Table of Contents

Preface

SECTION 1 Introduction
Q2 2021 in Review
PJM Market Summary Statistics
PJM Market Background
Conclusions
Energy Market Conclusion
Capacity Market Conclusion
Tier 2 Synchronized Reserve Market Conclusion
Day-Ahead Scheduling Reserve Market Conclusion
Regulation Market Conclusion
FTR Auction Market Conclusion
Role of MMU
Reporting
Monitoring
Market Design
New Recommendations
New Recommendation from Section 3, Energy Market
New Recommendation from Section 4, Energy Uplift
Total Price of Wholesale Power
Components of Total Price
Section Overviews
Overview: Section 3, Energy Market
Overview: Section 4, Energy Uplift
Overview: Section 5, Capacity Market
Overview: Section 6, Demand Response
Overview: Section 7, Net Revenue
Overview: Section 8, Environmental and Renewables
Overview: Section 9, Interchange Transactions
Overview: Section 10, Ancillary Services
Overview: Section 11, Congestion and Marginal Losses

Overview: Section 12, Planning	
Overview: Section 13, FTRs and ARRs	

i

SECTION 2 Recommendations	81
New Recommendations	81
New Recommendation from Section 3, Energy Market	82
New Recommendation from Section 4, Energy Uplift	82
Complete List of Current MMU Recommendations	82
Section 3, Energy Market	82
Section 4, Energy Uplift	86
Section 5, Capacity Market	88
Section 6, Demand Response	91
Section 7, Net Revenue	93
Section 8, Environmental and Renewables	93
Section 9, Interchange Transactions	94
Section 10, Ancillary Services	95
Section 11, Congestion and Marginal Losses	97
Section 12, Planning	97
Section 13, FTRs and ARRs	99

SECTION 3 Energy Market

Overview	104
Supply and Demand	104
Competitive Assessment	106
Recommendations	108
Conclusion	112
Supply and Demand	116
Market Structure	116
Market Behavior	132
Generator Offers	132
Parameter Limited Schedules	135
Virtual Offers and Bids	140

Market Performance	150
LMP	150
Zonal LMP and Dispatch	170
Fuel Prices, LMP, and Dispatch	176
Components of LMP	184
Shortage	187
Emergency Procedures	188
Shortage and Shortage Pricing	191
Competitive Assessment	202
Market Structure	202
Market Behavior	207
Market Performance	233
Market Structure, Participant Behavior, and Market Performance	244

SECTION 4 Energy Uplift (Operating Reserves)	
--	--

Overview	247
Energy Uplift Credits	247
Energy Uplift Charges	248
Geography of Charges and Credits	248
Recommendations	248
Conclusion	250
Energy Uplift Credits Results	252
Characteristics of Credits	253
Types of Units	253
Day-Ahead Unit Commitment for Reliability	254
Balancing Operating Reserve Credits	256
Lost Opportunity Cost Credits	258
Uplift Eligibility	260
Economic and Noneconomic Generation	261
Uplift Resettlement	262
Concentration of Energy Uplift Credits	262
Credits and Charges Categories	266
Energy Uplift Charges Results	267

Energy Uplift Charges	267
Operating Reserve Rates	270
Reactive Services Rates	273
Balancing Operating Reserve Determinants	274
Geography of Charges and Credits	275
Energy Uplift Issues	276
Intraday Segments Uplift Settlement	276
Uplift Credits and Offer Capping	277
SECTION 5 Capacity Market	279
Overview	280
RPM Capacity Market	280
Reliability Must Run Service	281
Generator Performance	281
Recommendations	281
Conclusion	284
Installed Capacity	288
Fuel Diversity	290
RPM Capacity Market	291
Market Structure	292
Market Conduct	304
Market Performance	309
MOPR and FRR	314
CRF Issue	316
Timing of Unit Retirements	318
Reliability Must Run (RMR) Service	318
Generator Performance	320
Capacity Factor	320
Generator Performance Factors	321
Generator Forced Outage Rates	323

SECTION 6 Demand Response	327
Overview	327
Recommendations	328
Conclusion	329
PJM Demand Response Programs	332
Non-PJM Demand Response Programs	333
PJM Demand Response Programs	333
Emergency and Pre-Emergency Load Response Programs	334
Economic Load Response Program	346
Energy Efficiency	354
Distributed Energy Resources	355
SECTION 7 Net Revenue	357
Overview	357
Net Revenue	357
Recommendations	357
Conclusion	357
Net Revenue	357
Spark Spreads and Dark Spreads	358
Theoretical Energy Market Net Revenue	360
New Entrant Combustion Turbine	362
New Entrant Combined Cycle	363
New Entrant Coal Plant	363
New Entrant Nuclear Plant	364
New Entrant Diesel	364
New Entrant Onshore Wind Installation	365
New Entrant Offshore Wind Installation	365
New Entrant Solar Installation	365
Historical New Entrant CC Revenue Adequacy	366
Nuclear Net Revenue Analysis	367

