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Issues: Generation Capacity and Reliability
Witness: Edward C Pfeiffer
Sponsoring Party: Grain Belt Express Clean Line LLC
Type of Exhibit: Direct Testimony
Case No.: EA-2016-0358
Date Testimony Prepared: August 30, 2016

MISSOURI PUBLIC SERVICE COMMISSION

CASE NO. EA-2016_0358

DIRECT TESTIMONY OF

EDWARD C. PFEIFFER

ON BEHALF OF

GRAIN BELT EXPRESS CLEAN LINE LLC

August 30, 2016

TABLE OF CONTENTS

I. WITNESS INTRODUCTION AND PURPOSE OF TESTIMONY

Q. Please state your name, present position and business address.

A. My name is Edward C. Pfeiffer and I am an Executive Advisor at Quanta Technology, LLC ("Quanta Technology"). My business address is 4020 Westchase Boulevard, Suite 300, Raleigh, NC 27607.

Q. What is the business of Quanta Technology?

A. Quanta Technology is a full service consulting firm providing a variety of services to the utility industry with clients that include utilities, Regional Transmission Organizations ("RTOs"), as well as industry research and support organizations, among others. Included in the many services we provide are transmission and resource planning services.

Q. What are your duties and responsibilities as an Executive Advisor?

A. As an Executive Advisor, I provide direction to our analysis teams in the performance of their study work. I also perform various analytical studies for and provide technical expertise to our clients.

Q. Please describe your education and professional background.

A. I received a Bachelor of Science in Electrical Systems and Sciences Engineering from Southern Illinois University, Carbondale in 1975 and a Master of Science degree in Electrical Systems and Sciences Engineering from Southern Illinois University, Carbondale in 1978. I was employed by Union Electric, which became Ameren, from 1978 until 2009. During my time at Ameren, I performed a variety of engineering studies including transmission interconnection, generation interconnection, transmission service, and import/transfer capability studies. I was the Supervising Engineer of the operational planning group and was the Manager of Transmission Planning when I retired from Ameren. I was a member of the North American Electric Reliability Corporation

("NERC") Planning Committee and the chair of the SERC Engineering Committee. While serving on the NERC Planning Committee I was a member of the Transmission Availability Data System Task Force and the Generation and Transmission Reliability Models Task Force. I participated in several planning groups and committees at the Midcontinent Independent System Operator ("MISO", formerly the Midwest Independent Transmission System Operator), including observing the Loss of Load Expectation ("LOLE") Working Group materials to keep abreast of transmission issues related to resource adequacy. I also participated in the Ameren Integrated Resource Plan for Missouri as it pertained to transmission issues. Since leaving Ameren, I have provided consulting services to different clients, including the assessment of transmission and generation interconnections, evaluation of the availability of transmission service, and participation in the Eastern Interconnection Planning Collaborative on behalf of a consortium of Non-Government Organizations. Finally, I am a licensed Professional Engineer in the State of Missouri.

Q. Please describe the study teams' and your background in performing reliability benefit studies.

A. I collaborated with Alex Schneider, PE of Quanta Technology, in performing the LOLE analyses, which is supported by my testimony. Mr. Schneider has extensive experience in performing a variety of statistical analyses, including LOLE studies. Mr. Schneider performed LOLE studies when he was a staff member at the Mid-American Interconnection Network reliability entity. He has also performed LOLE studies for various clients as a consultant. As the Manager of Transmission Planning for Ameren, I was directly responsible for assessing the reliability of the Ameren transmission system, ensuring compliance with NERC Planning Standards, developing a long range transmission plan to maintain the reliability of the Ameren transmission system, and assessing the benefits to the Ameren system of proposed transmission expansion plans.

Q. What is the purpose of your direct testimony?

A. I am testifying to the reliability benefits that the Grain Belt Express Clean Line transmission project (the "Grain Belt Express Project" or "Project") will provide to the State of Missouri. Specifically, I will describe the LOLE study for the Project that Quanta Technology performed and which is attached hereto as Schedule **ECP-1**. In addition, I will describe the intent of an RTO's interconnection study process for the Project and the benefits of interregional transmission access provided by the Project.

II. SUMMARY OF LOSS OF LOAD EXPECATION ANALYSIS

Q. Please define LOLE and explain how it provides a gauge of system reliability.

A. An LOLE or Loss of Load Probability ("LOLP") analysis is a statistical comparison of the electrical load of a given power system and the available generation resources to supply that load. The statistical analysis takes into consideration peak load demand, hourly load profile, generation capacity, and the availability of the generation capacity. LOLP represents the probability that the available resources in any given hour are not sufficient to meet the load. The sum of these hourly LOLP values over the course of a year can be interpreted as the LOLE for the year, or the number of expected time periods in which there will not be enough generation to meet load during a given year. The sum of the expected energy needs unserved in a year, expressed in megawatt-hours, is the loss of energy expectation ("LOEE").

Q. Are the LOLE study and the methodology you describe in this testimony generally accepted in the electric industry as measures of reliability?

A. Yes. LOLE studies have been conducted for several decades in the determination of proper capacity reserve levels and remain an important component in the transmission expansion planning processes of RTOs. The details of the methodology and inputs of this analysis are described in **Schedule ECP-1**.

Q. What was the geographic scope of your LOLE analysis?

A. The geographic scope of this analysis was the State of Missouri. The analysis considered limited interconnections to neighboring states representing the resources and obligations of Missouri utilities which are physically located outside of Missouri.

Q. What comparative cases were developed for the LOLE study?

A. The LOLE analysis looked at two cases. One, the "Base Case", considered Missouri, as defined by the inputs available for this analysis, without the 500 MW of capacity made available by the Grain Belt Express Project. The second case, the "Grain Belt Express Case", considered the same system as the Base Case plus the inclusion of the 500 MW of capacity made available by the Grain Belt Express Project within Missouri. The difference between these two cases is solely attributable to the addition of the Grain Belt Express Project.

Q. What is the expected impact on LOLE for the State of Missouri due to the Project?

A. Without the Project, the 2022 Loss of Load Expectation of Missouri, is as follows.

Index	Total
Loss of Load Expectation (Days)	.013
Loss of Load Expectation (Hours)	.040
Loss of Energy Expectation (MWh)	18.8

Leaving all other factors the same and inserting the 500 MW contribution of the Grain Belt Express Project as described above, the LOLE is as follows.

Index	Total	Impact from the Project
Loss of Load Expectation (Days)	.004	-69%
Loss of Load Expectation (Hours)	.014	-65%
Loss of Energy Expectation (MWh)	6.5	-65%

Q. Based on the results of your LOLE study, what is your conclusion as to whether installation of the Grain Belt Express Project will increase the reliability of electric service in Missouri?

A. The Project has a substantial and favorable effect on the reliability of electric service in Missouri. The primary measures of reliability are each improved by approximately 65 – 70%.

III. ROLE OF THE REGIONAL PLANNING AUTHORITY AND BENEFITS OF INTER-REGIONAL TRANSMISSION

Q. Have you worked with any RTO/ISO or other Regional Planning Authority?

A. Yes. In my roles as a transmission planner and as the Manager of Transmission Planning at Ameren, I have been involved in numerous planning activities, including generation interconnection studies, regional transmission planning, calculation of Available Transmission Capacity, and regional cost allocation.

Q. What is the intent of the MISO interconnection study process?

A. The intent of the MISO interconnection study process is to evaluate the impact of a proposed new or modified interconnection project, such as the Grain Belt Express Project's connection to the Ameren Missouri transmission system, to ensure that the proposed interconnection does not have a negative impact on the reliability of the Ameren Missouri transmission system or those of neighboring systems. MISO accomplishes this through the commission of an impact study to assess the impact of the new or modified interconnection project with respect to NERC Transmission Planning ("TPL") standards.

