Subsidies and Markets

PA Energy Management Conference

November 8, 2017

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PJM Market Monitor

Monitoring Analytics

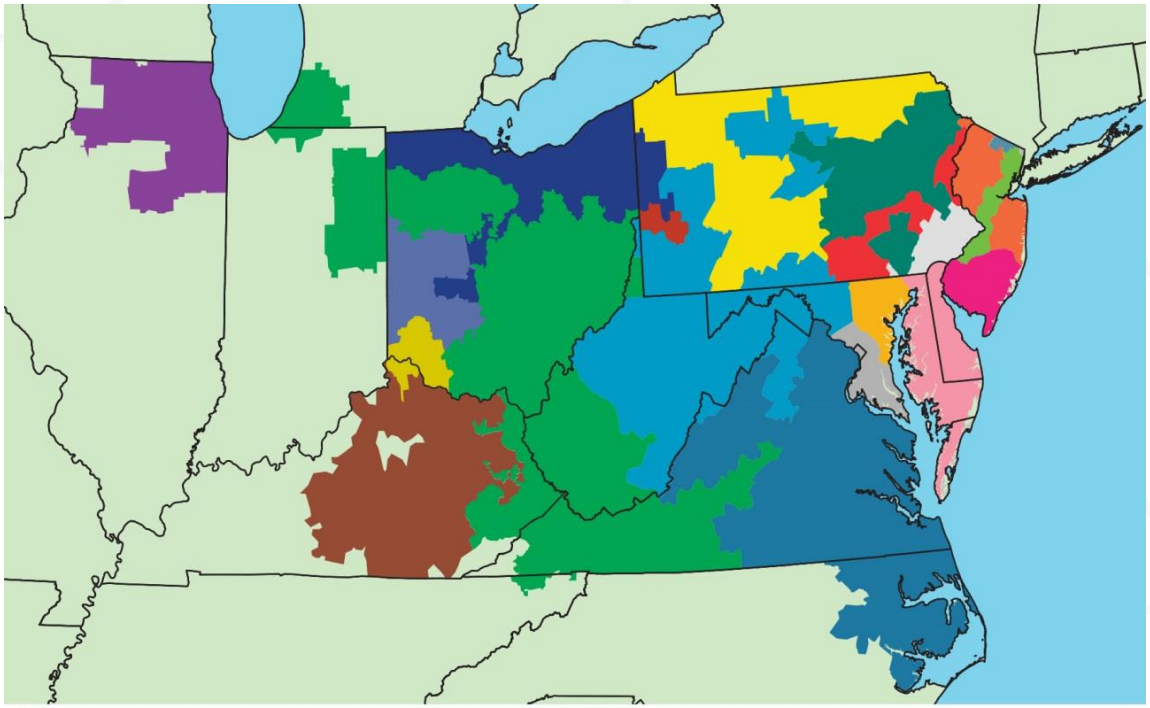
PJM Market Monitor

- Since 1999, the PJM Market Monitoring Unit has been responsible for promoting a robust, competitive and nondiscriminatory electric power market in PJM by implementing the PJM Market Monitoring Plan.
- Monitoring Analytics is the Independent Market Monitor for PJM.
- Monitoring Analytics was created in 2008 by spinning off the Market Monitoring Unit of PJM Interconnection as a result of a disagreement about independence.

MMU Functions

- Monitoring
  - Compliance with market rules
  - Exercise of market power
  - Retrospective mitigation
  - Inputs to prospective mitigation
- Reporting
  - State of the market reports
  - Reports on specific issues
- Market Design
  - Adequacy of market rules/market design
  - Recommendations for improved market design

PJM's footprint and its 20 control zones



Legend

- Allegheny Power Company (AP)
- American Electric Power Co., Inc (AEP)
- American Transmission Systems, Inc. (ATSI)
- Atlantic Electric Company (AECO)
- Baltimore Gas and Electric Company (BGE)
- ComEd
- Dayton Power and Light Company (DAY)
- Delmarva Power and Light (DPL)
- Dominion
- Duke Energy Ohio/Kentucky (DEOK)
- Duquesne Light (DLCO)
- Eastern Kentucky Power Cooperative (EKPC)
- Jersey Central Power and Light Company (JCPL)
- Metropolitan Edison Company (Met-Ed)
- PECO Energy (PECO)
- Pennsylvania Electric Company (PENELEC)
- Pepco
- PPL Electric Utilities (PPL)
- Public Service Electric and Gas Company (PSEG)
- Rockland Electric Company (RECO)

