

TABLE OF CONTENTS

PREFACE	I
SECTION 1 INTRODUCTION	1
2017 in Review	1
PJM Market Summary Statistics	6
PJM Market Background	7
Conclusions	8
Energy Market Conclusion	8
Capacity Market Conclusion	10
Tier 2 Synchronized Reserve Market Conclusion	10
Day-Ahead Scheduling Reserve Market Conclusion	10
Regulation Market Conclusion	11
FTR Auction Market Conclusion	11
Role of MMU	11
Reporting	12
Monitoring	12
Market Design	13
New Recommendations	13
New Recommendation from Section 3, Energy Market	13
New Recommendations from Section 5, Capacity Market	14
New Recommendations from Section 6, Demand Response	14
New Recommendations from Section 10, Ancillary Services	14
New Recommendation from Section 12, Generation and Transmission Planning	15
New Recommendations from Section 13, Financial Transmission and Auction Revenue Rights	15
Total Price of Wholesale Power	15
Components of Total Price	15
Section Overviews	22
Overview: Section 3, Energy Market	22
Overview: Section 4, Energy Uplift	29
Overview: Section 5, Capacity Market	34
Overview: Section 6, Demand Response	42
Overview: Section 7, Net Revenue	46
Overview: Section 8, Environmental and Renewables	48
Overview: Section 9, Interchange Transactions	50
Overview: Section 10, Ancillary Services	53
Overview: Section 11, Congestion and Marginal Losses	60
Overview: Section 12, Planning	62
Overview: Section 13, FTRs and ARRs	66

SECTION 2 RECOMMENDATIONS	73
New Recommendations	73
New Recommendation from Section 3, Energy Market	74
New Recommendations from Section 5, Capacity Market	74
New Recommendations from Section 6, Demand Response	74
New Recommendations from Section 10, Ancillary Services	75
New Recommendation from Section 12, Generation and Transmission Planning	75
New Recommendations from Section 13, Financial Transmission and Auction Revenue Rights	75
History of MMU Recommendations	75
Complete List of Current MMU Recommendations	76
Section 3, Energy Market	76
Section 4, Energy Uplift	78
Section 5, Capacity Market	80
Section 6, Demand Response	83
Section 7, Net Revenue	85
Section 8, Environmental	85
Section 9, Interchange Transactions	85
Section 10, Ancillary Services	86
Section 11, Congestion and Marginal Losses	87
Section 12, Planning	88
Section 13, FTRs and ARRs	89
Adopted Recommendations	90
Adopted 2017	90
Adopted 2016	90
Adopted 2015	90
Adopted 2014	91
Adopted 2013	92
Adopted 2012	92
Adopted 2011	93
Adopted 2010	93
Adopted 2009	93
Adopted 2008	93
Adopted 2006	93
Adopted Date Not Determined	94
SECTION 3 ENERGY MARKET	95
Overview	96
Market Structure	96
Market Behavior	97
Market Performance	98
Scarcity	99

Recommendations	99
Conclusion	101
Market Structure	103
Market Concentration	103
Ownership of Marginal Resources	106
Type of Marginal Resources	107
Supply	109
Generator Offers	112
Demand	119
Supply and Demand: Load and Spot Market	126
Market Behavior	127
Offer Capping for Local Market Power	127
TPS Test Statistics	133
Parameter Limited Schedules	135
Markup Index	138
Energy Market Cost-Based Offers	141
Frequently Mitigated Units (FMU) and Associated Units (AU)	147
Virtual Offers and Bids	149
Market Performance	159
Markup	159
Prices	166
Scarcity	181
Emergency Procedures	182
Scarcity and Scarcity Pricing	185
PJM Cold Weather Operations 2017	194
SECTION 4 ENERGY UPLIFT (OPERATING RESERVES)	197
Overview	197
Energy Uplift Results	197
Characteristics of Credits	197
Geography of Charges and Credits	198
Recommendations	198
Conclusion	200
Energy Uplift	202
Credits and Charges Categories	202
Energy Uplift Results	203
Energy Uplift Charges	203
Operating Reserve Rates	206
Reactive Services Rates	207
Balancing Operating Reserve Determinants	208
Year over Year Energy Uplift Charges Analysis	209
Energy Uplift Credits	210

