

Resilience, Reliability, and Markets

Nov. 28, 2017

Joe Bowring

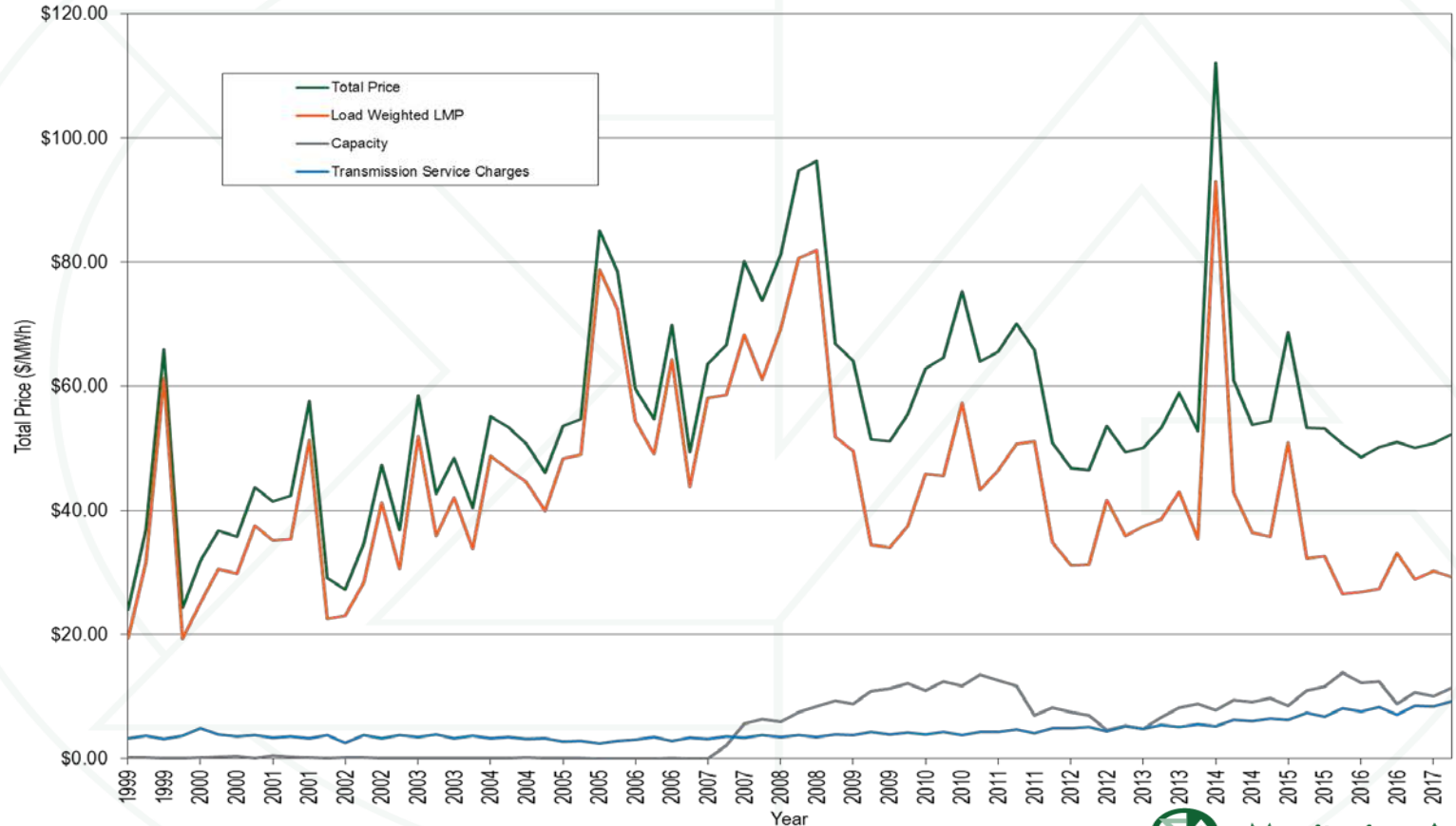


Monitoring Analytics

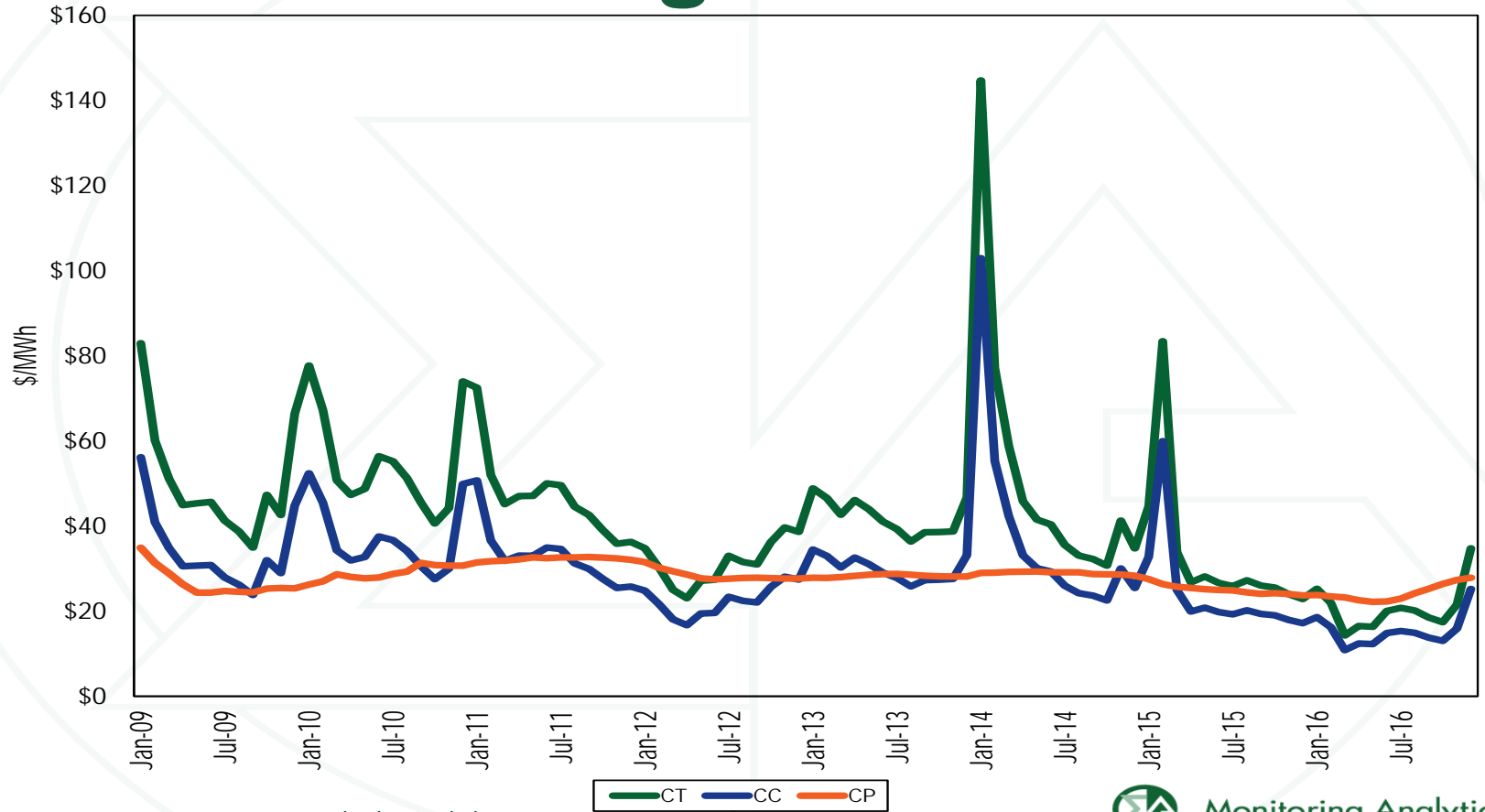
Total Wholesale Power Price

Category	2015		2015 Percent of		2016		Percent Change Totals
	2015	\$/MWh	Total	2016	\$/MWh	Total	
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%)