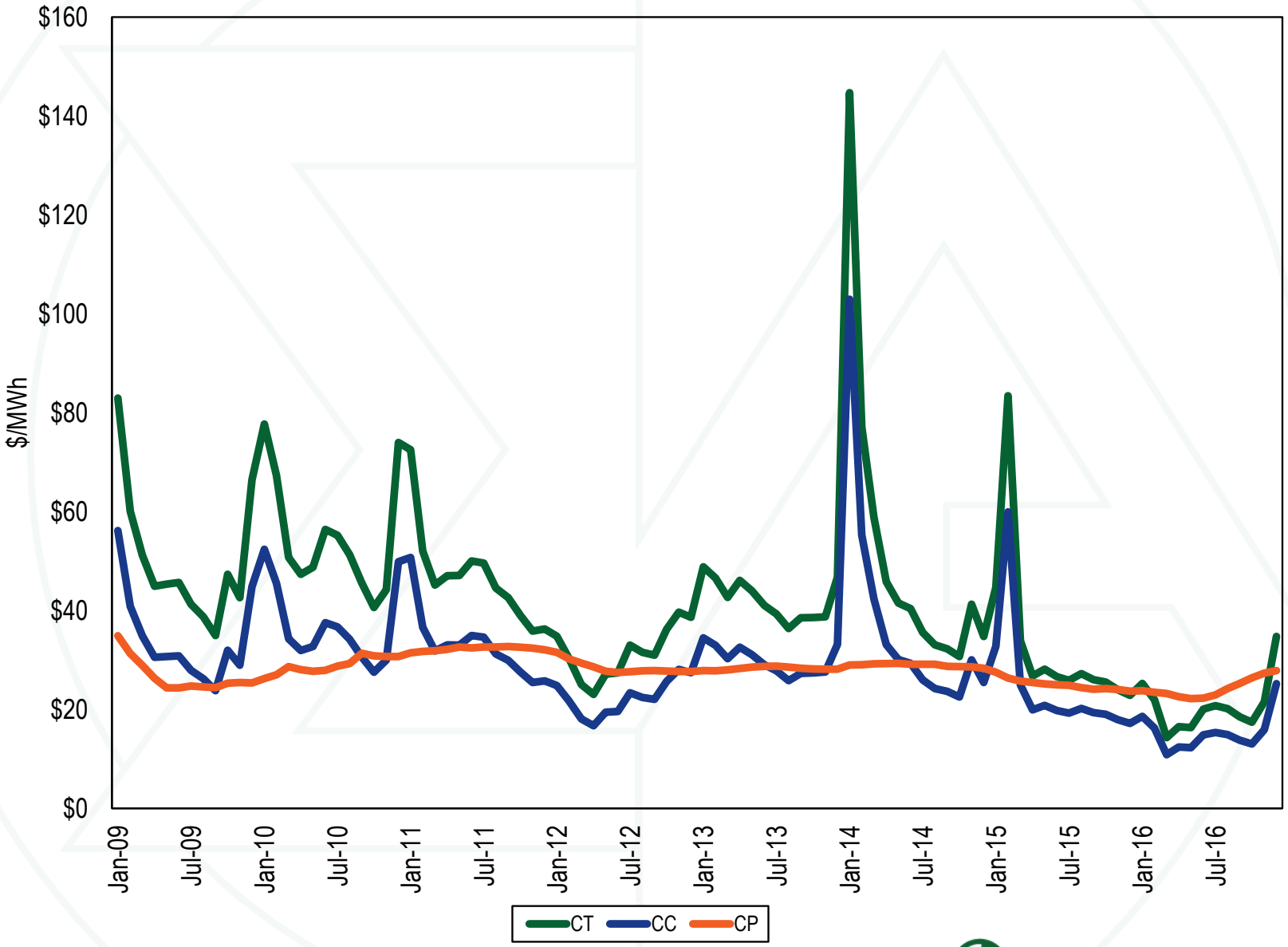
PJM Markets

- Energy Market
  - Day Ahead
  - Real Time (Balancing)
- Capacity Market (RPM)
  - Base Residual Auctions
  - Incremental Auctions
- Financial Transmission Rights Market (FTR)
  - ARR/FTR
  - Long term/Annual/Balance of period/Monthly
  - Auction Options
- Ancillary Services
  - Regulation Market
  - Synchronized Reserve Market
  - Black Start Service
  - Reactive Service

Total wholesale power price by category

Category	2015 $/MWh	2015 Percent of Total	2016 $/MWh	2016 Percent of Total	Percent Change Totals
Load Weighted Energy	$36.16	63.6%	$29.23	58.5%	(19.2%)
Capacity	$11.12	19.6%	$10.96	21.9%	(1.5%)
Transmission Service Charges	$7.09	12.5%	$7.81	15.6%	10.1%
Transmission Enhancement Cost Recovery	$0.51	0.9%	$0.52	1.0%	2.1%
PJM Administrative Fees	$0.44	0.8%	$0.45	0.9%	2.5%
Reactive	$0.37	0.7%	$0.39	0.8%	4.9%
Energy Uplift (Operating Reserves)	$0.38	0.7%	$0.17	0.3%	(54.8%)
Regulation	$0.23	0.4%	$0.11	0.2%	(53.2%)
Transmission Owner (Schedule 1A)	$0.09	0.2%	$0.09	0.2%	3.8%
Black Start	$0.08	0.1%	$0.08	0.2%	8.8%
Day Ahead Scheduling Reserve (DASR)	$0.10	0.2%	$0.07	0.1%	(24.4%)
Synchronized Reserves	$0.11	0.2%	$0.05	0.1%	(53.5%)
NERC/RFC	$0.03	0.1%	$0.03	0.1%	3.0%
Load Response	$0.02	0.0%	$0.01	0.0%	(38.9%)
Non-Synchronized Reserves	$0.02	0.0%	$0.01	0.0%	(48.3%)
RTO Startup and Expansion	$0.01	0.0%	$0.00	0.0%	(43.4%)
Transmission Facility Charges	$0.00	0.0%	$0.00	0.0%	(59.2%)
Capacity (FRR)	$0.13	0.2%	$0.00	0.0%	(100.0%)
Emergency Load Response	$0.00	0.0%	$0.00	0.0%	(100.0%)
Emergency Energy	$0.00	0.0%	$0.00	0.0%	0.0%
Total Price	$56.88	100.0%	$49.99	100.0%	(12.1%)

Short run marginal costs: gas and coal



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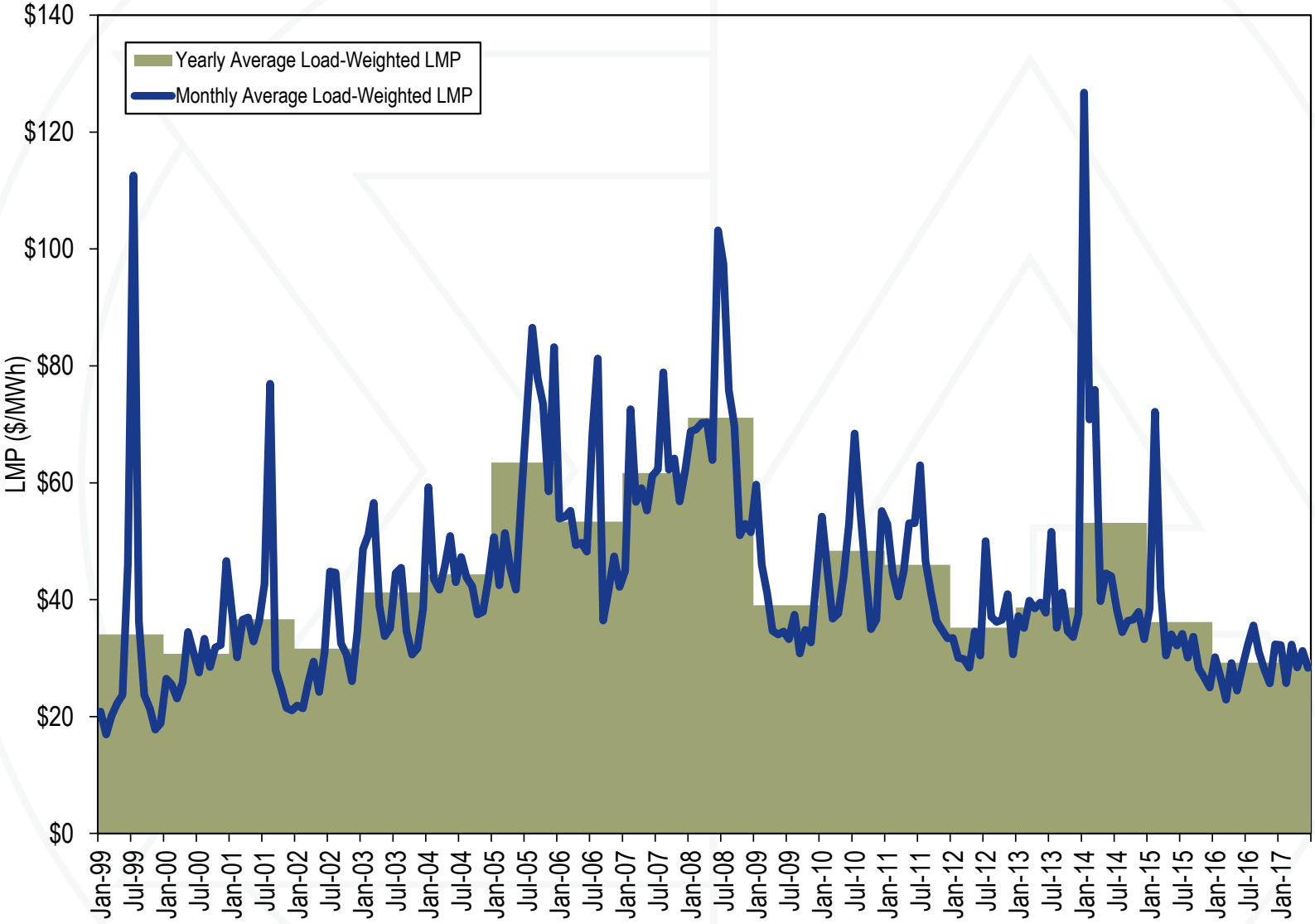
Capacity factor by unit type