Characteristics of Credits	210
Types of Units	210
Concentration of Energy Uplift Credits	211
Uplift Eligibility	213
Economic and Noneconomic Generation	214
Day-Ahead Unit Commitment for Reliability	214
Geography of Charges and Credits	215
Energy Uplift Issues	217
Lost Opportunity Cost Credits	217
Closed Loop Interfaces	219
Price Setting Logic	221
Confidentiality of Energy Uplift Information	221
Energy Uplift Recommendations	222
Recommendations for Calculation of Credits	222
Recommendations for Allocation of Charges	226
Quantifiable Recommendations Impact	230
SECTION 5 CAPACITY MARKET	233
Overview	233
RPM Capacity Market	233
Reliability Must Run Service	237
Generator Performance	237
Recommendations	237
Conclusion	240
Installed Capacity	244
Fuel Diversity	245
RPM Capacity Market	246
Market Structure	246
Market Conduct	260
Market Performance	270
Reliability Must Run (RMR) Service	275
Generator Performance	277
Capacity Factor	277
Generator Performance Factors	277
Generator Forced Outage Rates	279
SECTION 6 DEMAND RESPONSE	285
Overview	285
Recommendations	286
Conclusion	287
PJM Demand Response Programs	289
Non-PJM Demand Response Programs	290

Participation in Demand Response Programs	290
Economic Program	291
Emergency and Pre-Emergency Programs	298
SECTION 7 NET REVENUE	309
Overview	309
Net Revenue	309
Historical New Entrant CT and CC Revenue Adequacy	310
Conclusion	310
Net Revenue	310
Spark Spreads, Dark Spreads, and Quark Spreads	311
Theoretical Energy Market Net Revenue	313
Capacity Market Net Revenue	315
Net Revenue Adequacy	315
Levelized Total Costs	316
Levelized Cost of Energy	316
New Entrant Combustion Turbine	316
New Entrant Combined Cycle	318
New Entrant Coal Plant	319
New Entrant Nuclear Plant	321
New Entrant Diesel	323
New Entrant Wind Installation	324
New Entrant Solar Installation	324
Historical New Entrant CT and CC Revenue Adequacy	325
Factors in Net Revenue Adequacy	326
Actual Net Revenue	328
Nuclear Net Revenue Analysis	331
SECTION 8 ENVIRONMENTAL AND RENEWABLE ENERGY REGULATIONS	337
Overview	337
Federal Environmental Regulation	337
State Environmental Regulation	338
State Renewable Portfolio Standards	338
Emissions Controls in PJM Markets	338
Renewable Generation	338
Recommendations	338
Conclusion	338
Federal Environmental Regulation	339
Control of Mercury and Other Hazardous Air Pollutants	339
Air Quality Standards: Control of NO _x , SO ₂ and O ₃ Emissions Allowances	340
Emission Standards for Reciprocating Internal Combustion Engines	342

Regulation of Greenhouse Gas Emissions	343
Federal Regulation of Environmental Impacts on Water	344
Federal Regulation of Coal Ash	345
State Environmental Regulation	346
New Jersey High Electric Demand Day (HEDD) Rules	346
Illinois Air Quality Standards (NO _x , SO ₂ and Hg)	347
State Regulation of Greenhouse Gas Emissions	347
State Renewable Portfolio Standards	349
Distributed Energy Resources	360
Emissions Controlled Capacity and Renewables in PJM Markets	360
Emission Controlled Capacity in the PJM Region	360
Wind and Solar Peak Hour Output	363
Wind Units	363
Solar Units	365
 SECTION 9 INTERCHANGE TRANSACTIONS	 367
Overview	367
Interchange Transaction Activity	367
Interactions with Bordering Areas	367
Recommendations	368
Conclusion	369
Interchange Transaction Activity	369
Charges and Credits Applied to Interchange Transactions	369
Aggregate Imports and Exports	370
Real-Time Interface Imports and Exports	372
Real-Time Interface Pricing Point Imports and Exports	374
Day-Ahead Interface Imports and Exports	377
Day-Ahead Interface Pricing Point Imports and Exports	380
Loop Flows	386
PJM and MISO Interface Prices	393
PJM and NYISO Interface Prices	396
Summary of Interface Prices between PJM and Organized Markets	398
Neptune Underwater Transmission Line to Long Island, New York	398
Linden Variable Frequency Transformer (VFT) facility	400
Hudson Direct Current (DC) Merchant Transmission Line	402
Interchange Activity During High Load Hours	403
Operating Agreements with Bordering Areas	403
PJM and MISO Joint Operating Agreement	404
PJM and New York Independent System Operator Joint Operating Agreement (JOA)	405
PJM and TVA Joint Reliability Coordination Agreement (JRCA)	406
PJM and Duke Energy Progress, Inc. Joint Operating Agreement	407
PJM and VACAR South Reliability Coordination Agreement	409