SECTION 8 Environmental and Renewable Ener Regulations	375
Overview	375
Federal Environmental Regulation	375
State Environmental Regulation	376
State Renewable Portfolio Standards	376
Emissions Controls in PJM Markets	377
Renewable Generation	377
Recommendations	377
Conclusion	377
Federal Environmental Regulation	379
CAA: NESHAP/MATS	380
CAA: NAAQS/CSAPR	380
CAA: NSR	382
CAA: RICE	383
CAA: Greenhouse Gas Emissions	383
CWA: WOTUS Definition and Effluents	384
RCRA: Coal Ash	385
State Environmental Regulation	387
State Emissions Regulations	387
State Regulation of Greenhouse Gas Emissions	387
State Renewable Portfolio Standards	393
Alternative Compliance Payments	407
Emission Controlled Capacity and Emissions	411
Emission Controlled Capacity	411
Emissions	412
Renewable Energy Output	414
Wind and Solar Peak Hour Output	414
Wind Units	415
Solar Units	418

Primary Reserve

Price and Cost

Market Structure

SECTION 9 Interchange Transactions

Overview	421
Interchange Transaction Activity	421
Interactions with Bordering Areas	422
Recommendations	422
Conclusion	423
Interchange Transaction Activity	424
Charges and Credits Applied to Interchange Transactions	424
Aggregate Imports and Exports	426
Real-Time Interface Imports and Exports	428
Real-Time Interface Pricing Point Imports and Exports	429
Day-Ahead Interface Imports and Exports	432
Day-Ahead Interface Pricing Point Imports and Exports	434
Loop Flows	438
PJM and MISO Interface Prices	446
PJM and NYISO Interface Prices	448
Summary of Interface Prices between PJM and Organized Markets	450
Neptune Underwater Transmission Line to Long Island, New York	450
Linden Variable Frequency Transformer (VFT) facility	452
Hudson Direct Current (DC) Merchant Transmission Line	454
Interchange Activity During High Load Hours	455
Operating Agreements with Bordering Areas	455
PJM and MISO Joint Operating Agreement	456
PJM and New York Independent System Operator Joint Operating	
Agreement (JOA)	458
PJM and TVA Joint Reliability Coordination Agreement (JRCA)	459
PJM and Duke Energy Progress, Inc. Joint Operating Agreement	459
PJM and VACAR South Reliability Coordination Agreement	460
VACAR Reserve Sharing Agreement	460
Balancing Authority Operations Coordination Agreement between	
Wisconsin Electric Power Company (WEC) and PJM	
Interconnection, LLC	460
Northeastern ISO-Regional Transmission Organization Planning	
Coordination Protocol	460

Interchange Transaction Issues	460
PJM Transmission Loading Relief Procedures (TLRs)	460
Up To Congestion Transactions	461
Sham Scheduling	464
Elimination of Ontario Interface Pricing Point	465
PJM and NYISO Coordinated Interchange Transactions	466
Reserving Ramp on the PJM/NYISO Interface	470
PJM and MISO Coordinated Interchange Transaction Proposal	470
Willing to Pay Congestion and Not Willing to Pay Congestion	473
Spot Imports	474
Interchange Optimization	475
Interchange Cap During Emergency Conditions	475
45 Minute Schedule Duration Rule	476
MISO Multi-Value Project Usage Rate (MUR)	477
SECTION 10 Ancillary Service Markets	479
SECTION 10 Ancillary Service Markets	479 480
Overview	
Overview Primary Reserve	480
Overview Primary Reserve Tier 1 Synchronized Reserve	480 480
Overview Primary Reserve Tier 1 Synchronized Reserve Tier 2 Synchronized Reserve Market	480 480 480
Overview Primary Reserve Tier 1 Synchronized Reserve	480 480 480 481
Overview Primary Reserve Tier 1 Synchronized Reserve Tier 2 Synchronized Reserve Market Nonsynchronized Reserve Market	480 480 480 481 482
Overview Primary Reserve Tier 1 Synchronized Reserve Tier 2 Synchronized Reserve Market Nonsynchronized Reserve Market Secondary Reserve (DASR)	480 480 481 482 482
Overview Primary Reserve Tier 1 Synchronized Reserve Tier 2 Synchronized Reserve Market Nonsynchronized Reserve Market Secondary Reserve (DASR) Regulation Market	480 480 480 481 482 482 483
Overview Primary Reserve Tier 1 Synchronized Reserve Tier 2 Synchronized Reserve Market Nonsynchronized Reserve Market Secondary Reserve (DASR) Regulation Market Black Start Service	480 480 481 482 482 483 483
Overview Primary Reserve Tier 1 Synchronized Reserve Tier 2 Synchronized Reserve Market Nonsynchronized Reserve Market Secondary Reserve (DASR) Regulation Market Black Start Service Reactive	480 480 481 482 482 482 483 484 485
Overview Primary Reserve Tier 1 Synchronized Reserve Tier 2 Synchronized Reserve Market Nonsynchronized Reserve Market Secondary Reserve (DASR) Regulation Market Black Start Service Reactive Frequency Response	480 480 481 482 482 483 483 484 485 485
Overview Primary Reserve Tier 1 Synchronized Reserve Tier 2 Synchronized Reserve Market Nonsynchronized Reserve Market Secondary Reserve (DASR) Regulation Market Black Start Service Reactive Frequency Response Ancillary Services Costs per MWh of Load	480 480 481 482 482 483 483 484 485 485 485