Q. What are the benefits of interregional transmission access as a result of the Grain Belt Express Project?

A. The Project will provide Missouri with the delivery of 500 MW of wind resources directly connected to the western converter station in Kansas without any exposure to market congestion in the intervening Southwestern Power Pool, Inc. ("SPP") transmission system. In addition, the Project will also provide access to available capacity and energy resulting from market and load diversity from the 79,000 MW of installed capacity in SPP and the 185,000 MW of installed capacity in PJM Interconnection, LLC ("PJM"). Capacity and energy, which can be delivered to the Grain Belt Express Project converter stations in either of these markets, will be able to reach the Missouri loads without potential limitations or added congestion charges that would otherwise result from transmission constraints on the intervening alternating current ("AC") networks. The ability to avoid such upstream constraints and congestion charges will increase access for the State of Missouri to these large reservoirs of capacity and energy.

Q. Is there anything unique about Missouri with respect to its location that further highlights the benefits of additional market access that is made available by the Grain Belt Express Project?

A. Yes. Missouri is electrically diverse in that there are four Transmission Service Providers ("TSPs") that operate within the state – SPP, MISO, Associated Electric Cooperatives, Inc., and Southwestern Power Administration. This means that the flow of power across, into, and out of the State of Missouri could require multiple transmission wheels and coordination with multiple TSPs. Additionally, the electric system within the State of Missouri is overseen by three Reliability Coordinators (SPP, MISO, and the Tennessee Valley Authority) and two NERC Regional Entities (SERC Reliability Corporation-Gateway and SPP-North). Also, Missouri is in the MISO Central sub-region with limited access to the MISO South sub-region to which it has a direct 500 kV connection. The various entities providing oversight of reliability, energy markets, and resource and transmission planning efforts introduces difficulty in identification of and cost allocation for new cross-seams transmission projects. Therefore, by providing an interregional transmission access point within the State of Missouri, the Grain Belt Express Project is valuable because it 1) provides access to highly energetic renewables that would otherwise find difficulty accessing Missouri loads across the existing AC transmission systems and 2) provides a new, direct transmission path between MISO and SPP as well as MISO and PJM that is not cost allocated to load customers in these regions.

Q. Are there any recent RTO studies or reports which discuss resource adequacy within Missouri?

A. Yes, the 2016 Organization of MISO States ("OMS") MISO Survey Results discusses resource adequacy across the MISO footprint. These results are attached hereto as **Schedule ECP-2**. The results of the survey indicate that Load Resource Zone ("LRZ") five (5), which includes Ameren Missouri and the City of Columbia, was identified as having an 800 MW and 1,300 MW capacity deficiency in the MISO assessment of Planning Reserve Requirements for 2017 and 2021, respectively. The results of our LOLE analysis indicate that access to an additional 500 MW of generation capacity via the Grain Belt Express Project will improve the aggregate resource adequacy of the State of Missouri. Also, the Grain Belt Express Project proposes to interconnect within MISO's LRZ five (5), therefore providing the opportunity for direct benefits to this LRZ in which OMS has identified a likely need for capacity in the future.

Q. Does this conclude your direct testimony?

A. Yes it does.

BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF MISSOURI

In the Matter of the Application of Grain Belt Express Clean Line LLC for a Certificate of Convenience and Necessity Authorizing it to Construct, Own, Control, Manage, Operate and Maintain a High Voltage, Direct Current Transmission Line and an Associated Converter Station Providing an Interconnection on the Maywood-Montgomery 345 kV Transmission Line	)))))))	Case No. EA-2016-0358

AFFIDAVIT OF EDWARD C. PFEIFFER

STATE OF Colorado)
) ss
COUNTY OF Larimer)

Edward C. Pfeiffer, being first duly sworn on his oath, states:

1. My name is Edward C. Pfeiffer. I am an Executive Advisor at Quanta Technology, LLC.

2. Attached hereto and made a part hereof for all purposes is my Direct Testimony on behalf of Grain Belt Express Clean Line LLC consisting of 10 pages, having been prepared in written form for introduction into evidence in the above-captioned docket.

3. I have knowledge of the matters set forth therein. I hereby swear and affirm that my answers contained in the attached testimony to the questions therein propounded, including any attachments thereto, are true and accurate to the best of my knowledge, information and belief.

Edward C. Pfeiffer

Subscribed and sworn before me this 25 day of Aug, 2016.

Notary Public

SCOTT MULLINIX
Notary Public
State of Colorado
Notary ID 20154041437
My Commission Expires Oct 21, 2019

My commission expires: Oct 21, 2019

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Grain Belt Express Clean Line HVDC Project
Loss of Load Expectation Study

PREPARED FOR: Grain Belt Express Clean Line LLC

REPORT DATE: June 30, 2016

PREPARED BY:

A. W .Schneider Jr. PE
aschneider@quanta-technology.com
630-613-3395

Edward C Pfeiffer, PE
epfeiffer@quanta-technology.com
919-334-3054

QUANTA TECHNOLOGY, LLC
4020 WESTCHASE BOULEVARD, SUITE 300, RALEIGH, NC 27607 USA
Oakland | Chicago | Boston | Toronto
WWW.QUANTA-TECHNOLOGY.COM
Quanta Technology, LLC is a wholly-owned subsidiary of Quanta Services, Inc. (NYSE: PWR)

EXECUTIVE SUMMARY

Grain Belt Express LLC ("Grain Belt Express") is a transmission developer proposing to build the Grain Belt Express Clean Line HVDC project (the "Project") from wind-rich western Kansas, with a 500 MW delivery to the Midcontinent Independent System Operator ("MISO") in Ralls County, MO, and an additional 3,500 MW delivery to PJM at the Sullivan Substation near the Illinois-Indiana border.

In support of Grain Belt Express' application for a Certificate of Convenience and Necessity in the State of Missouri, Grain Belt Express commissioned a study to measure the reliability benefit of the Project. The study performs a comparison of system reliability, measured by Loss of Load Expectation or LOLE, with and without the proposed HVDC line. The model used was designed to be rigorous but not include complexities which will have no effect on the comparison. For the purposes of this analysis, all of the utilities within the State of Missouri and all of their designated resources and load obligations were treated as a single aggregated entity.

The addition of the interconnection of the Missouri HVDC converter station and associated 500 MW of capacity injection from the Grain Belt Express Project reduced LOLE for the State of Missouri, which was studied as an aggregated single system, from 0.013 days per year to 0.004 days per year. This is a 69% improvement. Comparable improvement was observed in LOLE expressed in hours per year and in loss of energy.

TABLE OF CONTENTS

1 METHODOLOGY

The study uses three common, industry-accepted metrics of electric reliability: Loss of Load Probability ("LOLP"), LOLE and loss of expected energy ("LOEE"). In a power system, the excess of available generating capacity over load is termed "reserve". If reserve is greater than zero, all load will be served and some generating capacity will be operated at less than its maximum output. If reserve is less than zero, some load will be unserved or "lost". LOLP, LOLE and LOEE are all measures of the likelihood and severity of lost load due to a lack of adequate generation reserves.

1.1 Loss of Load Probability

Neither the available capacity nor the load at a future time are known precisely; in a statistical sense they are termed "random variables".

Past operating history of each generating unit forms a basis for predicting probabilities of each unit being in various operating states from fully available to fully out-of-service. Better estimated probabilities, having a smaller error band, may be calculated by "pooling" the operating histories of similar units.

All generating units, regardless of technology, require outages for maintenance. These are typically on a schedule extending several years into the future, but subject to modification based on system conditions. Maintenance of units in each plant and across the system is coordinated to fall primarily in off peak periods, with due consideration of holiday schedules and workload constraints with each plant.

In addition to maintenance outages, generators also experience un-scheduled (forced) outages. The Generator Availability Data System ("GADS") database, assembled annually by the North American Electric Reliability Corporation ("NERC"), is the primary source of generator outage probabilities (i.e. forced outage rates) in North America. Assumptions around generator availability used in this study are further described in Section 2 of this report.

Forecasting peak loads for future years can be approached by a variety of econometric and statistical techniques. Loads throughout the year are typically estimated by multiplying the peak by a matrix of proportions between 0 and 1 called a "load profile". Sanity checks of such profiles are appropriate to insure that hour-to-hour, day-to-day and week-to-week changes are not unreasonably large and that seasonal variations are appropriate. For instance, August and January peak loads are higher than May or October.

Not all uses of electricity are equally valued by the customers. Historically some customers have been willing to accept postponing a portion of their use in exchange for a reduction of their rate. This is referred to as Demand Side Management ("DSM"). While this can reduce the need to build generating capacity it should be recognized that it is only effective if the customer would have that type of load in the absence of DSM; interrupting air conditioners in January will not reduce load significantly.