Unit Type	2015 Generation (GWh)	2015 Capacity Factor	2016 Generation (GWh)	2016 Capacity Factor	Change in 2016 from 2015
Battery	7.6	0.5%	15.7	0.6%	0.1%
Combined Cycle	159,420.8	62.5%	187,368.5	62.0%	(0.5%)
Combustion Turbine	14,213.8	5.6%	17,980.5	6.8%	1.2%
Diesel	578.9	15.2%	662.7	16.9%	1.7%
Diesel (Landfill gas)	1,508.6	45.6%	1,501.9	45.1%	(0.4%)
Fuel Cell	227.1	86.4%	227.6	86.4%	(0.0%)
Nuclear	279,106.5	94.5%	279,546.4	93.0%	(1.4%)
Pumped Storage Hydro	6,038.4	12.8%	6,074.3	13.9%	1.1%
Run of River Hydro	7,000.9	30.5%	7,609.6	31.3%	0.8%
Solar	531.8	16.0%	970.3	17.7%	1.7%
Steam	388,709.8	43.8%	375,485.9	32.5%	(11.3%)
Wind	16,609.7	28.4%	17,696.2	28.0%	(0.3%)
Total	873,954.0	47.6%	895,139.6	41.2%	(6.4%)

PJM energy prices



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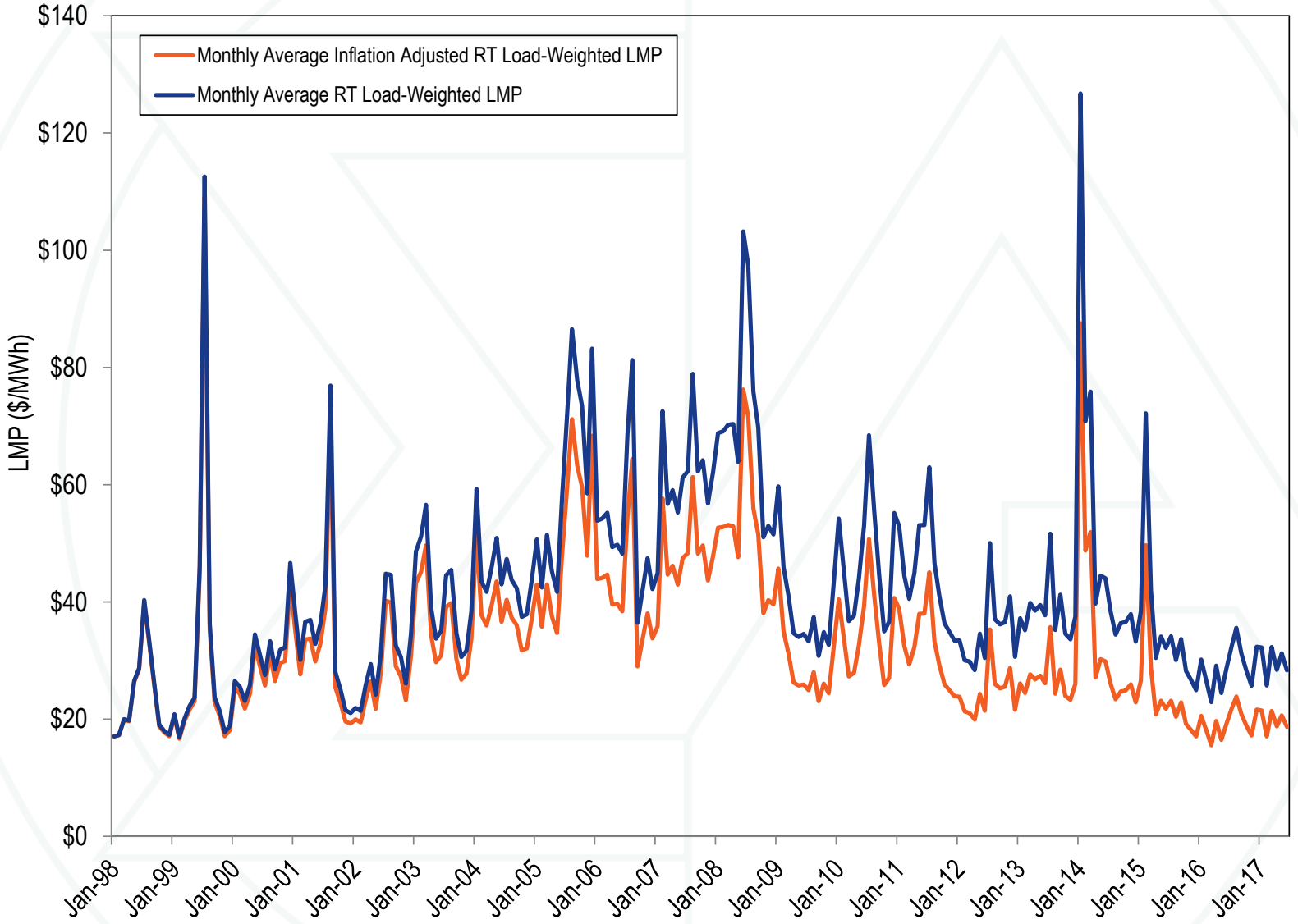
PJM inflation adjusted energy prices



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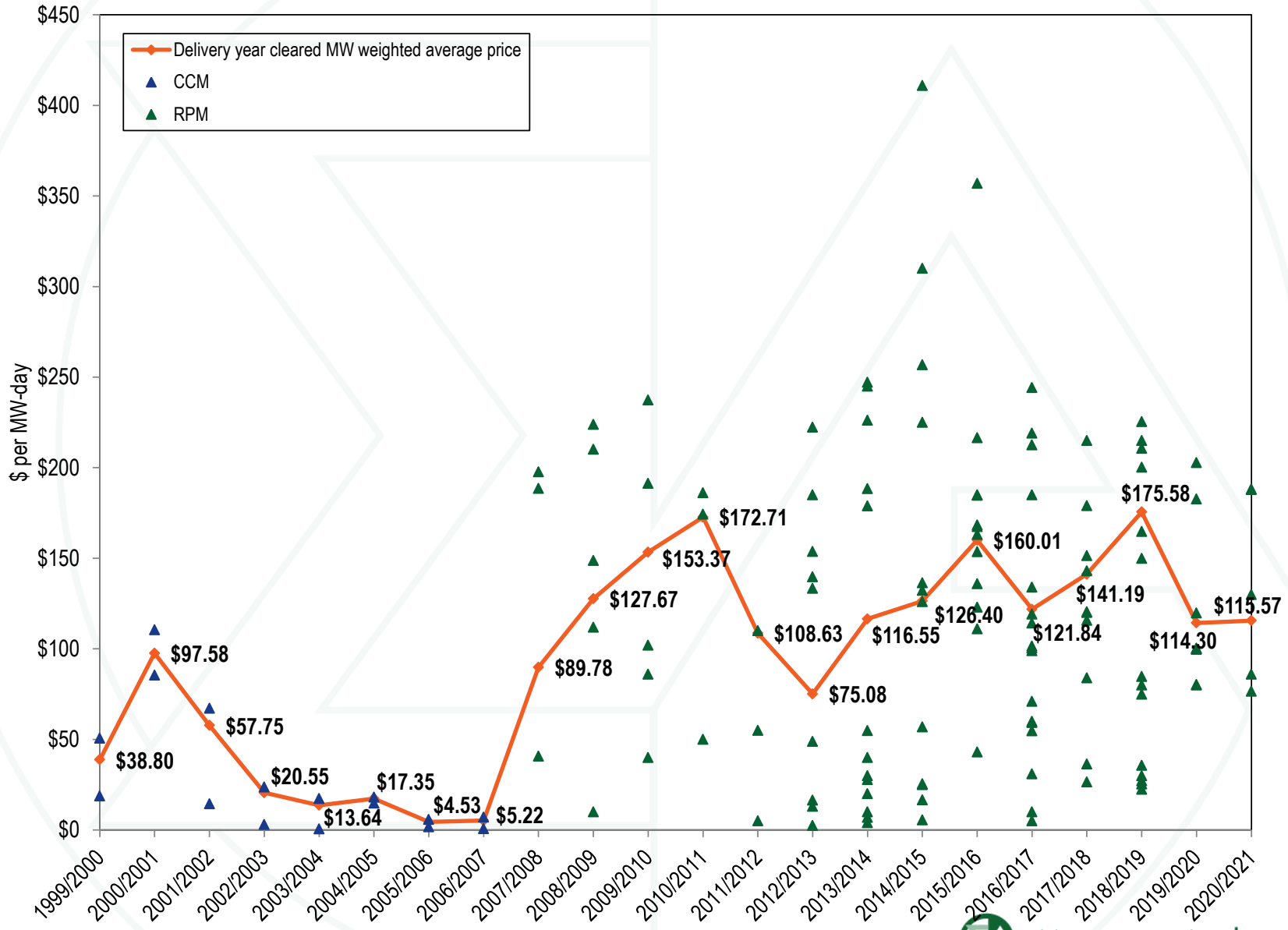
PJM capacity prices



