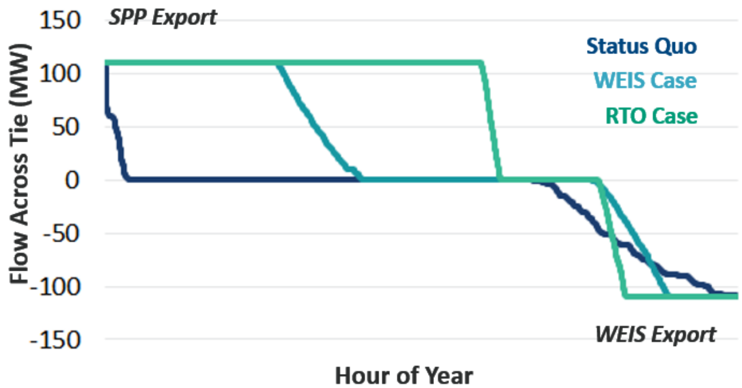


Figure 12 shows flows on the Stegall tie in the three cases. In the Status Quo Case, the majority of hours have no flows over the tie, and in the hours when the tie utilized there are more flows from the WEIS to SPP. As we move from the WEIS Case to the RTO Case, the simulated flows on the tie become increasingly responsive to price signals on either side of the tie. In the RTO Case, we see that SPP becomes a large exporter into the WEIS, with flows moving in the direction of the WECC in about 60% of hours.

FIGURE 13: RAPID CITY TIE FLOWS

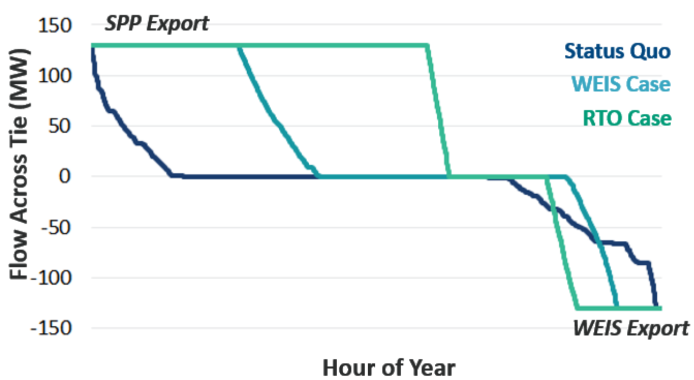
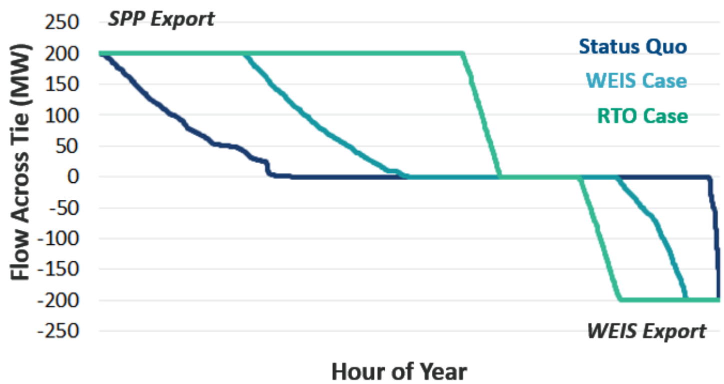


Figure 13 illustrates that the portion of the Rapid City tie in the WEIS footprint demonstrates a similar pattern as the Stegall tie, as it is largely unused in the Status Quo Case but used largely for exports from SPP to WEIS in the RTO Case. Similarly, Figure 14 shows the same general pattern on the Sidney tie, with large amounts of exports from SPP to the WEIS in the RTO Case.

FIGURE 14: SIDNEY TIE FLOWS



The four figures illustrate how the flows on the DC ties help create benefits from participation in the WEIS Market and the expanded SPP RTO. In both market structures, the additional flows on the DC ties move low cost power from SPP into the WECC, which creates benefits for both the SPP members through additional sales revenue and for the WEIS members by substituting higher-cost production and by increasing sales to other areas of the WECC.

IV. Conclusions

This study estimates the benefits in production cost savings for the WEIS and SPP participants due to the creation of the WEIS Market and from the expansion of the SPP RTO market to the WEIS footprint. Benefits in this study are measured as adjusted production cost savings and additional wheeling revenues that may be generated by the formation of the RTO market. Adjusted production cost is an approximation of the cost to serve load, which we estimate in a Status Quo Case and the two market participation cases. The difference in APC between cases demonstrates how the cost to serve load will change due to market formation. Additional wheeling revenue arise in the RTO Case as the WEIS members are able to utilize each other's transmission systems and the four DC ties without incurring any wheeling fees to sell power to other entities in the WECC.

The benefits for the two market participation cases are summarized as follows:

- **WEIS Case.** Benefits in the WEIS case are derived from hurdle-free transmission between the WEIS members in the real-time cycle, economic trading across the DC ties in the real-time, and full transfer capabilities across transmission paths TOT 2A, TOT 3 and TOT 5. The WEIS Market produces APC benefits of over $16 million/year for the combined SPP and WEIS footprint (or 0.3% of total production costs). The WEIS members receive roughly $9 million/year in APC savings, and the SPP members receive about $7 million/year in APC savings. Benefits in the WEIS Case are derived mostly from increased power flows over DC ties in the real-time market. Hurdle-free transmission between the WEIS members in the real-time allows for lower-cost power from SPP to substitute higher-cost power in the WEIS footprint.

- **RTO Case.** The RTO Case produces benefits of $49 million/year for the combined SPP and WEIS footprints (0.6% of total production costs). In this case, the SPP footprint experiences $24 million/year of APC reduction while the WEIS footprint experiences $8.5 million/year in production cost savings and over $16 million/year in wheeling revenues from exports tariffs. Benefits in this case are derived from full DC tie optimization in the day-ahead and real-time, SPP and WEIS reserve sharing capabilities, hurdle-free transmission between the WEIS members in the day-ahead and real-time, and utilization of the full transmission capability in the WEIS footprint.

The benefits estimated in this study are driven by optimized dispatch across the footprints, removing inefficiencies in bilateral trading (as represented by hurdle rates in unit commitment and dispatch cycles), allowing available transmission to be co-optimized across the interconnection on the DC ties (and within footprints), and in the RTO Case, allowing the SPP and WEIS areas to co-service reserves obligations. These simulations are likely a conservative estimation of market benefits, because the simulations do not estimate additional benefits from market participation, including market benefits associated with management of intra-hourly deviations for variable resources, uncertainty in load or renewables, generation or transmission outages, inefficiencies of bilateral trading, or potential reductions in operating reserve requirements, among others.