Taking the above factors into account, a probability distribution of load and a probability distribution of available capacity can be estimated for a particular future time. When combined, a generator distribution and a load distribution imply a probability distribution of reserves. The probability of negative reserves, or lost load, is termed the Loss of Load Probability (LOLP) and the expected shortfall is termed the Loss of Expected Energy (LOEE), in megawatt hours. These metrics can be calculated for a single hour, but the more relevant metric is LOLP and LOEE for an entire year. The method for an annual calculation is described below.

1.2 Loss of Load Expectation

If the probabilistic analysis described above is repeated for all 365 days in the year, daily probabilities of negative reserves can be interpreted as "days per year" of lost load, and summed to give a value of Loss of Load Expectation in days per year. An accepted target value in North America is 0.1 *d*ay per year. As a practical matter, daily LOLP values are highest near seasonal load peaks and may be negligible for much of the rest of the year.

Analysis may be further refined by considering hourly loads rather than daily peak loads, as was done in this study. In such an approach, the implicit assumption of the approach outlined above, that the distribution of available generating capacity on each day is statistically independent of the previous and subsequent days, becomes unsupportable. The average duration of forced outages is on the order of hours, so while assuming independence of available capacity on successive daily peaks may be plausible assuming independence on successive hours is not.

1.3 Sequential Monte Carlo Methods

The Multi-Area Reliability Simulation (MARS) program licensed by General Electric (GE), utilizes a Monte Carlo technique to estimate LOLE and LOEE for a portion of the power system. This technique uses repeated trials with the values of random variables, such as the start time and end time of a generator outage, set by a random number generator. The numbers of days and hours having a loss of load, and energy not served, are recorded, and at each iteration cumulative averages are calculated. In the current project 2000 model iterations were run for each case considered.

GE MARS uses sequential Monte Carlo techniques to address the issue of lack of independence of successive generating capacity outcomes. The transitions from one capacity state to another of each generating unit are assumed to be a Poisson process, which means that the rate of transitions is independent of the time the unit has been in its current state, and the distribution of state "dwell times" is exponential.

The GE MARS program has been widely accepted in the industry for a variety of LOLE studies. It is the most widely used program for that purpose in North America today.

2 GENERATING UNIT POPULATION AND PARAMETERS

There are five major components of generating unit input data for this study:

- The population of generating units in the area to be analyzed;
- Forced outage data, based on national averages for comparable units from the NERC GADS survey of generating unit performance;
- A maintenance requirement in weeks per year for each unit;
- Wind, hydro and solar characteristics; and
- Import and export capability

Each of these components is described further below.

2.1 Generating Unit Data

A population of generating units in Missouri was developed by Mr. Neil Copeland of GDS Associates, Inc. for his testimony concerning the production simulation analyses in consideration of the Grain Belt Express Project. This unit population was based on the MISO "Business as Usual" scenario for 2022 from the 2015 MISO Transmission Expansion Plan (MTEP) model. The same population of generating units was used in this analysis. This generator population, as provided by Grain Belt Express witness Mr. Copeland, was used with minor modification, primarily in separating equivalent models of the entire Keokuk, Osage and Taum Sauk hydro and pumped storage plants into individual unit models.

The MISO power flow cases for various scenarios commonly include Regional Resource Forecast ("RRF") units representing unidentified future capacity required to attain appropriate reliability or other goals. The solar plant discussed in Section below is such a resource. A second RRF combustion turbine unit of 600 MW was also included in this analysis since the unit was included in the MTEP15 power flow model. This RRF unit was included to address a perceived capacity shortfall in Load Resource Zone Five (LRZ 5) which includes Ameren Missouri and the City of Columbia. The capacity of this RRF unit was reduced to 75 MW due to the retirement of the 475 MW of Noranda aluminum smelter load plus the associated 12% reserves that would be required to ensure service to the Noranda load.

MISO made certain assumptions about retirements across the Eastern Interconnection and has shut down capacity and added it back via RRF units without consulting the neighboring regions. In our particular case they have added a 600 MW RRF combined cycle unit in Empire District Electric's (EMDE) territory to meet projected resource requirements of the SPP region based on the MISO assumption of how much capacity would be retired in SPP. MISO sites RRF units based on an algorithm which considers the approximate injection capability at various nodes on the transmission system. In the case of the RRF unit sited in the EMDE system, there was no correlation between siting the unit in Missouri in general and EMDE in particular. It was a proxy generator added to meet the regional resource requirements of SPP. Including this 600 MW RRF unit in the State of Missouri, with no direct connection to the resource requirements of any Missouri utility, would have skewed the LOLE results based on the presence of a capacity resource not designated by a Missouri utility.2.6

The MW capacity of units of each type, by owner, is shown in Table 2-1.

QUANTA TECHNOLOGY

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Table 2-1 Generating Unit Population

Area	CC	Conven-tional Hydro	CT Gas	CT Oil	IC Gas	IC Oil	IC Renew-able	Nuclear	Pumped Storage Hydro	Solar PV	ST Coal	ST Gas	Wind	Total
Ameren Missouri		373	3435	350			18	1224	400		4650	274		10724
Associated Electric Cooperative Inc.	492	85	608	45					31		2270		308	3839
City Power & Light Independence			89	68										157
City Utilities Springfield Missouri			375				3				282			660
Columbia Missouri Water and Light Department			237	42		16						35		330
Empire District Electric Co.	1100	16	409								189			1714
Kansas City Power & Light Co.	292		639	520	39					25	3547		249	5310
KCPL-Greater Missouri (MPS)	693		797	61			3				333	38		1925
MidAmerican Energy Co.													146	146
South Mississippi Electric Power Association											658			658
Westar Energy/Western Resources											2164			2164
Total	**2577**	**474**	**6589**	**1087**	**39**	**16**	**24**	**1224**	**431**	**25**	**14093**	**347**	**703**	**27627**

2.2 Unit Forced Outages

Each unit was assumed to have two capacity states, fully on and fully off. Forced outage rate and duration values were also compiled by Mr. Copeland from the generation database using in his production simulation analyses. A summary of average values for each unit type is shown in **Error! Not a valid bookmark self-reference.**. Transition rates were calculated by the following equations.

$$\lambda = \frac{FOR}{FOD * (1 - FOR)}$$

$$\mu = {}^{1}/_{FOD}$$

Where:

λ = rate of forced outage transitions, events per hour

FOR = Forced Outage Rate as a fraction

FOD = Forced Outage Duration, hours

μ = rate of restorations, events per hour

Table 2-2 Generating Unit Forced Outage Performance

Type	Forced Outage Rate (%)	Forced Outage Duration (Hrs)
CC	5.44	31
Conventional Hydro	0.50	24
CT Gas	4.36	58
CT Oil	5.78	58
IC Gas	4.20	12
IC Oil	4.79	12
IC Renewable	3.60	12
Nuclear	4.02	168
Pumped Storage Hydro	0.00 (1)	N/A
Solar PV	0.00	24
ST Coal	7.78	46
ST Gas	7.70	75
Wind	0.00	24

(1) GE MARS does not support forced outages of energy storage units.

2.3 Unit Maintenance

Average unit maintenance requirements, in hours per year, were also obtained from Mr. Copeland's data. In accordance with GE MARS data entry formats, these were rounded to the nearest week.

Table 2-3 Generating Unit Maintenance Requirements

Type	Hours per year
CC	355
Conventional Hydro	535
CT Gas	369
CT Oil	402
IC Oil	201
Interruptible Loads	0
Nuclear	Specific 5 week schedule
Pumped Storage Hydro	672
Solar PV	0
ST Coal	845
ST Gas	537
Wind	0

2.4 Missouri Internal Wind Generation

Many system operators assign a relatively low capacity benefit to wind turbines, recognizing that they cannot be depended on to deliver maximum power at peak times even when they are mechanically in good order. GE MARS permits recognizing this by entering a set of eleven probabilities for output states at increments of 10% of total capacity, from 0% to 100%. In this study it was assumed that each wind plant located in Missouri had a probability of 0.20 (20%) of being at zero output, 0.50 (50%) of being at 10% or less, and 1.00 (100%) of being at 20% or less of nameplate rating. This represents a capacity benefit of 13%[1]:

$$0\% \ x \ 0.2 + 10\% \ x \ (0.5 - 0.2) + 20\% \ (1.0 - 0.5) = 0\% + 3\% + 10\% = 13\%$$

Note that variations at different wind plants are assumed to be independent.