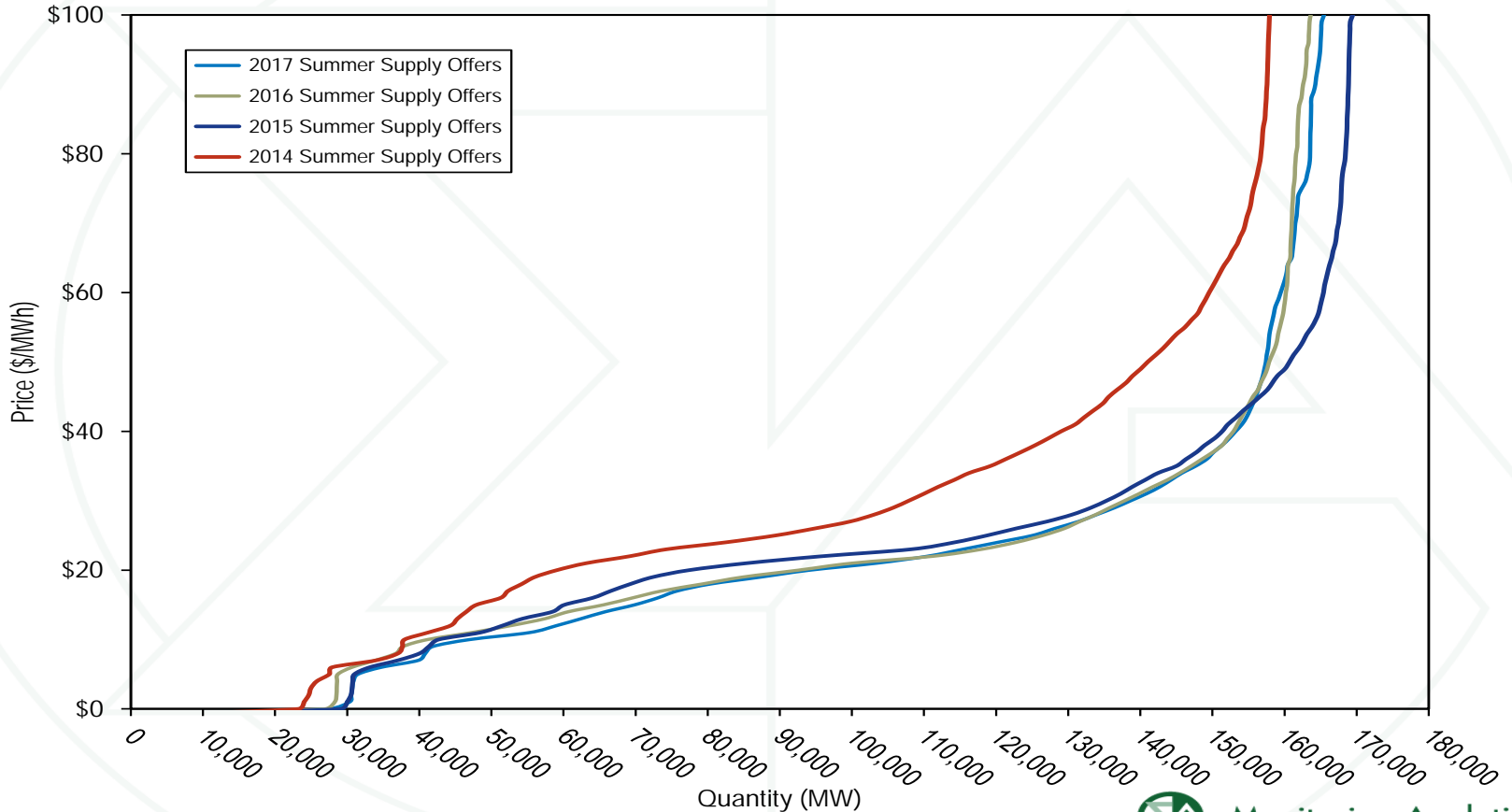
PJM All In Price



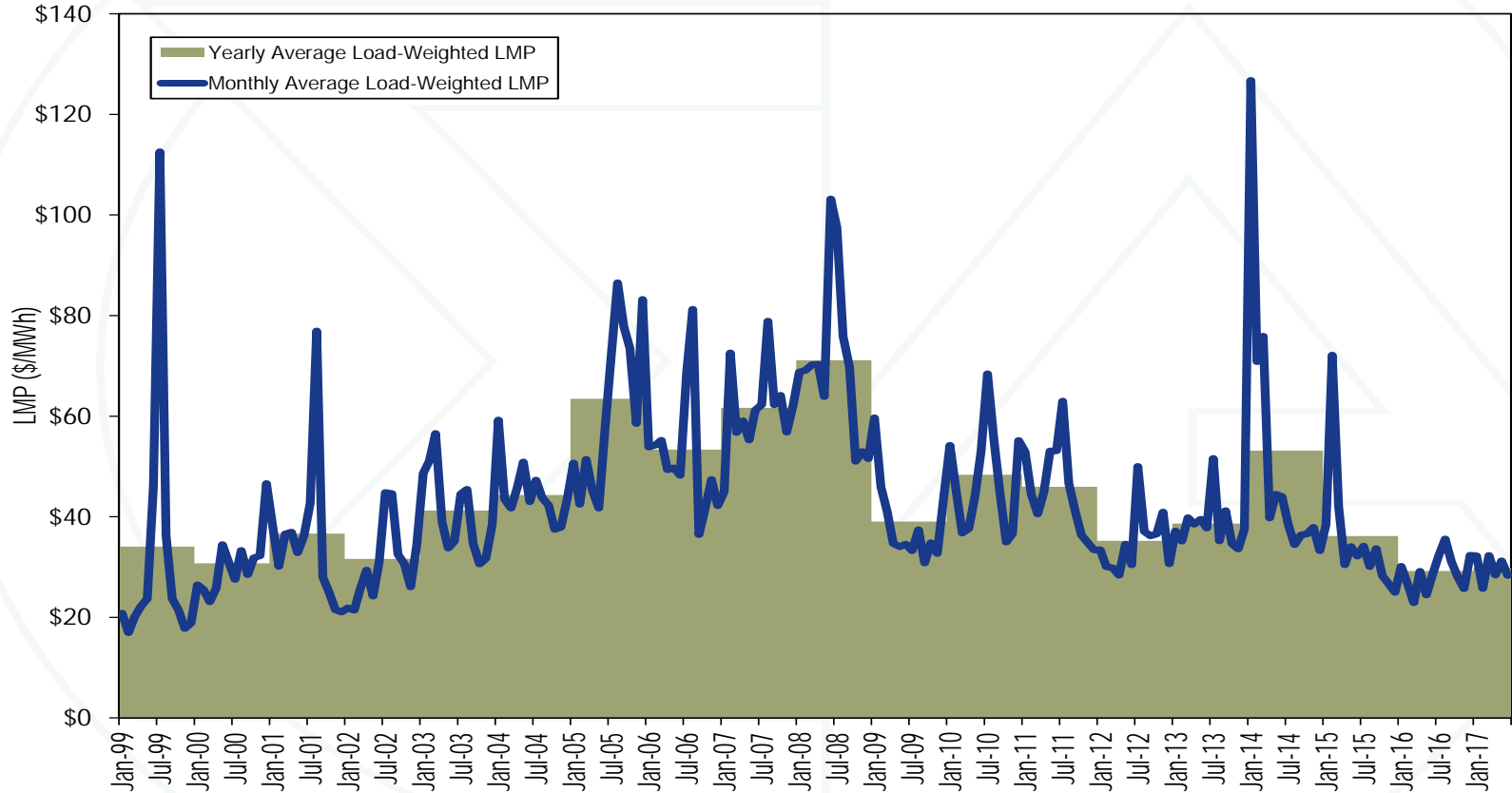
Short Run Marginal Costs



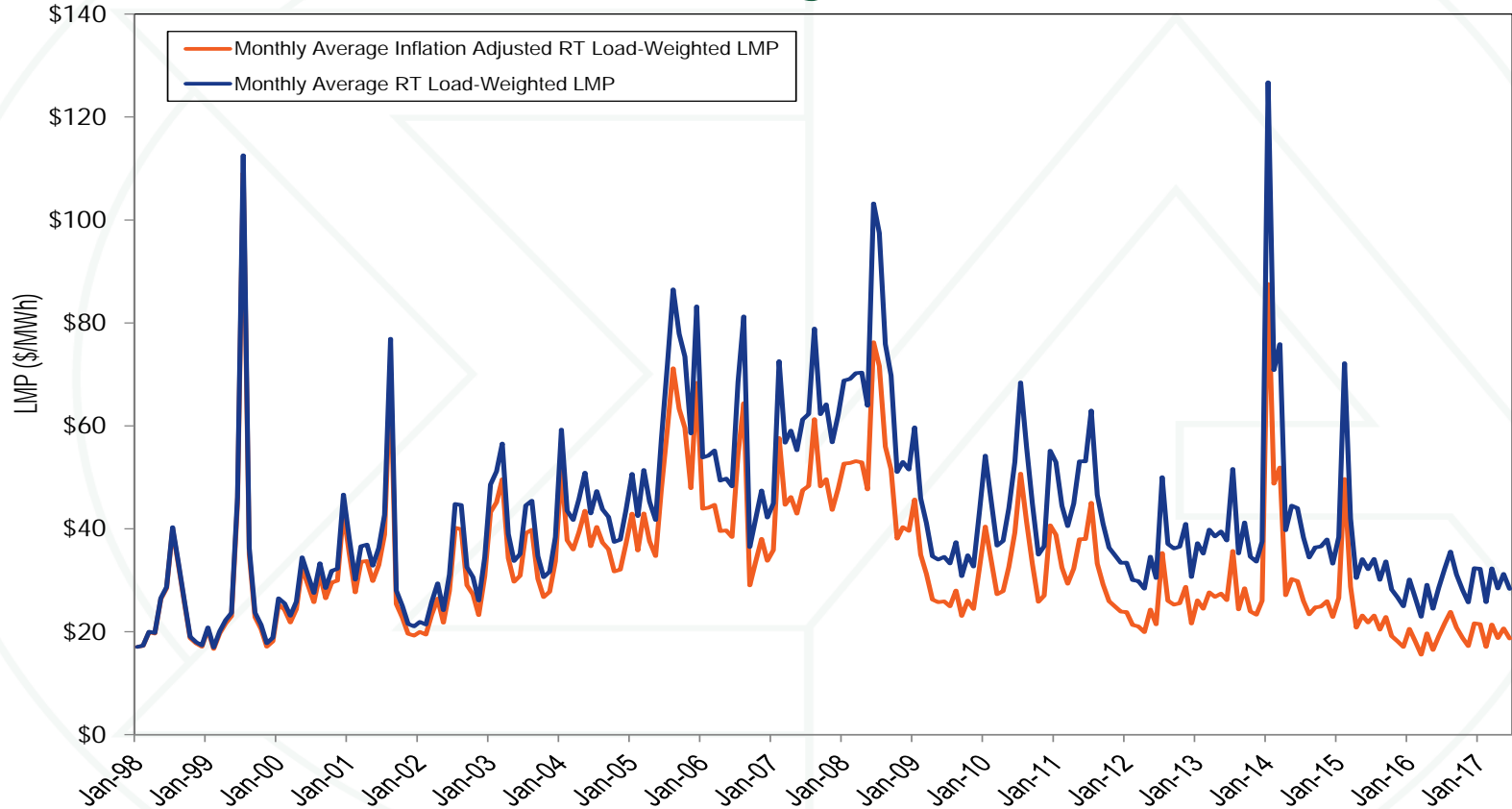
Average RT supply curves



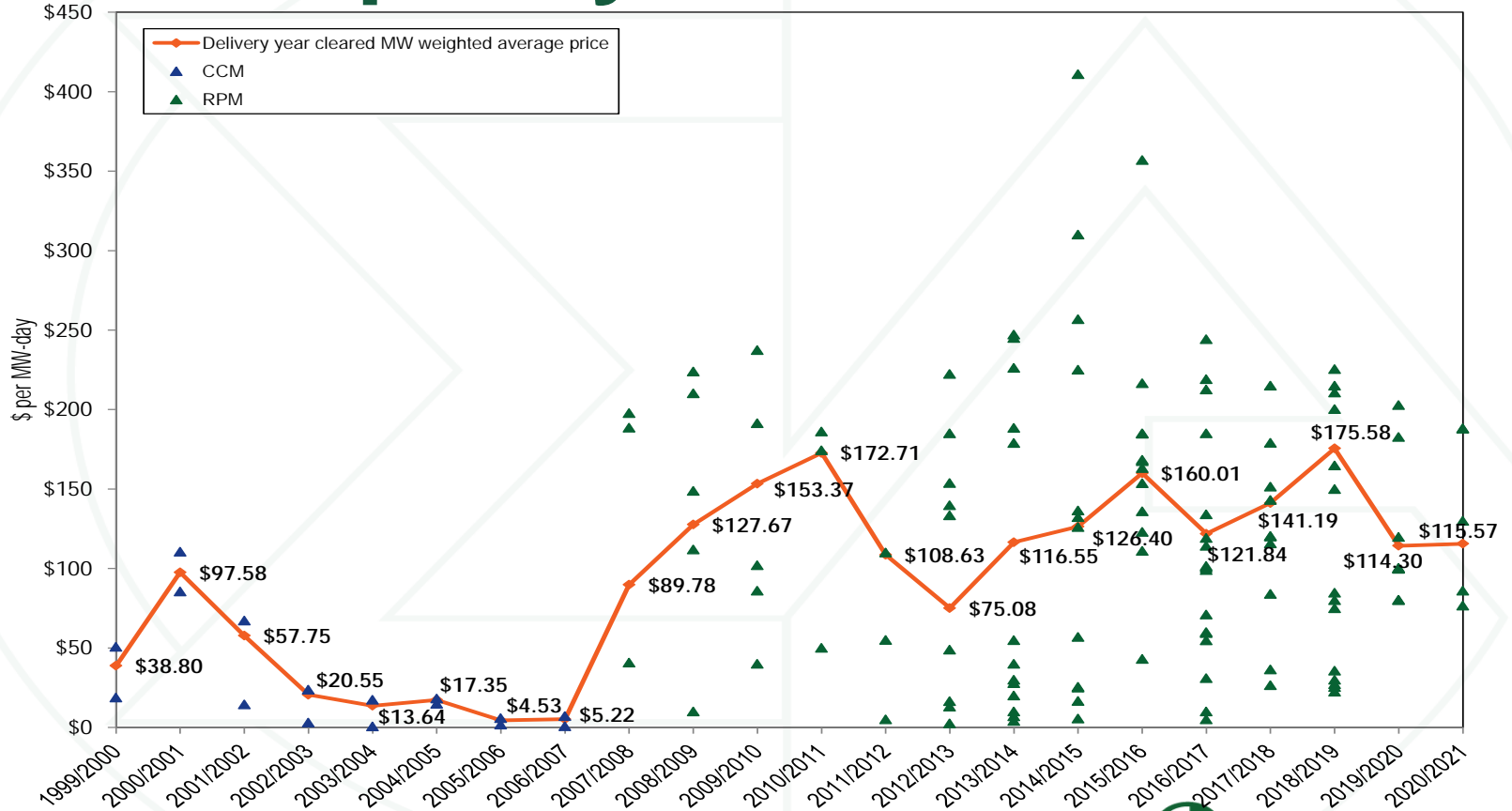