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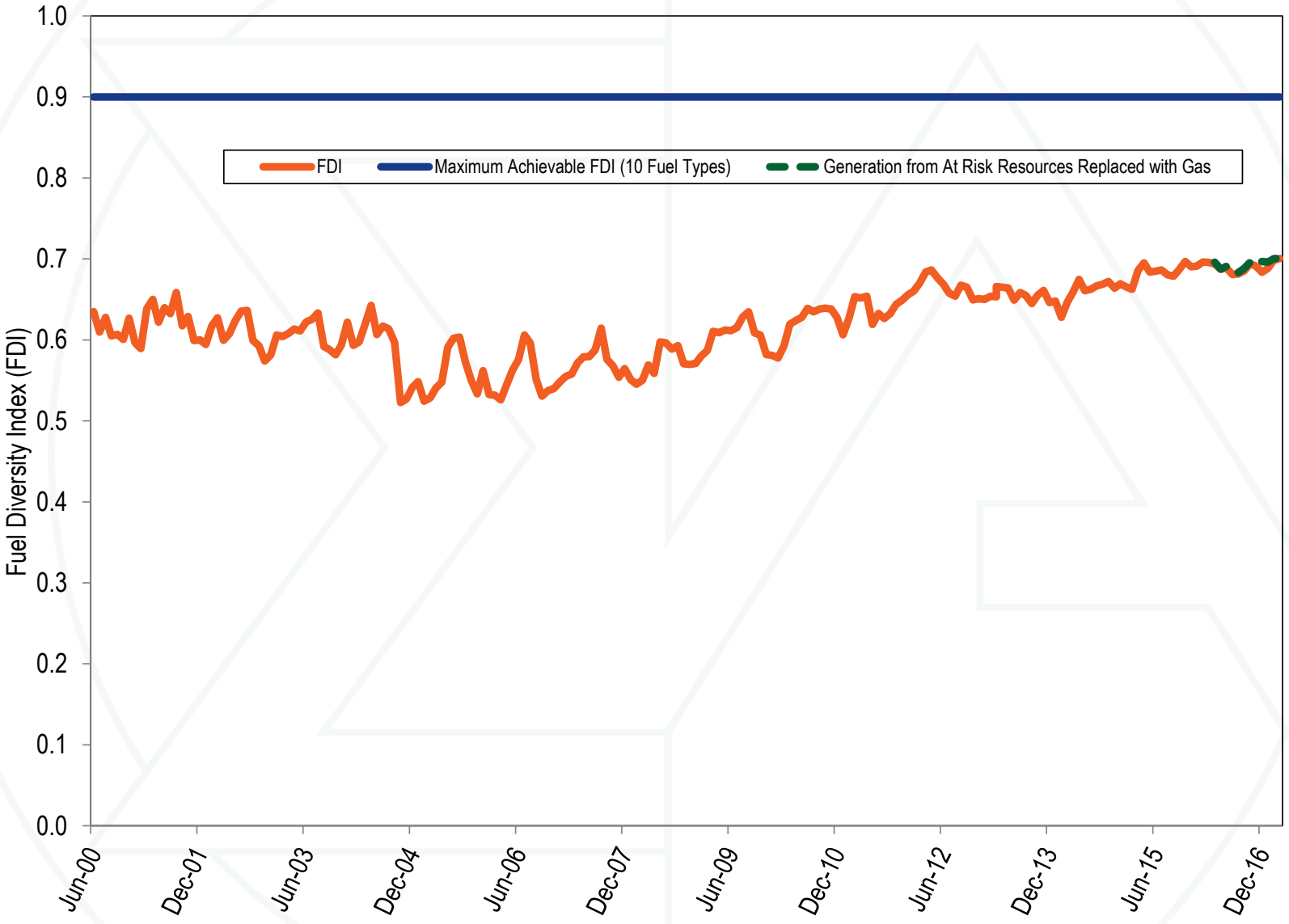
PJM generation fuel diversity index



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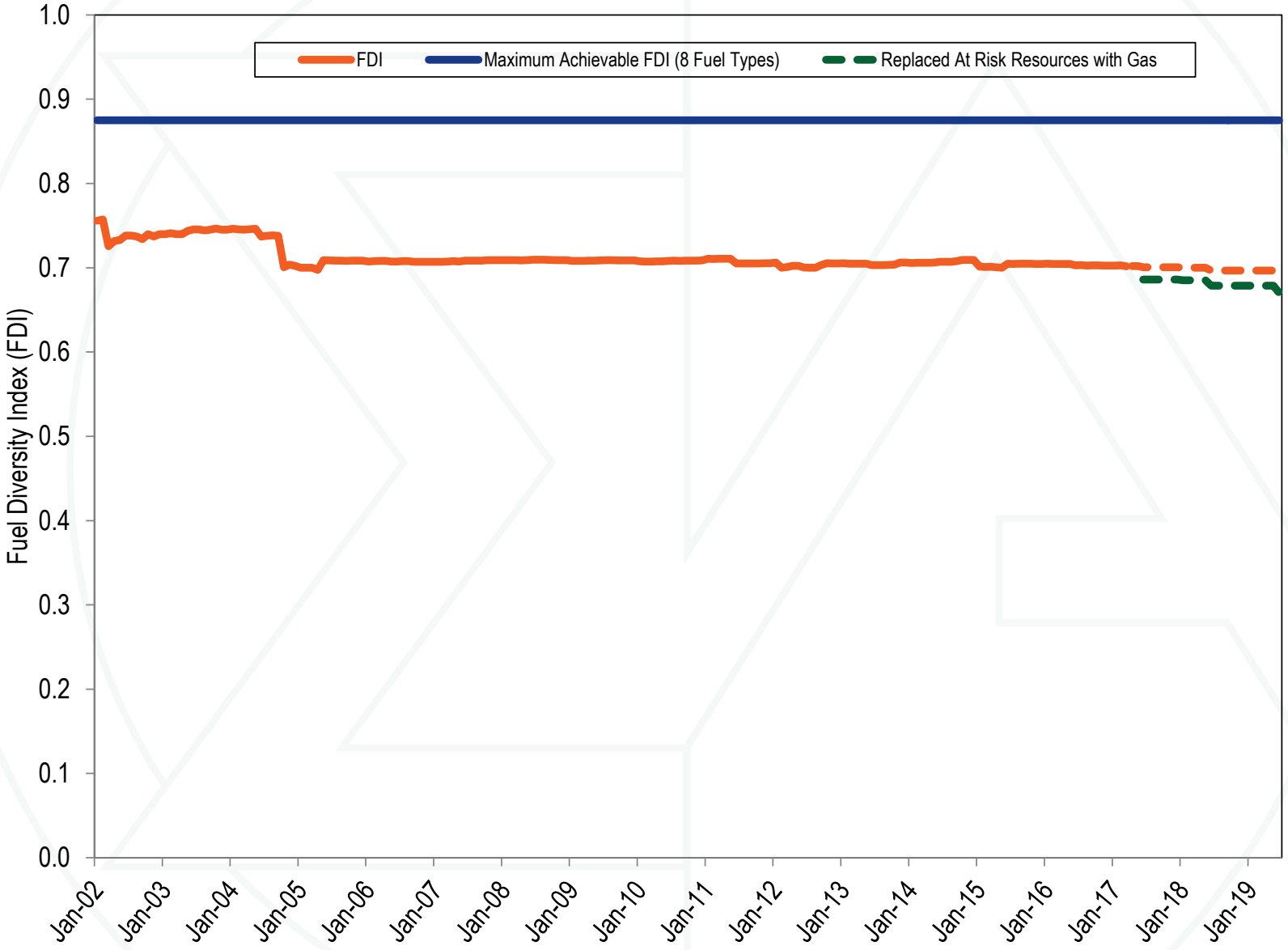
PJM generation by fuel source