2.5 Pumped Storage Hydro Generation

Pumped storage units must use considerably more energy in pumping water to the upper reservoir than can be recovered during periods when they are generating. It was assumed that the Clarence Cannon Dam plant had a daily cycle of 8 hours pumping at 35 MW, 6 hours generating at 31 MW, while each of the two Taum Sauk units had sixteen hours of pumping followed by eight hours of generating, both at 200 MW.

[1] This corresponds with the 12.4% value assigned to Zone 4 and 5 wind facilities by MISO in the December 2015 Wind Capacity Credit report. *Planning Year 2016-2017 Wind Capacity Credit, MISO, December 2015, (available at):* https://www.misoenergy.org/Library/Repository/Report/2016%20Wind%20Capacity%20Report.pdf.

All pumped storage units were modeled such that their full capacity was available across the peak load hours and the pumping load occurred off-peak.

2.6 Solar Generation

There are no utility-scale solar plants in Missouri represented in the generation database in MISO at this time, but it was assumed that one will be built to address renewable energy goals. It was assumed that its output was maximum for a four hour period in midday, zero for a 10 hour period overnight, and linearly increasing in the morning and decreasing in the afternoon and early evening. This reflects summer conditions when reserves are tight.

2.7 Imports

The Missouri system is not an electrical island. Units outside Missouri are contracted to supply Missouri load, while units inside Missouri are contracted to supply external loads. The Eastern Interconnection Reliability Assessment Group (ERAG) builds power flow models of the eastern interconnection through its Multi-Regional Modeling Working Group (MMWG). Data published as part of this effort includes a detailed tabulation of capacity transactions between utilities. This tabulation of transactions includes the external resources and obligations which have been mutually agreed to by each utility in the Eastern Interconnection and make up the net scheduled interchange between regions. These transactions result in a net scheduled import of 2337 MW of external designated resources to supply Missouri load:

- External coal 344 MW
- External gas 4 units at 75 MW each, 1 unit at 85 MW
- External hydro 3 units at 289 MW each
- External wind 1 unit at 100 MW, 1 unit at 75 MW
- External Nuclear 566 MW of Wolf Creek Nuclear Plant

The Grain Belt Express Project was modeled as a 500 MW import within the State of Missouri. The Grain Belt Express Project will enable transmission of more than 4,000 MW of new wind generation resources from the Kansas converter station allowing for delivery of up to 500 MW of power to MISO and 3,500 MW of power to PJM. In addition, the Grain Belt Express Project's Kansas converter station will connect to the SPP system, as described in the direct testimony of Grain Belt Express witness Dr. Galli. This will provide the State of Missouri with access to diverse resources from the roughly 79,000 MW of installed capacity in the SPP integrated market in addition to the wind resources which are directly connected to the Grain Belt Express Project. The Grain Belt Express Project's Illinois converter station will connect to the PJM system in Indiana, also as described in the direct testimony of Grain Belt Express witness Dr. Galli. This will provide the State of Missouri with access to additional generation resources from the approximately 185,000 MW of diverse, installed capacity in the PJM integrated market.

Therefore, due to the design of the Grain Belt Express Project, Missouri has access to over 265,000 MW of capacity causing the Missouri terminal to be virtually guaranteed to be capable to deliver 500 MW of capacity at any given time subject to the operating arrangements implemented by Grain Belt Express and the interconnecting utilities. The means by which Load Serving Entities will be able to obtain access to the supplemental generation resources in the SPP and/or PJM regions is described in the direct testimony of Grain Belt Express witness Dr. Galli. The geographic diversity of the SPP, MISO, and PJM regions and the diverse resource mixes that these regions manage through their energy and capacity markets, coupled with the wind generation resources that will be enabled by the Grain Belt Express Project, the assumption that, during capacity emergencies which would lead to a loss of load, the Missouri converter station will be able to deliver the rated capacity of 500 MW to the State of Missouri.

2.8 Exports

In a similar fashion, and based on the same ERAG MMWG net scheduled interchange tables, the capacities of certain units in Missouri or owned by Missouri utilities were adjusted, as they are partly committed to serving load outside Missouri.

- Dogwood 3 Reduced from 693 MW to 593 MW
- State Line 3 Reduced from 500 MW to 300 MW
- Lacygne 2 Reduced from 700 MW to 0 MW

3 DEMAND

Mr. Copeland supplied a load profile with a maximum (peak) of 18064 MW, based on the load represented at Missouri buses at Missouri buses in the MISO power flow case. This was increased by 476 MW (2.6%) to account for firm exports identified exports identified in the ERAG MMWG net scheduled interchange data as described above, and a further 445 MW (2.4%) for 445 MW (2.4%) for transmission losses based on the MTEP peak power flow model and which are part of the resource the resource obligation of Load Serving Entities. Based on the dataset supplied, the peak was identified as occurring in the as occurring in the hour ending at 5 PM on July 22, 2022. Monthly peaks were as shown in

Table 3-1.

Table 3-1 Monthly Peak Loads before adjustment

Month	Peak Load	%
January	12496	66%
February	13627	72%
March	11779	62%
April	11814	62%
May	13831	73%
June	16199	85%
July	18949	100%
August	18762	99%
September	14034	74%
October	14485	76%
November	12937	68%
December	14191	75%

4 RESULTS

The calculated indices for the state of Missouri in the year 2022, without and with the Grain Belt Express Project, are as shown in Table 4-1.

Table 4-1 2022 Missouri Reliability Indices

	Without Grain Belt Express Project	With Grain Belt Express Project	Impact of Grain Belt Express Project (%)
	Year Total	Year Total	Year Total
LOLE (days)	.013	.004	-69%
LOLE (hours)	.040	.014	-65%
LOEE (MWH)	18.8	6.5	-65%

The Grain Belt Express Project has a substantial favorable effect on the reliability of electric service in Missouri. The primary measures of reliability are each improved by approximately 65 – 70%.

2016 OMS MISO Survey Results

Furthering our joint commitment to regional resource assessment and transparency in the MISO region, OMS and MISO are pleased to announce the results of the 2016 OMS MISO Survey

June 2016

OMS – MISO Survey Executive Summary

MISO Region is projected to have adequate resources to meet its Planning Reserve Requirement for 2017; additional action will be needed to ensure sufficient resources are available going forward