PJM Energy Prices



PJM Inflation Adjusted Prices



PJM Capacity Prices



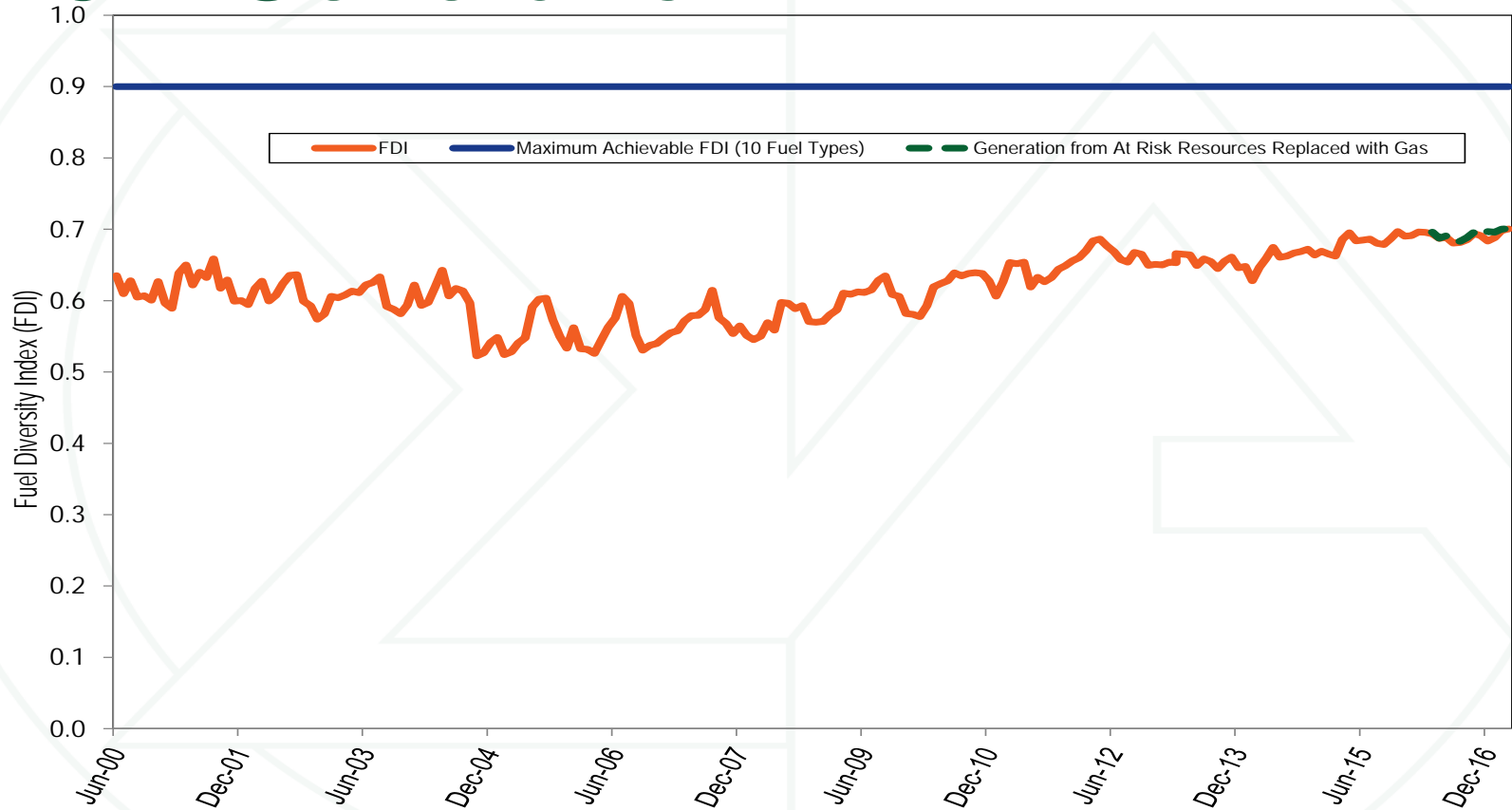
Capacity Factor by Unit Type

Unit Type	2015		2016		Change in 2016 from 2015
	Generation (GWh)	Capacity Factor	Generation (GWh)	Capacity Factor	
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 Generation by Fuel Source

	2015		2016		Change in Output
	GWh	Percent	GWh	Percent	
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%