	2015 GWh	2015 Percent	2016 GWh	2016 Percent	Change in Output
Coal	284,757.4	36.2%	275,281.7	33.9%	(3.3%)
Bituminous	257,700.0	32.8%	241,050.2	29.7%	(6.5%)
Sub Bituminous	22,528.7	2.9%	28,949.7	3.6%	28.5%
Other Coal	4,528.6	0.6%	5,281.7	0.7%	16.6%
Nuclear	279,106.5	35.5%	279,546.4	34.4%	0.2%
Gas	183,650.7	23.3%	217,214.5	26.7%	18.3%
Natural Gas	180,948.7	23.0%	215,022.4	26.5%	18.8%
Landfill Gas	2,275.8	0.3%	2,176.2	0.3%	(4.4%)
Other Gas	426.3	0.1%	15.9	0.0%	(96.3%)
Hydroelectric	13,067.2	1.7%	13,686.8	1.7%	4.7%
Pumped Storage	4,660.2	0.6%	4,840.2	0.6%	3.9%
Run of River	6,736.3	0.9%	7,332.8	0.9%	8.9%
Other Hydro	1,670.8	0.2%	1,513.8	0.2%	(9.4%)
Wind	16,609.7	2.1%	17,716.0	2.2%	6.7%
Waste	4,365.1	0.6%	4,139.8	0.5%	(5.2%)
Solid Waste	4,175.4	0.5%	4,139.8	0.5%	(0.9%)
Miscellaneous	189.7	0.0%	0.0	0.0%	(100.0%)
Oil	3,276.2	0.4%	2,163.6	0.3%	(34.0%)
Heavy Oil	622.9	0.1%	270.6	0.0%	(56.6%)
Light Oil	1,122.0	0.1%	341.1	0.0%	(69.6%)
Diesel	163.8	0.0%	59.4	0.0%	(63.7%)
Gasoline	0.0	0.0%	0.0	0.0%	NA
Kerosene	413.0	0.1%	74.8	0.0%	(81.9%)
Jet Oil	0.0	0.0%	0.0	0.0%	NA
Other Oil	954.5	0.1%	1,417.7	0.2%	48.5%
Solar, Net Energy Metering	548.4	0.1%	1,019.4	0.1%	85.9%
Energy Storage	7.6	0.0%	15.7	0.0%	106.7%
Battery	7.6	0.0%	15.7	0.0%	106.7%
Compressed Air	0.0	0.0%	0.0	0.0%	NA
Biofuel	1,309.6	0.2%	1,760.3	0.2%	34.4%
Geothermal	0.0	0.0%	0.0	0.0%	NA
Other Fuel Type	0.0	0.0%	0.0	0.0%	NA
Total	786,698.5	100.0%	812,544.1	100.0%	3.3%

PJM installed capacity fuel diversity index



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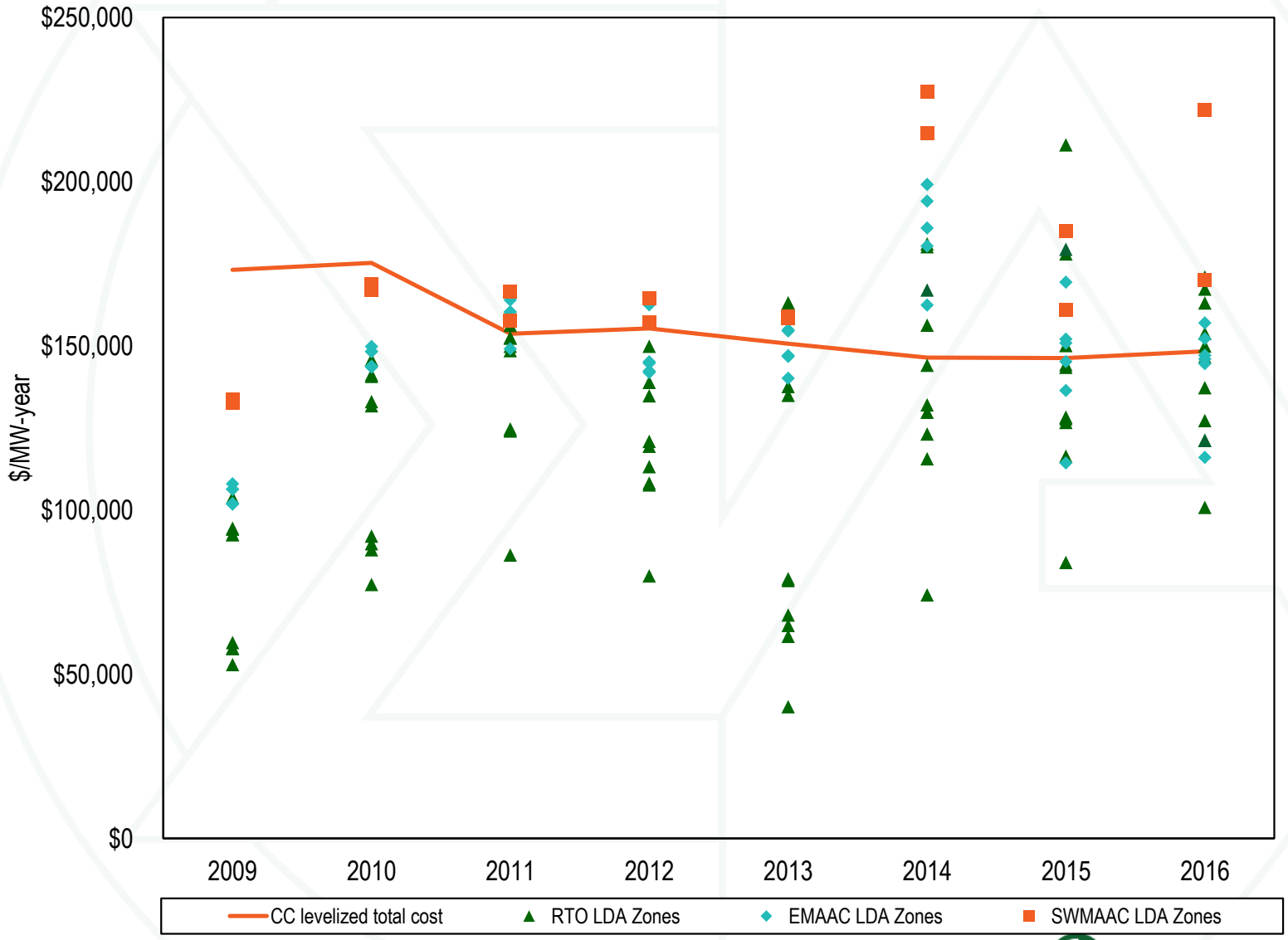
PJM installed capacity by fuel source