For 2017,

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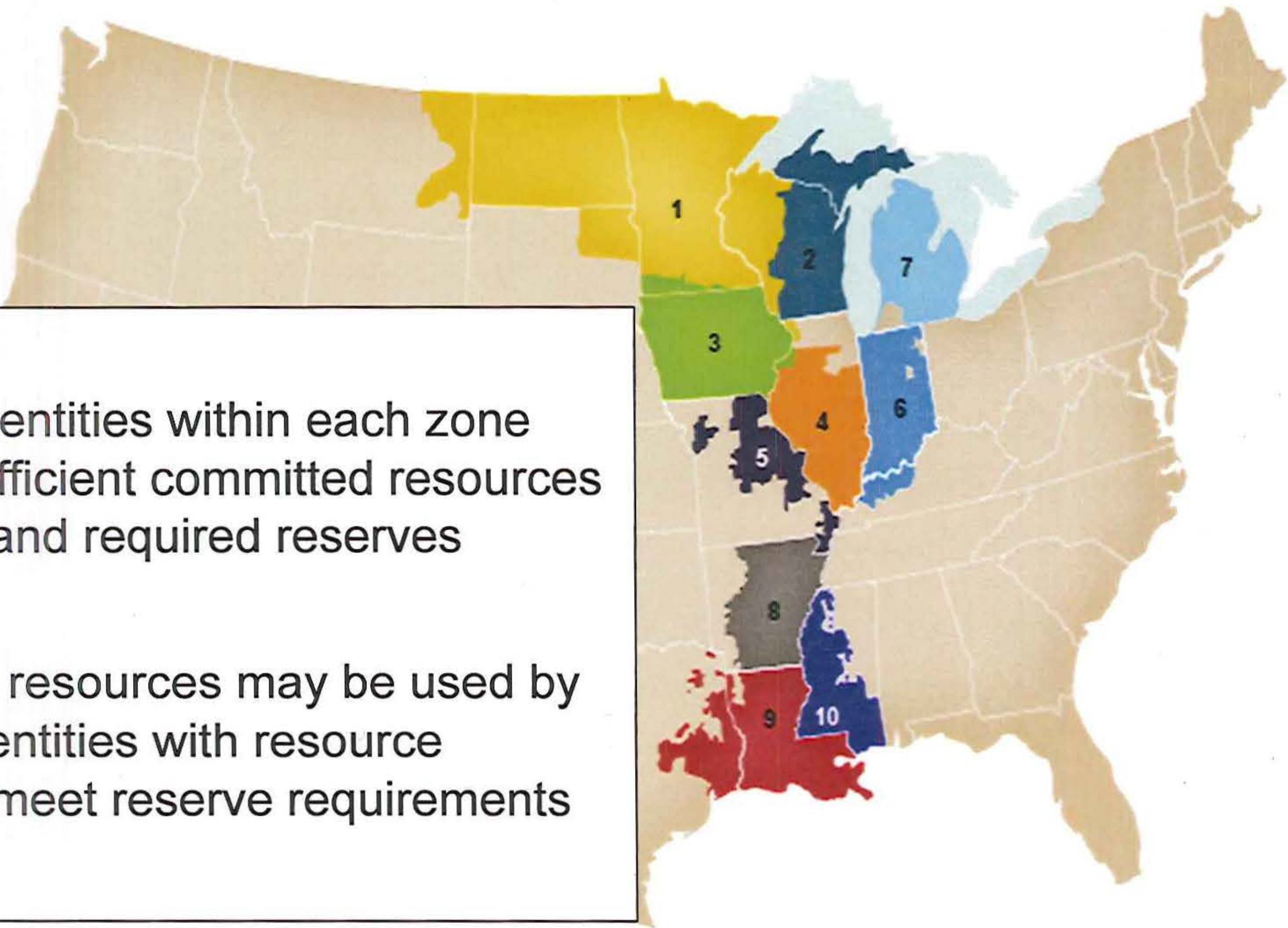
- Recent publicly announced retirements decrease this excess to 0.9 GW (0.7%)
- Several zones are below their resource requirement and will rely on imports
- Demand has shrunk due to reduced forecasts and point load reductions
- Supply has declined due to plant retirements in excess of new resource additions

Beyond 2017,

- Continued resource adequacy will depend on uncommitted resources or resources with potential retirements
- Continued commitment to firming up planned generation interconnections through the MISO process will also be required
- This outlook depends heavily on load projections; current forecasts of modest load growth are not in line with recent history of flat year-to-year loads

Understanding Resource Adequacy Requirements



- Load serving entities within each zone must have sufficient committed resources to meet load and required reserves

- Uncommitted resources may be used by load serving entities with resource shortages to meet reserve requirements

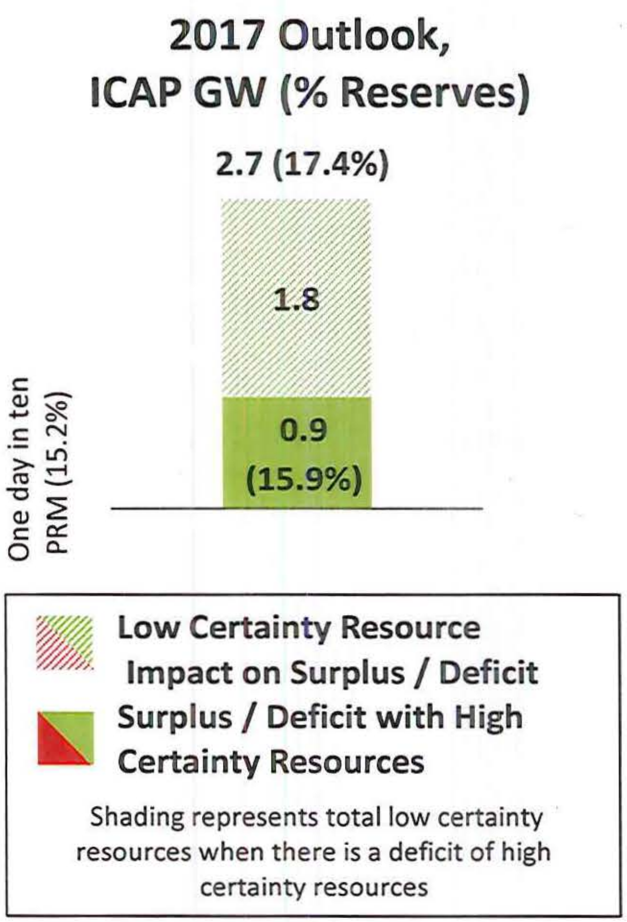
Understanding Resource Availability

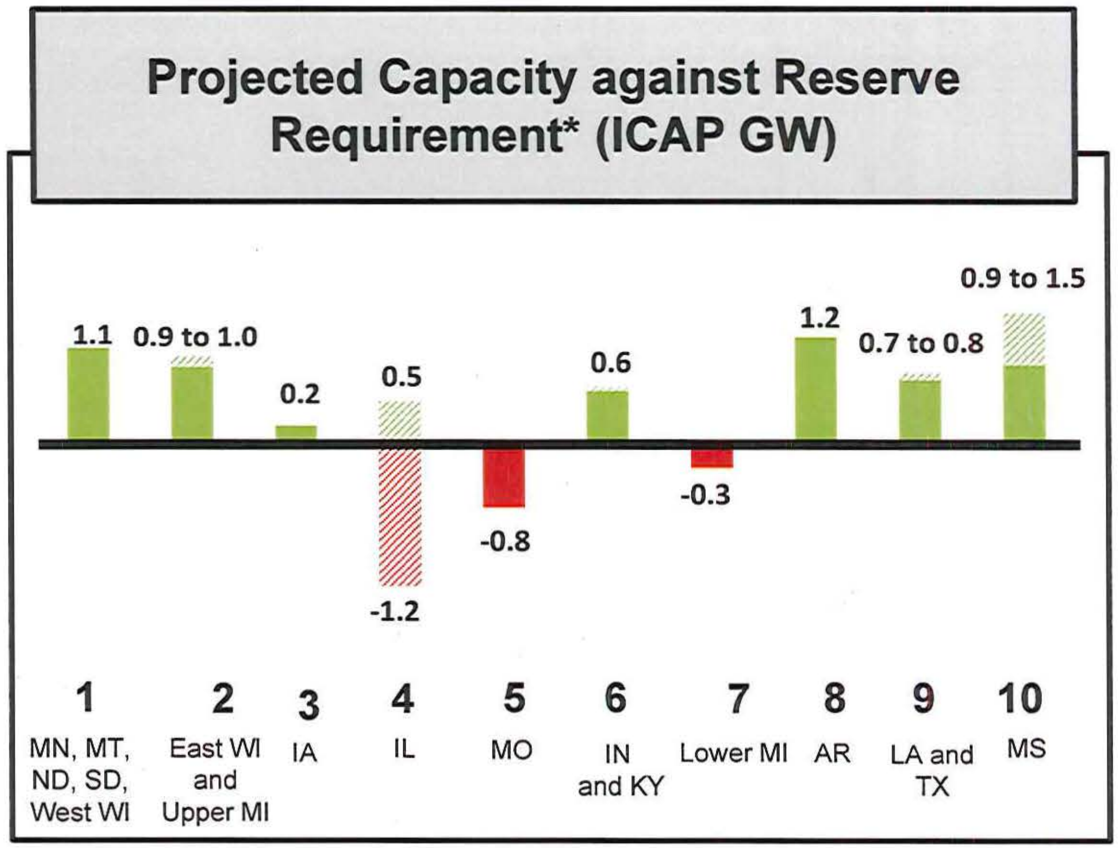
- **High Certainty Resources** are committed to serving MISO load
  - Resources within the rate base of MISO utilities
  - New generators with signed interconnection agreements
  - External resources with firm contracts to MISO load