Balancing Authority Operations Coordination Agreement between Wisconsin Electric Power Company (WEC) and PJM Interconnection, LLC	409
Northeastern ISO-Regional Transmission Organization Planning Coordination Protocol	409
Interface Pricing Agreements with Individual Balancing Authorities	409
Other Agreements with Bordering Areas	410
Interchange Transaction Issues	411
Hudson Transmission Partners (HTP) and Linden VFT Requests to Convert Firm Transmission Withdrawal Rights (FTWR) to Non Firm Transmission Withdrawal Rights (NFTWR)	411
PJM Transmission Loading Relief Procedures (TLRs)	413
Up to Congestion	415
Sham Scheduling	418
Elimination of Ontario Interface Pricing Point	419
PJM and NYISO Coordinated Interchange Transactions	420
Reserving Ramp on the PJM/NYISO Interface	423
PJM and MISO Coordinated Interchange Transaction Proposal	424
Willing to Pay Congestion and Not Willing to Pay Congestion	427
Spot Imports	427
Interchange Optimization	429
Interchange Cap During Emergency Conditions	429
45 Minute Schedule Duration Rule	430
MISO Multi-Value Project Usage Rate (MUR)	430
SECTION 10 ANCILLARY SERVICE MARKETS	433
Overview	434
Primary Reserve	434
Tier 1 Synchronized Reserve	434
Tier 2 Synchronized Reserve Market	435
Nonsynchronized Reserve Market	435
Secondary Reserve	436
Regulation Market	436
Black Start Service	438
Reactive	439
Frequency Response	439
Ancillary Services Costs per MWh of Load: January through September, 1999 through 2017	439
Recommendations	439
Conclusion	441
Primary Reserve	442
Market Structure	442
Price and Cost	446
Tier 1 Synchronized Reserve	446
Market Structure	447
Tier 1 Synchronized Reserve Event Response	448

Tier 2 Synchronized Reserve Market	452
Market Structure	452
Market Behavior	455
Market Performance	457
Nonsynchronized Reserve Market	462
Market Structure	462
Secondary Reserve	466
Market Structure	466
Market Conduct	468
Market Performance	468
Regulation Market	470
Market Design	470
Market Structure	481
Market Conduct	485
Market Performance	488
Black Start Service	492
NERC – CIP	494
Minimum Tank Suction Level (MTSL)	494
Reactive Service	495
Recommended Market Approach to Reactive Costs	495
Improvements to Current Approach	497
Reactive Costs	499
Frequency Response	500
Frequency Control Definition	500
 SECTION 11 CONGESTION AND MARGINAL LOSSES	 503
Overview	503
Congestion Cost	503
Marginal Loss Cost	504
Energy Cost	504
Conclusion	505
Locational Marginal Price (LMP)	505
Components	505
Hub Components	508
Component Costs	508
Congestion	509
Congestion Accounting	509
Total Congestion	510
Congested Facilities	514
Congestion by Facility Type and Voltage	515
Constraint Duration	518
Constraint Costs	520

Congestion-Event Summary for MISO Flowgates	523
Congestion-Event Summary for NYISO Flowgates	524
Congestion-Event Summary for the 500 kV System	525
Congestion Costs by Physical and Financial Participants	526
Congestion-Event Summary: Impact of Changes in UTC Volumes	526
Marginal Losses	527
Marginal Loss Accounting	527
Total Marginal Loss Cost	529
Energy Costs	533
Energy Accounting	533
Total Energy Costs	533
 SECTION 12 GENERATION AND TRANSMISSION PLANNING	 537
Overview	537
Planned Generation and Retirements	537
Generation and Transmission Interconnection Planning Process	537
Regional Transmission Expansion Plan (RTEP)	538
Transmission Facility Outages	538
Recommendations	538
Conclusion	540
Planned Generation and Retirements	541
Planned Generation Additions	541
Planned Retirements	543
Existing Generation Mix	548
Generation and Transmission Interconnection Planning Process	549
The Earlier Queue Submittal Task Force	549
Interconnection Queue Analysis	549
Relationship Between Project Developer and Transmission Owner	558
Regional Transmission Expansion Plan (RTEP)	562
Authorized TEAC Transmission Upgrades	562
Backbone Facilities	562
Market Efficiency Process	562
PJM MISO Interregional Targeted Market Efficiency Process (TMEP)	563
Artificial Island	563
Transmission Facility Outages	564
Scheduling Transmission Facility Outage Requests	564
Rescheduling Transmission Facility Outage Requests	567
Long Duration Transmission Facility Outage Requests	568
Transmission Facility Outage Analysis for the FTR Market	568
Annual FTR Market	568
Monthly FTR Market	571
Transmission Facility Outage Analysis in the Day-Ahead Energy Market	573

SECTION 13 FINANCIAL TRANSMISSION AND AUCTION REVENUE RIGHTS	577
Overview	578
Auction Revenue Rights	578
Financial Transmission Rights	579
Recommendations	581
Conclusion	581
Auction Revenue Rights	585
Market Structure	586
Market Performance	590
Financial Transmission Rights	593
Market Structure	594
Market Performance	598
Revenue Adequacy Issues and Solutions	618
ARRs as an Offset to Congestion for Load	624
FERC Order on FTRs: Balancing Congestion and M2M Payment Allocation	624
Credit Issues	625
FTR Forfeitures	625
FERC Order on FTR Forfeitures	625