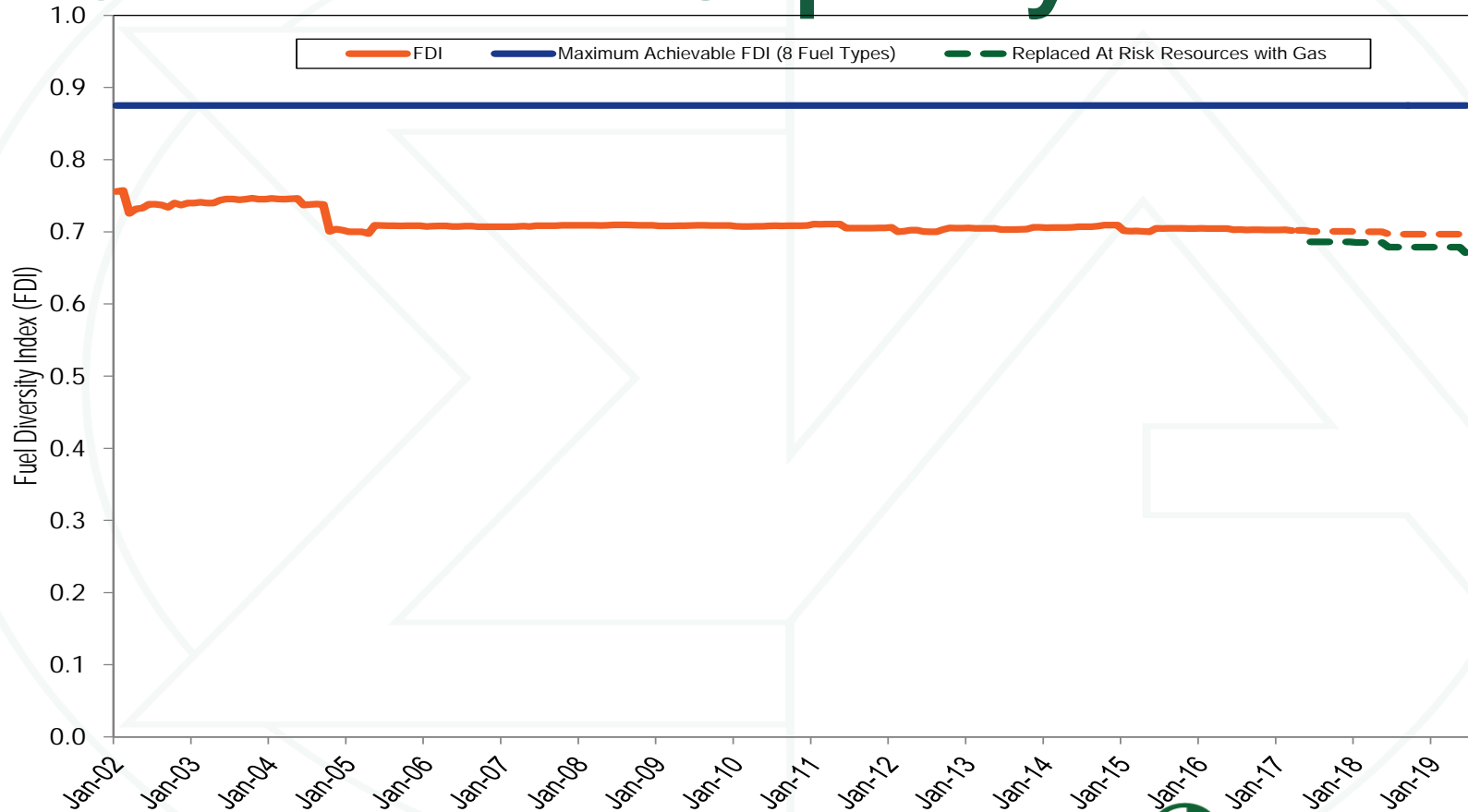
PJM Generation FDI



PJM Installed Capacity by Fuel

	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%

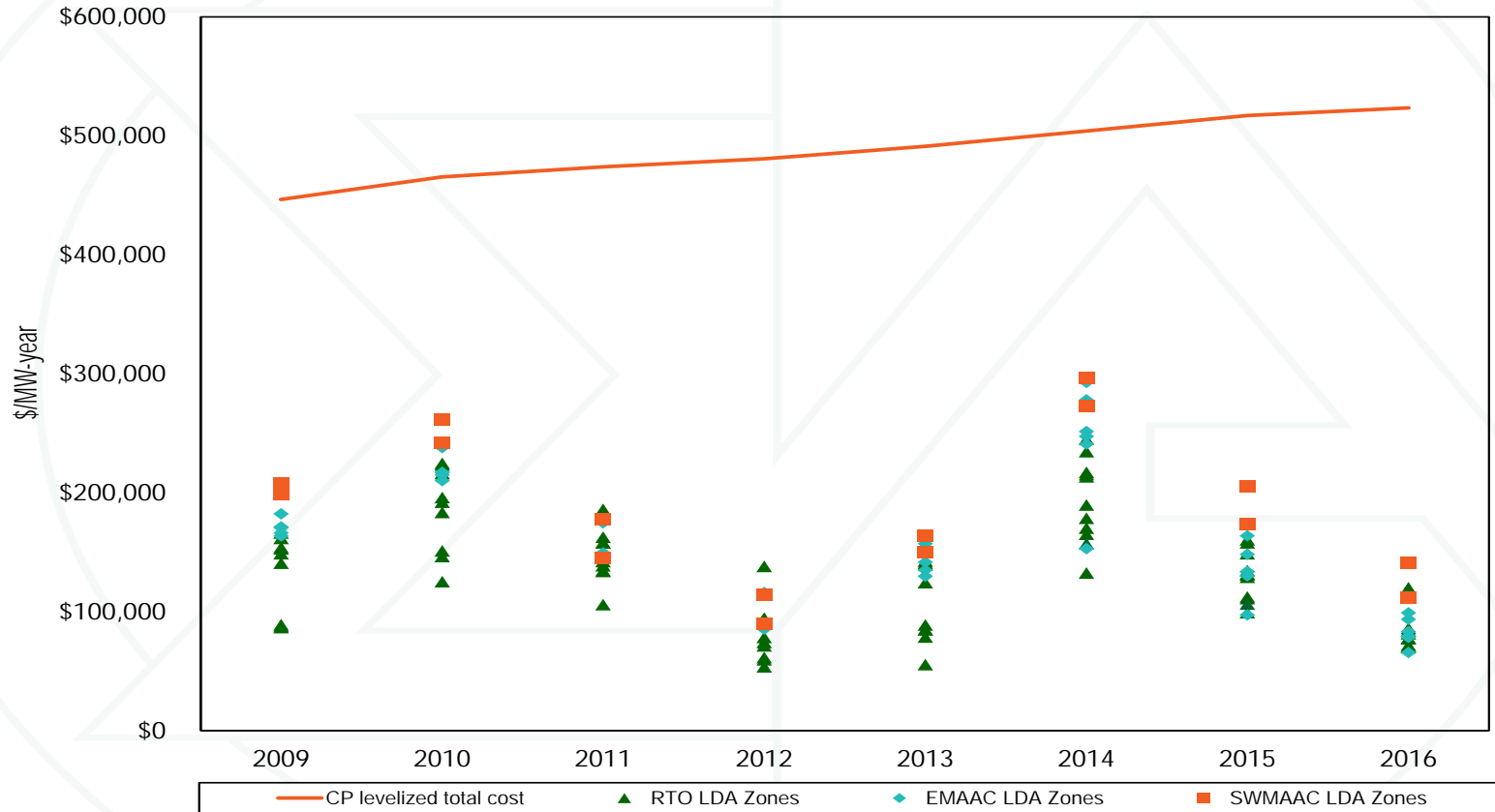
PJM Installed Capacity FDI



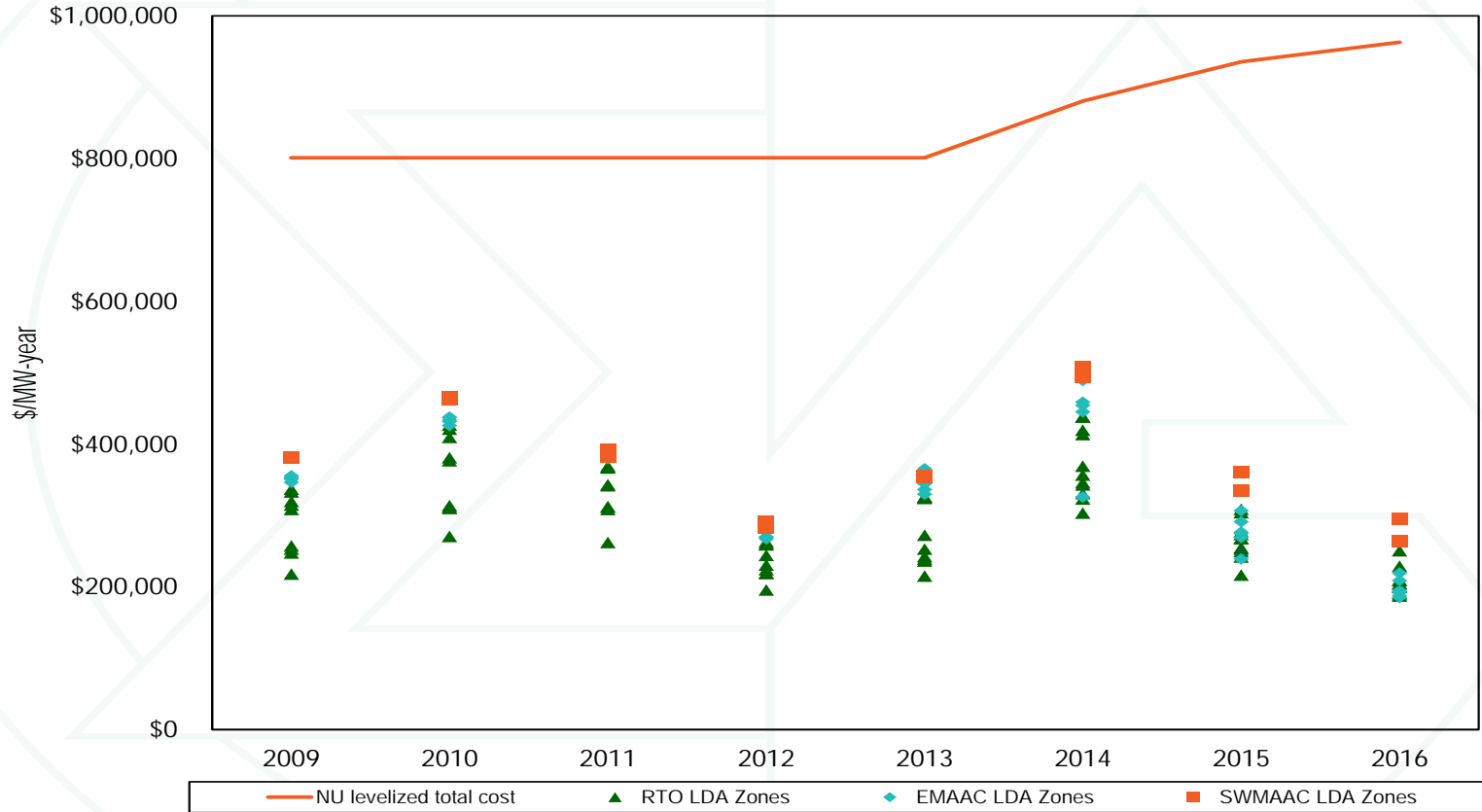
New Entrant CC Net Revenue



New Entrant Coal Net Revenue



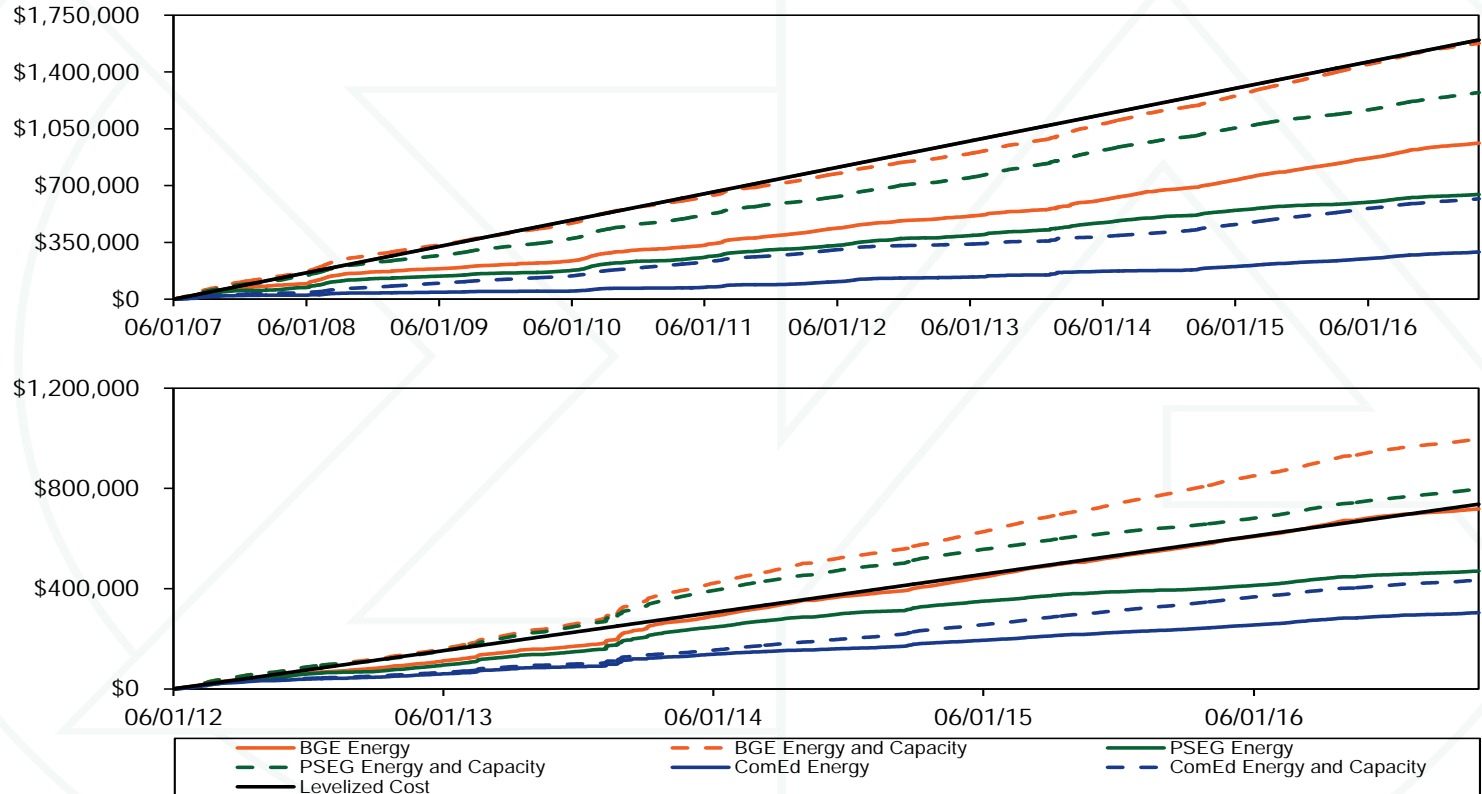