- **Low Certainty Resources** may be available to serve MISO load but do not have any firm commitments to do so
  - Most of these resources are potential retirements or suspensions

- **Unavailable resources** are not included in the survey totals
  - Resources with firm commitments to non-MISO load
  - Units with finalized retirements or suspensions
  - Potential new generators without a signed Generator Interconnection Agreement

In 2017, modest excess capacity is projected to address zonal deficits



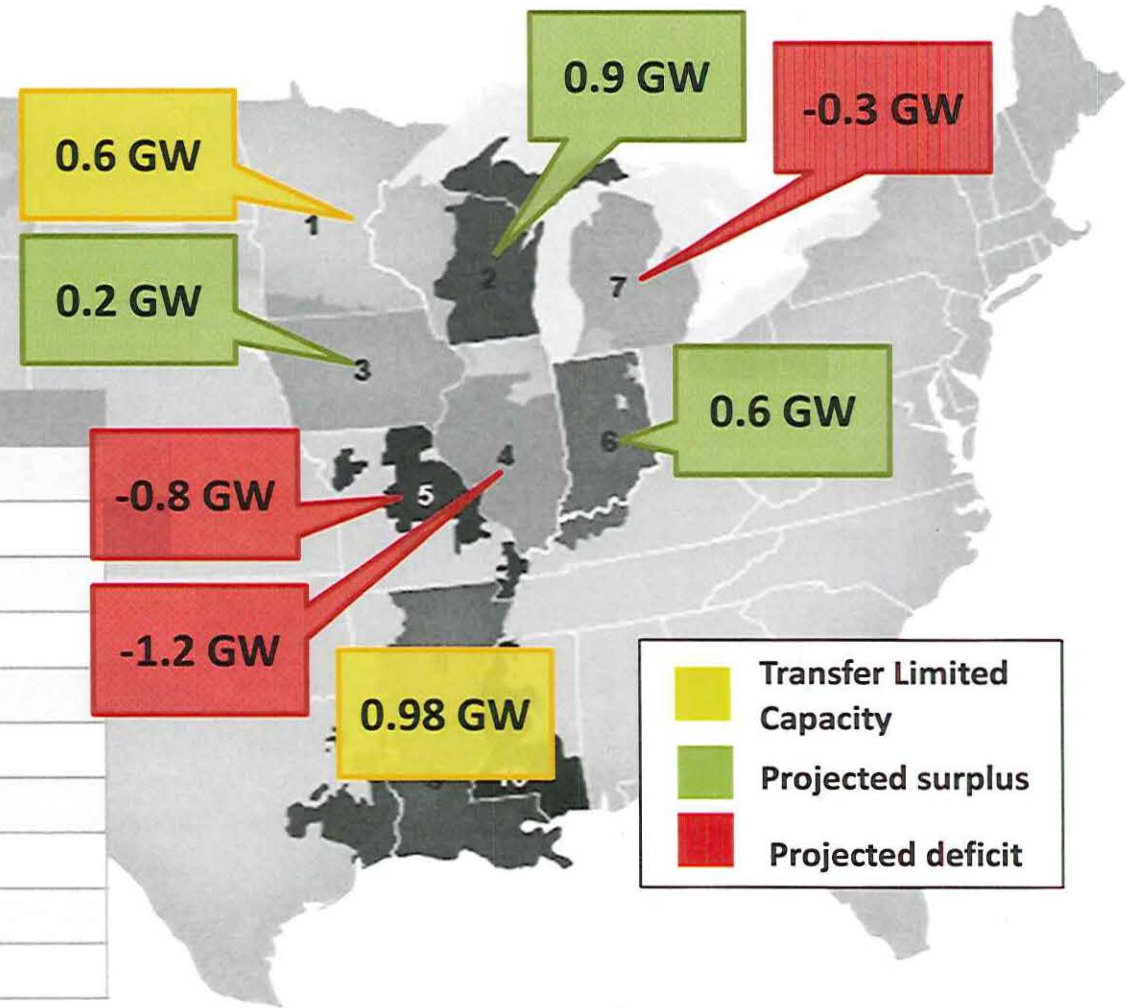


*Positions include reported inter-zonal transfers
Publicly announced potential retirements as of June 1, 2016 were included as low certainty resources
Exports from Zone 1 were limited by the zone's Capacity Export Limit to 0.6 GW
Exports from Zone 8, 9, and 10 were limited by the Subregional Power Balance Constraint to 0.98 GW

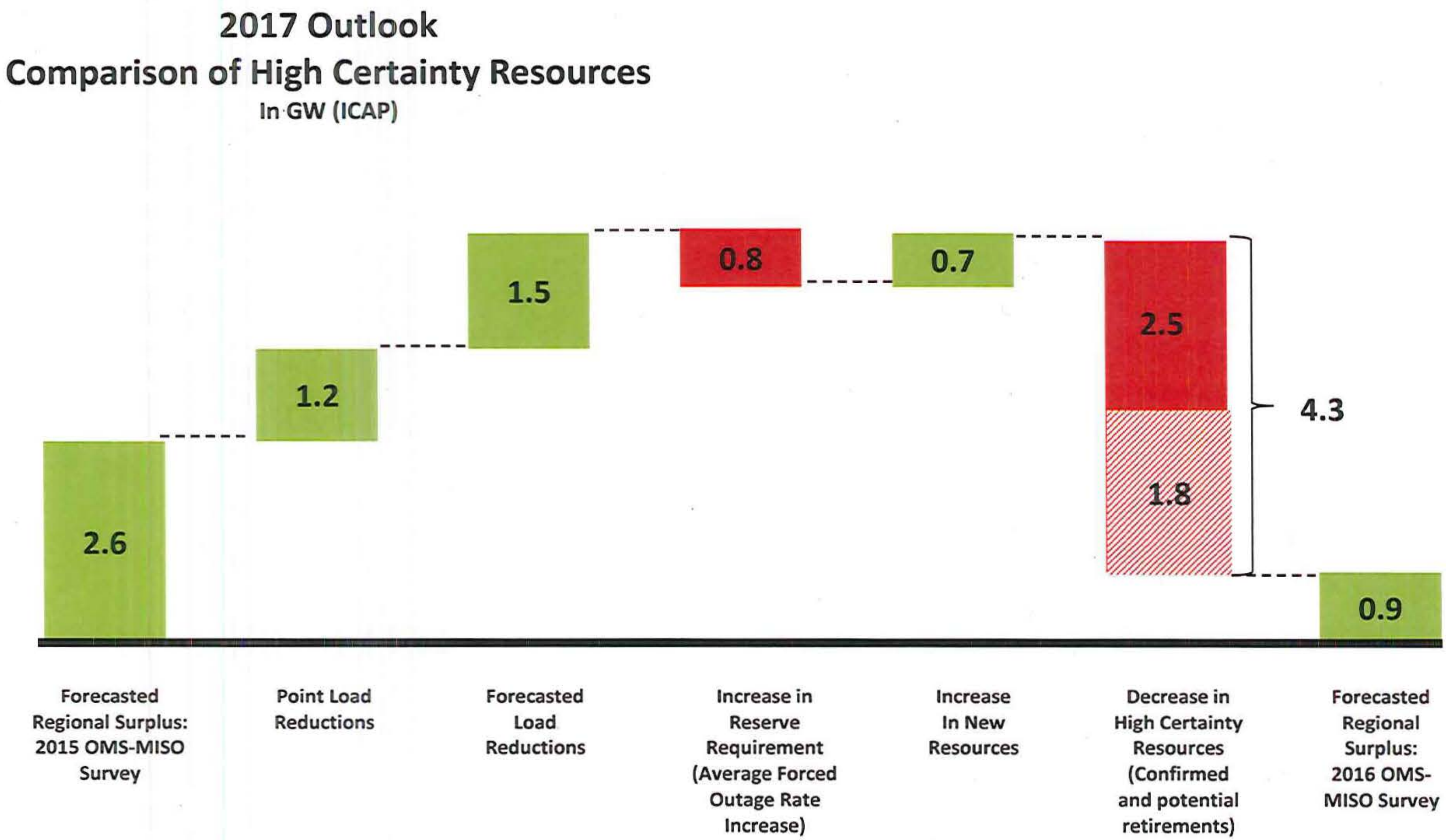
For 2017, all projected capacity is not available to serve load outside of its zone due to transfer limitations