Tier 1 Synchronized Reserve
Market Structure
Tier 1 Synchronized Reserve Payments
Tier 2 Synchronized Reserve Market
Market Structure
Market Behavior
Market Performance
Nonsynchronized Reserve Market
Market Structure
Secondary Reserve (DASR)
Market Structure
Market Conduct
Market Performance
Regulation Market
Market Design
Market Structure
Market Conduct
Market Performance
Black Start Service
CRF Issues
NERC – CIP
Minimum Tank Suction Level (MTSL)
Reactive Power Service and Capability
Recommended Market Approach to Reactive Costs
Improvements to Current Approach
Reactive Costs
Frequency Response
Frequency Control Definition
VACAR Reserve Sharing Agreement
lssues
Recommendations

SECTION 11 Congestion and Marginal Losses	557
Overview	558
Congestion Cost	558
Marginal Loss Cost	559
System Energy Cost	559
Conclusion	560
lssues	560
Closed Loop Interfaces and CT Pricing Logic	560
Balancing Congestion Cost Calculation Logic Change	561
Locational Marginal Price (LMP)	563
Components	563
Hub Components	568
Congestion	569
Congestion Accounting	569
Total Congestion	572
Charges and Credits versus Congestion: Virtual Transactions,	
Load and Generation	573
Congested Facilities	584
Congestion by Facility Type and Voltage	584
Constraint Frequency	589
Constraint Costs	591
Congestion Event Summary: Impact of Changes in UTC Volumes	594
Marginal Losses	595
Marginal Loss Accounting	595
Total Marginal Loss Cost	597
System Energy Costs	602
Energy Accounting	602
Total System Energy Costs	602

SECTION 12 Generation and Transmission Planning 607

Overview	607
Generation Interconnection Planning	607
Regional Transmission Expansion Plan (RTEP)	608
Transmission Facility Outages	609
Recommendations	609
Conclusion	612
Generation Interconnection Planning	613
Existing Generation Mix	613
Generation Retirements	620
Generation Queue	626
Regional Transmission Expansion Plan (RTEP)	654
RTEP Process	654
Market Efficiency Process	654
PJM MISO Interregional Market Efficiency Process (IMEP)	657
PJM MISO Targeted Market Efficiency Process (TMEP)	658
Supplemental Transmission Projects	659
Competitive Planning Process Exclusions	663
Storage As A Transmission Asset (SATA)	664
Board Authorized Transmission Upgrades	664
Qualifying Transmission Upgrades (QTU)	664
Cost Allocation	665
Transmission Line Ratings	665
Transmission Facility Outages	667
Scheduling Transmission Facility Outage Requests	667
Rescheduling Transmission Facility Outage Requests	671
Long Duration Transmission Facility Outage Requests	672
Transmission Facility Outage Analysis for the FTR Market	672
Transmission Facility Outage Analysis in the Day-Ahead Energy	
Market	680

SECTION 13 Financial Transmission and Auction		
Revenue Rights	683	
Overview	687	
Auction Revenue Rights	687	
Financial Transmission Rights	687	
Recommendations	689	
Conclusion	690	
Proposed Design	692	
Auction Revenue Rights	693	
Market Design	694	
Market Structure	695	
Market Performance	695	
IARRs	700	
Financial Transmission Rights	701	
Market Performance	707	
Surplus Congestion Revenue	723	
Revenue Adequacy	726	
ARRs as an Offset to Congestion for Load	729	
Zonal ARR Congestion Offset	731	
Offset Available from Self Scheduling	733	
Credit	734	
GreenHat Settlement Proceedings	734	
Default Portfolio Considerations	734	
FTR Forfeitures	735	