	1-Jan-16		31-May-16		1-Jun-16		31-Dec-16	
	MW	Percent	MW	Percent	MW	Percent	MW	Percent
Coal	66,674.8	37.5%	66,429.7	36.9%	66,619.9	36.6%	66,622.2	36.5%
Gas	60,487.4	34.0%	62,805.9	34.9%	64,721.7	35.5%	65,110.3	35.7%
Hydroelectric	8,787.5	4.9%	8,854.8	4.9%	8,850.4	4.9%	8,850.4	4.9%
Nuclear	33,071.5	18.6%	33,175.5	18.4%	33,050.6	18.2%	33,043.4	18.1%
Oil	6,851.8	3.9%	6,787.2	3.8%	6,779.8	3.7%	6,772.0	3.7%
Solar	128.0	0.1%	128.0	0.1%	252.4	0.1%	262.3	0.1%
Solid waste	769.4	0.4%	767.5	0.4%	767.5	0.4%	769.4	0.4%
Wind	912.4	0.5%	918.4	0.5%	1,019.1	0.6%	1,019.1	0.6%
Total	177,682.8	100.0%	179,867.0	100.0%	182,061.4	100.0%	182,449.1	100.0%

New entrant CC net revenue and total cost



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New entrant coal net revenue and total cost

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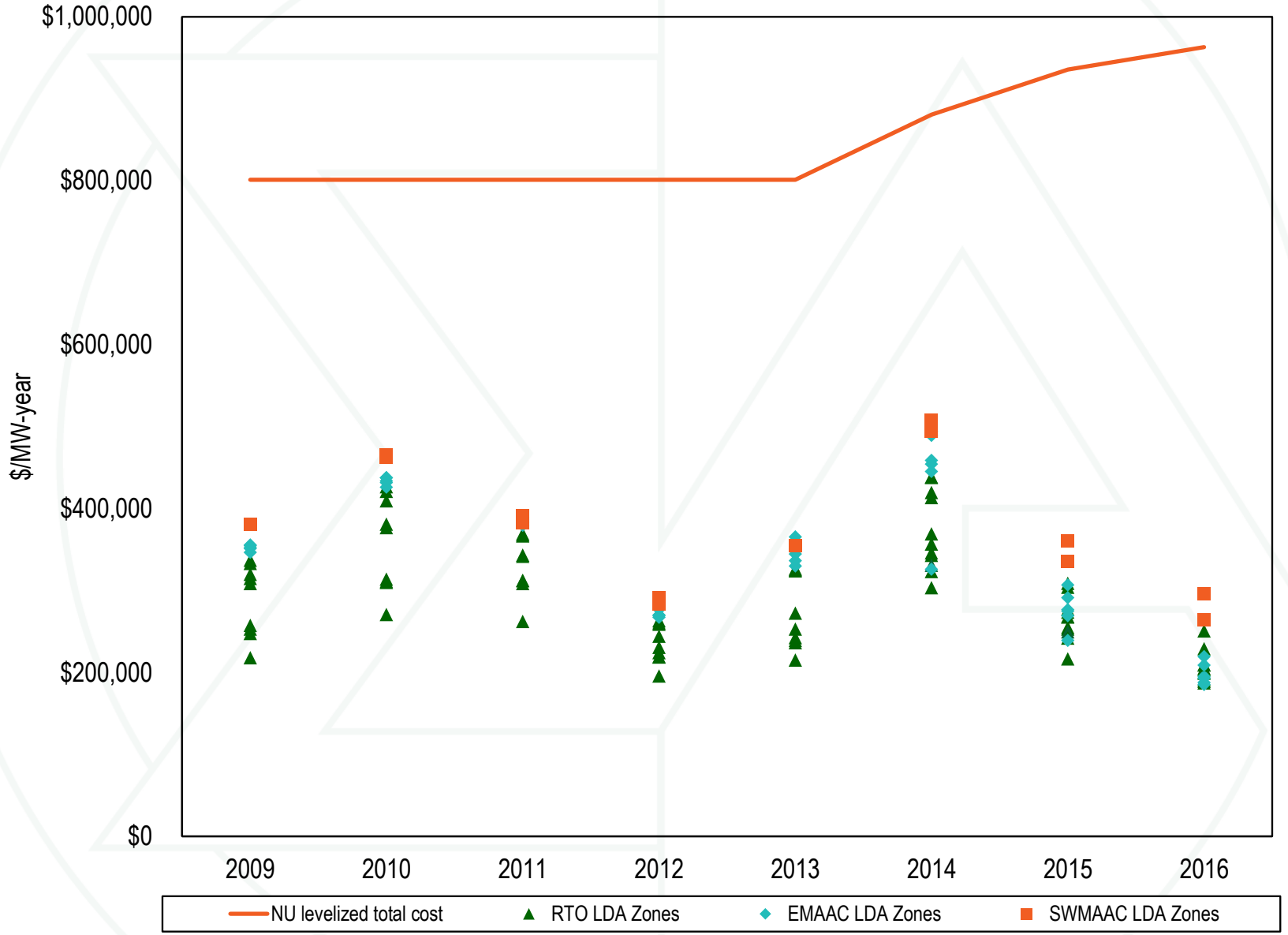
New entrant nuclear net revenue and total cost



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Avoidable cost recovery by quartile: 2016

Technology	Total Installed Capacity (ICAP)	Recovery of avoidable costs from energy and ancillary net revenue			Recovery of avoidable costs from all markets		
		First quartile	Median	Third quartile	First quartile	Median	Third quartile
CC - Combined Cycle	55,596	12%	288%	535%	256%	487%	706%
CT - Aero Derivative	6,173	10%	27%	42%	243%	322%	434%
CT - Industrial Frame	21,081	0%	13%	38%	400%	472%	532%
Coal Fired	61,317	6%	21%	52%	61%	85%	131%
Diesel	439	0%	56%	329%	426%	490%	696%
Hydro	9,725	127%	164%	233%	179%	277%	354%
Nuclear	31,661	61%	87%	104%	90%	119%	134%
Oil or Gas Steam	8,199	0%	0%	16%	163%	183%	214%
Pumped Storage	31,013	214%	260%	681%	250%	561%	715%