2017 High Certainty Resources Available to Support Other Zones (ICAP)

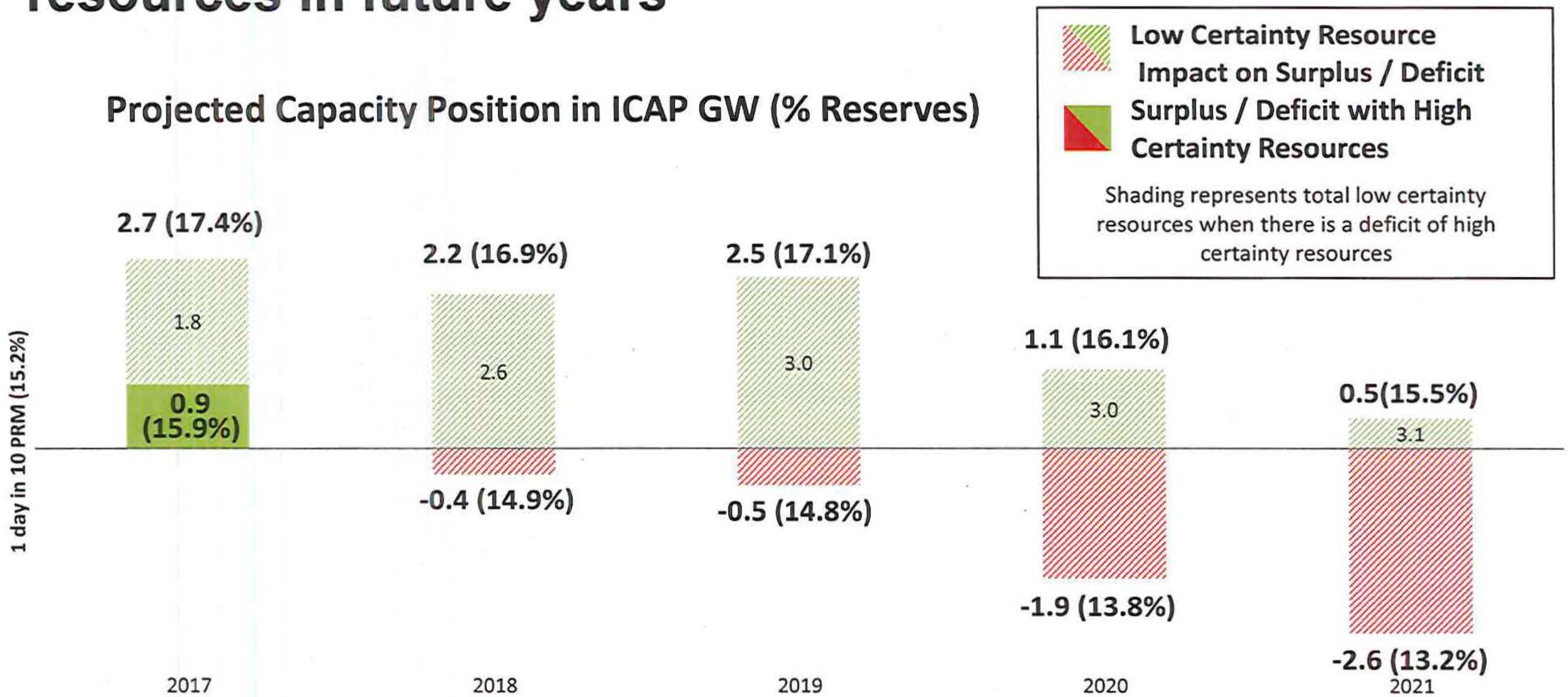
LRZ	Local Balancing Authorities
1	DPC, GRE, MDU, MP, NSP, OTP, SMP
2	ALTE,MGE,MIUP, UPPC, WEC, WPS
3	ALTW, MEC, MPW
4	AMIL, CWLP, SIPC
5	AMMO, CWLD
6	BREC, DUK(IN), HE, IPL, NIPSCO, SIGE
7	CONS, DECO
8	EAI
9	CLEC, EES, LAFA, LAGN, LEPA
10	EMI, SME



The 2017 results show the impacts of potential or actual generation retirements, as well as changes in load

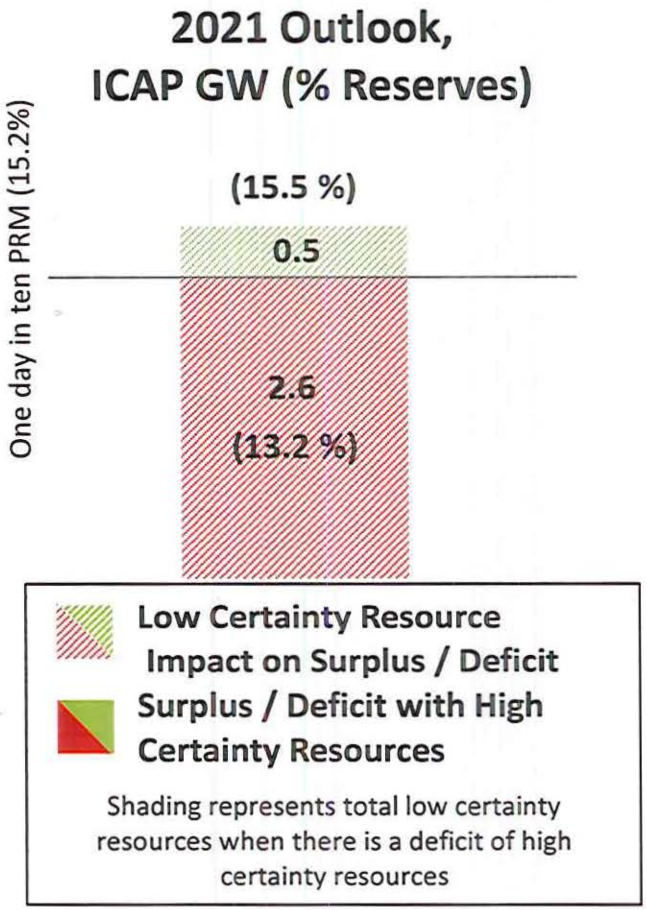


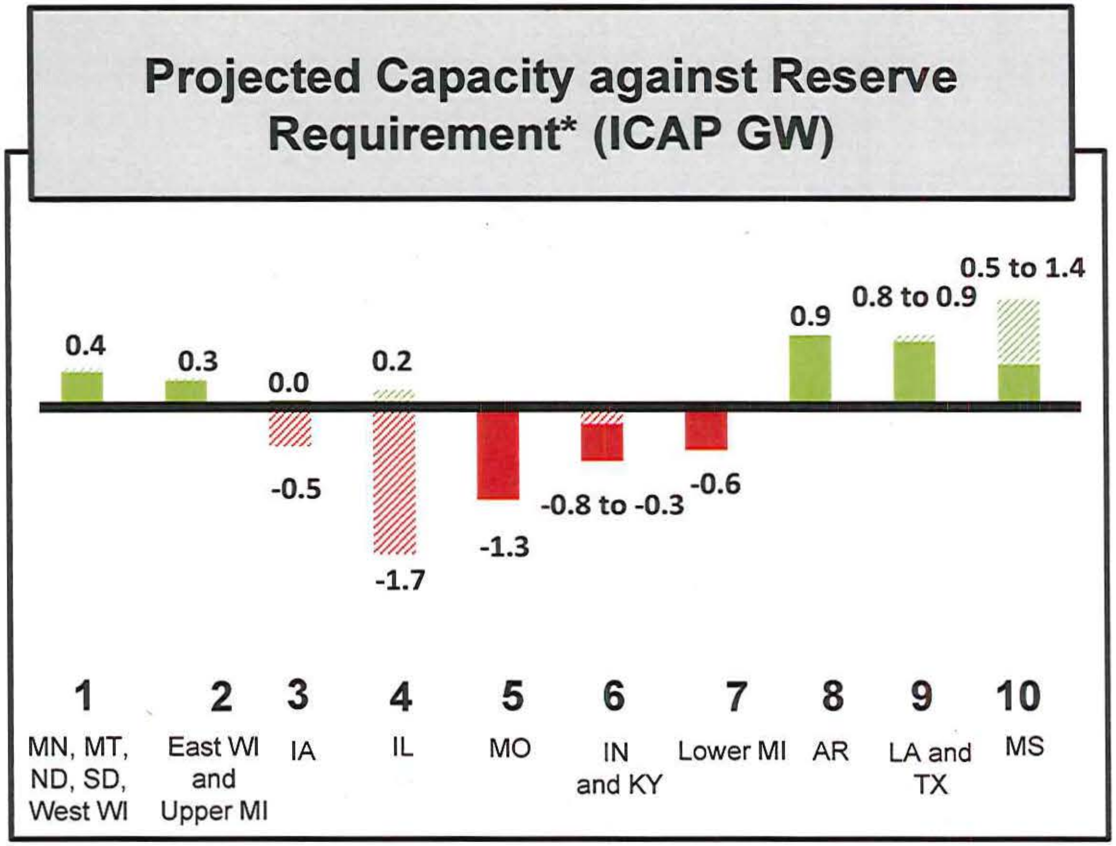
Action is required in the near term to ensure sufficient resources in future years