New Entrant Nuclear Net Revenue



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%

New Entrant CC Revenue Adequacy



Retirements 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

Additional Cost of DOE Proposal at 25% of Replacement Cost

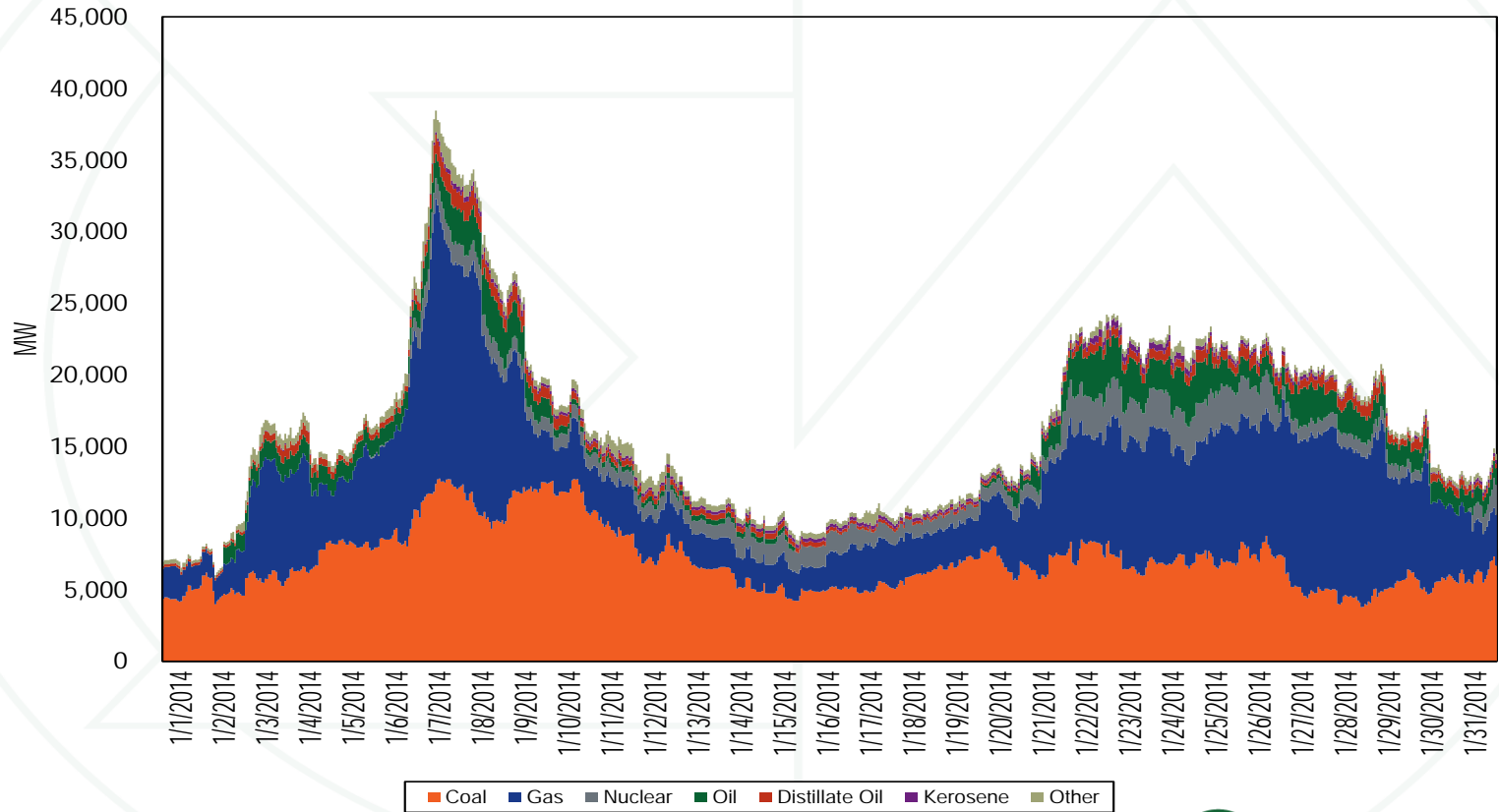
Additional Cost of DOE Proposal at 25 Percent of Replacement Cost
(\$ in millions)

	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%

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



Generation Commitment Status 2016

Energy Market	Self Scheduled (Must Run)	Self Scheduled (Dispatchable)	Pool Scheduled (Block Loaded)	Pool Scheduled (Dispatchable)	No Defined Status
Day Ahead	32.5%	29.3%	3.4%	34.8%	0.0%
Real Time	35.7%	24.9%	4.9%	34.2%	0.3%

PJM Price Formation Rationales

- **Need to recognize contribution of baseload**
- **Negative offers have pernicious effects on baseload retirement**
- **Falling energy net revenues for baseload**

PJM Price Formation Rationales

- **Desire to shift revenue from capacity to energy**
- **Flattening supply curve decreases net revenue**
- **Reducing uplift**

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