Avoidable cost recovery by unit type

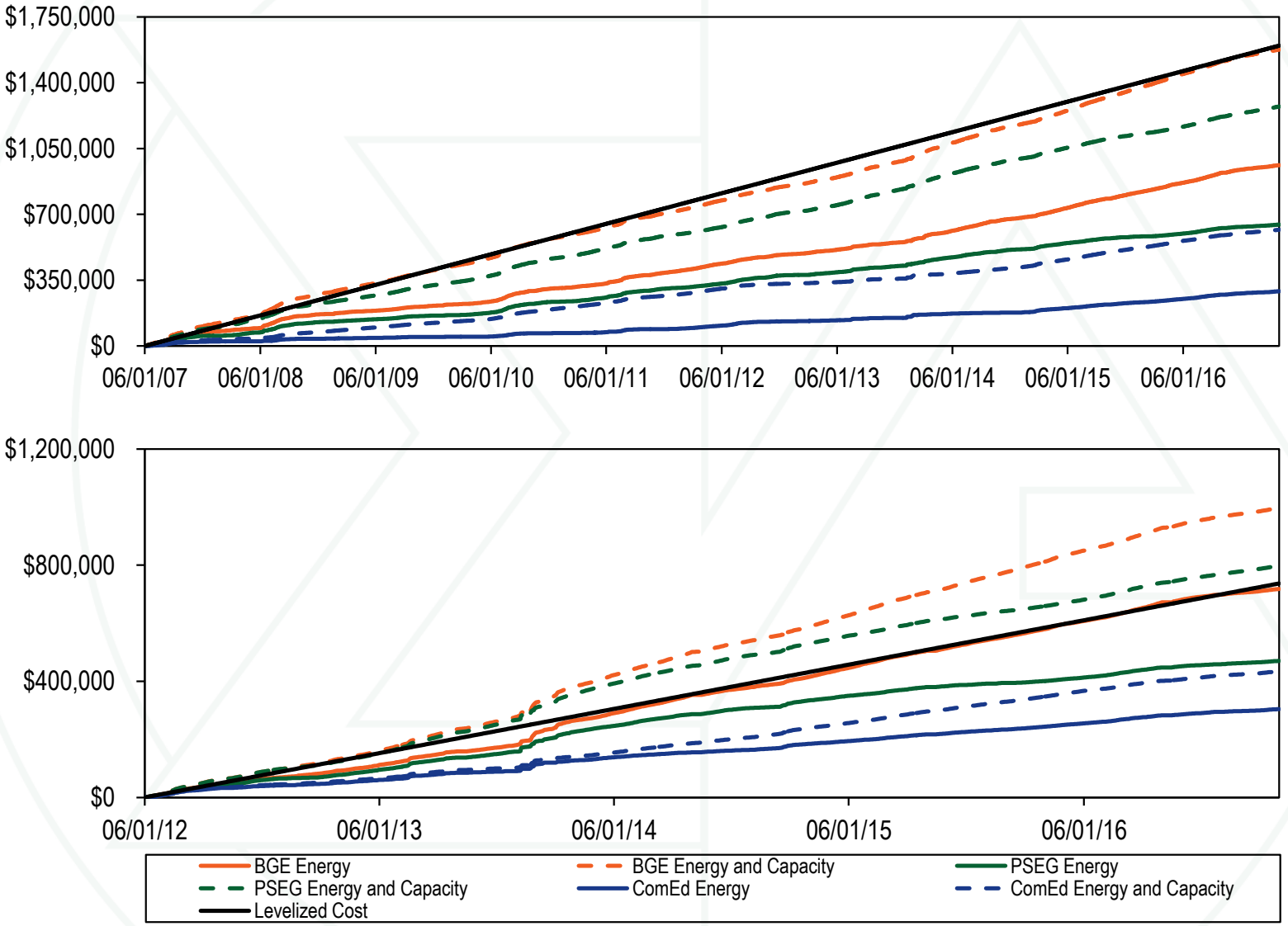
Technology	Units with full ACR recovery from energy and ancillary net revenue						Units with full ACR recovery from all markets					
	2011	2012	2013	2014	2015	2016	2011	2012	2013	2014	2015	2016
CC - Combined Cycle	55%	46%	50%	72%	59%	63%	85%	79%	79%	95%	88%	93%
CT - Aero Derivative	15%	6%	6%	53%	15%	8%	100%	96%	76%	98%	100%	99%
CT - Industrial Frame	26%	23%	17%	38%	13%	8%	99%	98%	83%	100%	100%	100%
Coal Fired	31%	17%	27%	80%	16%	15%	82%	36%	54%	85%	64%	41%
Diesel	48%	42%	37%	69%	56%	33%	100%	100%	77%	100%	100%	100%
Hydro	74%	61%	95%	97%	81%	79%	81%	77%	97%	98%	100%	100%
Nuclear	87%	65%	94%	100%	61%	32%	94%	84%	94%	100%	90%	74%
Oil or Gas Steam	8%	6%	11%	15%	3%	0%	92%	78%	86%	85%	91%	91%
Pumped Storage	NA	100%	95%	100%	100%	100%	NA	100%	100%	100%	100%	100%

Nuclear avoidable cost recovery

Technology	Total Installed Capacity (ICAP)	Recovery of avoidable costs from energy and ancillary net revenue			Recovery of avoidable costs from all markets		
		First quartile	Median	Third quartile	First quartile	Median	Third quartile
Nuclear (2016)	31,661	61%	88%	105%	91%	119%	135%
Nuclear (July 2016 through June 2017)	31,661	81%	95%	113%	104%	126%	143%

- **Negative LMPs reduced nuclear net revenues by an average of 0.3 percent and a maximum of 2.6 percent in 2016.**

Historical new entrant CC revenue adequacy



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Retirements by fuel type: 2011-2020

Fuel	Number of Units	Avg. Size (MW)	Avg. Age at Retirement (Years)	Total MW	Percent
Coal	144	175.2	54.4	25,229.6	77.3%
Diesel	5	21.3	39.8	106.3	0.3%
Heavy Oil	2	157.0	49.5	314.0	1.0%
Hydro	1	0.5	113.8	0.5	0.0%
Kerosene	20	41.4	45.5	828.2	2.5%
Landfill Gas	9	3.9	14.0	35.0	0.1%
Light Oil	30	46.2	43.2	1,384.9	4.2%
Natural Gas	55	58.9	47.3	3,237.3	9.9%
Nuclear	2	709.8	47.8	1,419.5	4.4%
Waste Coal	1	31.0	20.3	31.0	0.1%
Wind	1	10.4	15.6	10.4	0.0%
Wood Waste	2	12.0	23.2	24.0	0.1%
Total	272	119.9	49.1	32,620.7	100.0%

Units at risk of retirement

Technology	No. Units	ICAP (MW)	Avg. 2016 Run Hrs	Avg. Unit Age (Yrs)	Avg. Heat Rate
CC - Combined Cycle	4	915	1,002	28	9,523
CT - Aero Derivative	11	192	26	43	15,076
CT - Industrial Frame	44	1,217	123	39	14,542
Coal Fired	25	11,282	4,179	49	10,363
Diesel	4	30	330	25	10,999
Oil or Gas Steam	8	864	2,918	44	11,778
Total	96	14,500	3,197	34	11,391

Installed capacity of market units in PJM

	Units in the market (not cost of service)					
	2014		2015		2016	
	No. Units	ICAP (MW)	No. Units	ICAP (MW)	No. Units	ICAP (MW)
Coal	75	24,021	69	23,992	67	24,324
Nuclear	27	28,080	27	28,080	27	28,080
Total ICAP	102	52,101	96	52,072	94	52,404