- Regional outlook includes projected constraints on capacity, including Capacity Export Limits and the Subregional Power Balancing Constraint
- Resources with publicly announced potential retirements or suspensions as of June 1, 2016 were counted as low certainty.
- These figures will change as future capacity plans are solidified by load serving entities and state commissions.

2021 Capacity Projections

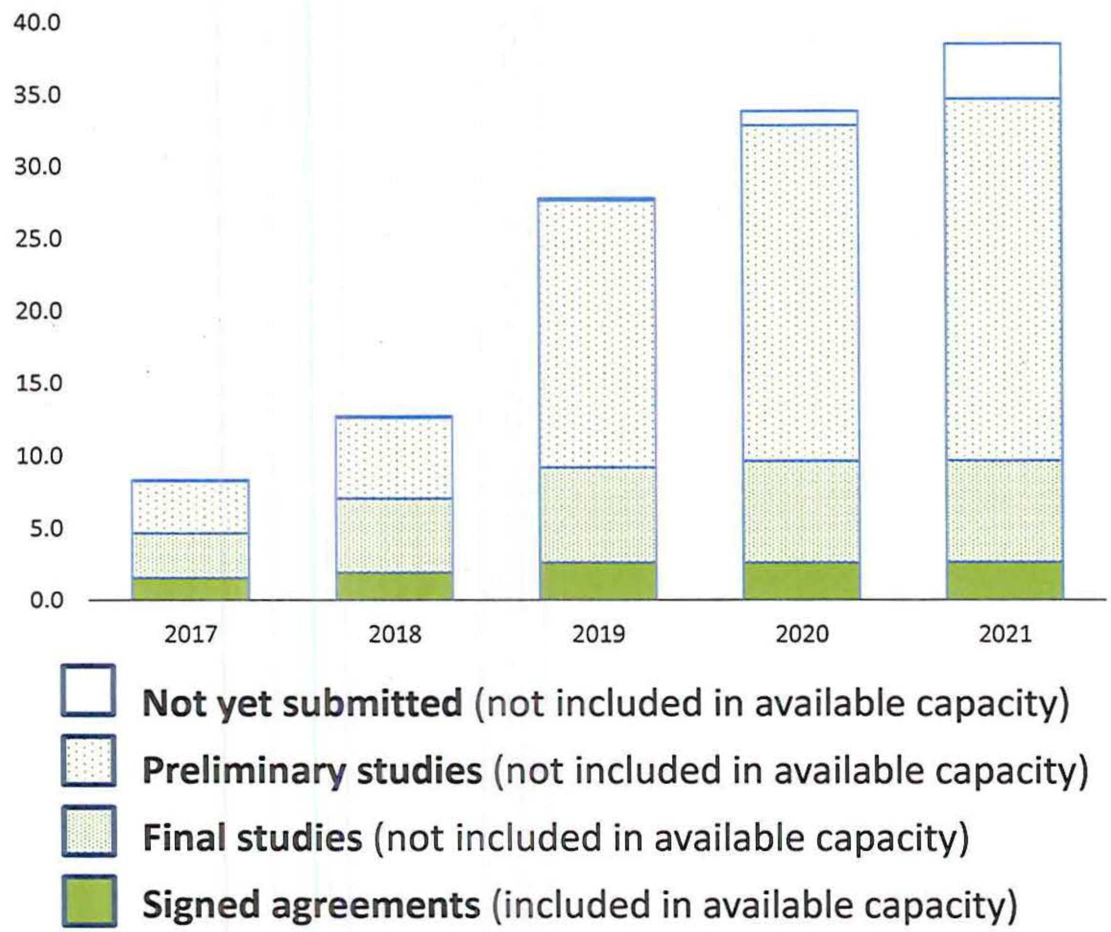


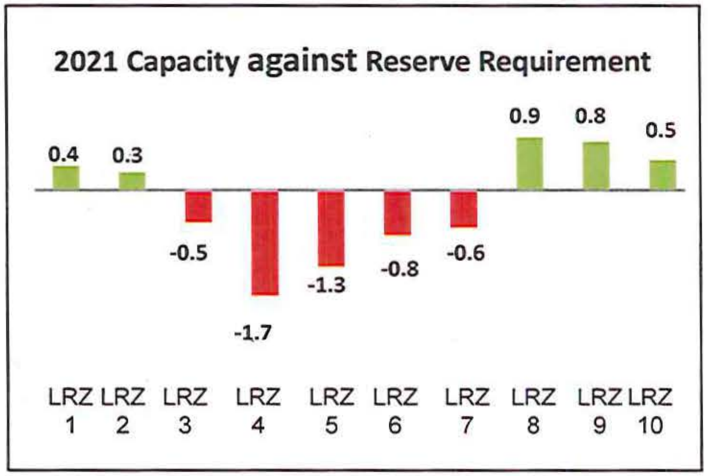


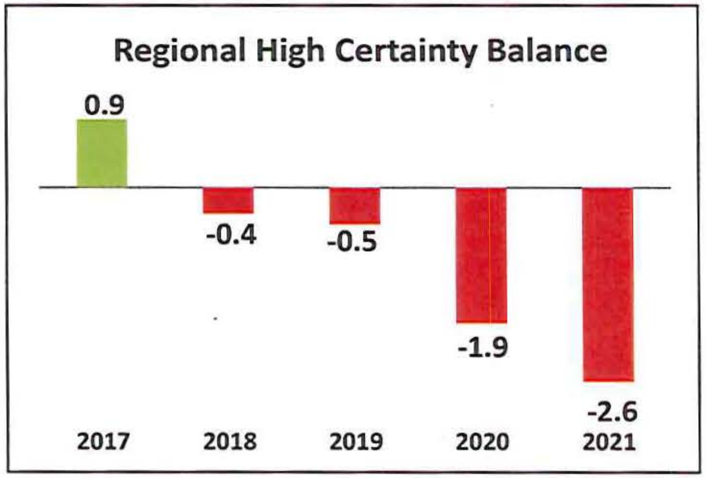
*Positions include reported inter-zonal transfers
Publicly announced potential retirements as of June 1, 2016 were included as low certainty resources
Exports from Zone 8, 9, and 10 were limited by the Subregional Power Balance Constraint to 1.5 GW

Continued commitment to firming up planned generation interconnections through the MISO process will be required

Potential Generation Additions, in GW*







MISO

* Wind and solar resources are represented at their expected capacity credit

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Appendix

Survey Improvements

- **Documentation and survey format**
  - Survey documentation created and reviewed with stakeholders
  - Improvements made to format of the survey requests and the resulting balance sheet to reduce the burden on respondents
- **Data collection**
  - Surveys sent to Load Serving Entities and Independent Power Producers
  - Load forecasts were aligned with the load submissions used in the most recent Planning Resource Auction
- **Post-Processing**
  - Separation of Zone 4 and Zone 5 results
  - Aligned survey results with publically announced potential suspensions and retirements