Replacement cost

	20-Year Levelized Total Cost ($/MW-Day)		
	2014	2015	2016
Coal Fired	$1,381	$1,416	$1,434
Nuclear	$2,413	$2,563	$2,639

25 percent of replacement cost

	20-Year Levelized Total Cost at 25% ($/MW-Day)		
	2014	2015	2016
Coal Fired	$345	$354	$359
Nuclear	$603	$641	$660

Additional cost of DOE proposal at 100 percent of replacement cost

	Additional Cost of NOPR at 100 Percent of Replacement Cost ($ in millions)		
	2014	2015	2016
Coal	$8,223	$10,550	$11,222
Nuclear	$14,999	$19,995	$21,561
Total ($ in millions)	$23,222	$30,545	$32,782
Total ($/MW-Yr)	$445,715	$586,601	$625,571
Total ($/MW-Day)	$1,221	$1,607	$1,714
Total Cost of Capacity ($ in millions)	$7,029	$8,632	$8,530
Total Cost of Energy ($ in millions)	$41,473	$28,064	$22,746
Total Cost of Wholesale Power ($ in millions)	$55,793	$44,141	$38,887
Total Cost as a Percentage of the Capacity Market	330%	354%	384%
Total Cost as a Percentage of the Energy Market	56%	109%	144%
Total Cost as a Percentage of the Wholesale Power Market	42%	69%	84%

Additional cost of DOE Proposal at 25 percent of replacement cost

	Additional Cost of DOE Proposal at 25 Percent of Replacement Cost ($ in millions)		
	2014	2015	2016
Coal	$404	$1,290	$1,691
Nuclear	$11	$633	$1,360
Total	$415	$1,923	$3,051
Total ($/MW-Yr)	$7,972	$36,925	$58,223
Total ($/MW-Day)	$22	$101	$160
Total Cost as a Percentage of the Capacity Market	6%	22%	36%
Total Cost as a Percentage of the Energy Market	1%	7%	13%
Total Cost as a Percentage of the Wholesale Power Market	1%	4%	8%

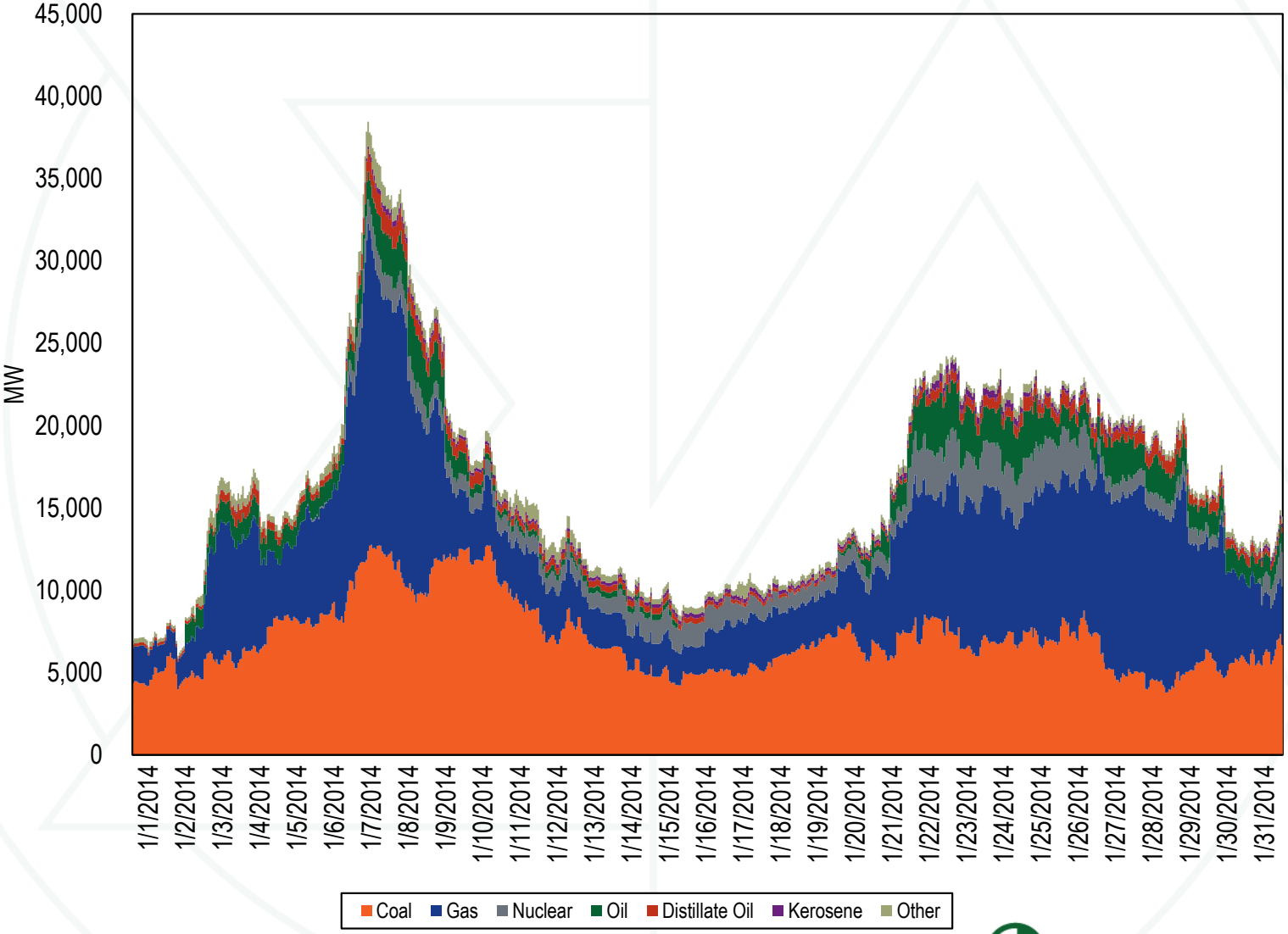
Cost of Implementing DOE Proposal for 10 Years

	Average of 2014-2016 Cost Over Ten Years ($ in millions)
Additional Cost at 100 Percent of Replacement Cost	$288,498
Additional Cost at 50 Percent of Replacement Cost	$97,154
Additional Cost at 25 Percent of Replacement Cost	$17,964

Forced outage rates by unit type

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Combined Cycle	3.7%	3.7%	4.1%	3.8%	3.4%	4.3%	3.1%	4.3%	2.8%	3.3%
Combustion Turbine	11.0%	11.1%	9.7%	9.0%	8.0%	8.2%	10.7%	15.8%	8.8%	5.8%
Diesel	11.7%	10.3%	9.3%	6.4%	9.3%	5.1%	6.6%	14.8%	9.1%	7.1%
Hydroelectric	2.0%	2.0%	3.2%	1.2%	2.9%	4.4%	3.7%	3.8%	5.2%	3.5%
Nuclear	1.4%	1.9%	4.1%	2.5%	2.8%	1.6%	1.2%	1.9%	1.4%	1.9%
Steam	9.1%	10.1%	9.3%	9.8%	11.2%	10.6%	11.6%	12.1%	10.2%	10.0%
Total	7.0%	7.7%	7.6%	7.3%	7.9%	7.5%	8.1%	9.4%	7.0%	6.3%

Generator outages in January 2014 by unit fuel source



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