Market Implications of Significant Renewable Penetration

Mike DeSocio
SENIOR MANAGER, MARKET DESIGN

Environmental Advisory Council

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Agenda

- Background
- NYISO's Efforts on Integrating Public Policy
- NYISO's Market Assessment
  - Market Study – Energy
  - Market Study – Capacity
  - Market Concepts
- Q&A
- Appendix – Modeling Assumptions

A Tale of Two Grids

“The emerging story of the New York electric system is a tale of two grids — a tale of clean energy abundance and surplus generating capacity upstate and fossil-fuel dependence and high demand downstate.”

Power Trends 2017

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New York has Goals, Mandates, and Mechanisms to Substantially Reduce CO_2 Emissions

State Energy Plan

- Reduce economy-wide greenhouse gas emissions 40% by 2030 and 80% by 2050, relative to 1990 levels
- 50% of electricity from renewables by 2030

Clean Energy Standard

- Renewable Energy Credits (RECs)
- Zero-Emission Credits (ZECs)

Numerous other policies

- Participation in the Regional Greenhouse Gas Initiative (RGGI)
- Reforming the Energy Vision
- Energy efficiency standards
- Governor's proposal to eliminate coal-fired generation by 2020

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Integrating Public Policy Project

The Brattle Group Work

Carbon Pricing:

Study whether incorporating a state policy defined cost of carbon in the wholesale market would improve the overall efficiency of the NYISO energy and capacity markets

NYISO Work

Market Impact Assessment of 50% Renewable Generation:

Study the impacts of decarbonization goals on the current NYISO energy and capacity markets from the high penetration of low carbon or carbon-free resources

Market Structure Assessment of 50% Renewable Generation:

Study whether other market products or changes to the existing market structure will be necessary to meet the anticipated reliability needs

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Market Assessment

50% Renewable Resource Penetration

*Further information can be found here

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Market Assessment – Two Purposes

1. **Market Study** - The NYISO's goal is to provide stakeholders with information regarding potential market conditions with the incorporation of renewables resources to meet 50% of the NYCA load.
2. **Market Concepts** - The NYISO is considering a broad spectrum of market product and/or structure enhancements that may be necessary to incent resource characteristics or behaviors needed to achieve 50% renewable generation by 2030.

Market Study - Energy

50% Renewable Resource Penetration

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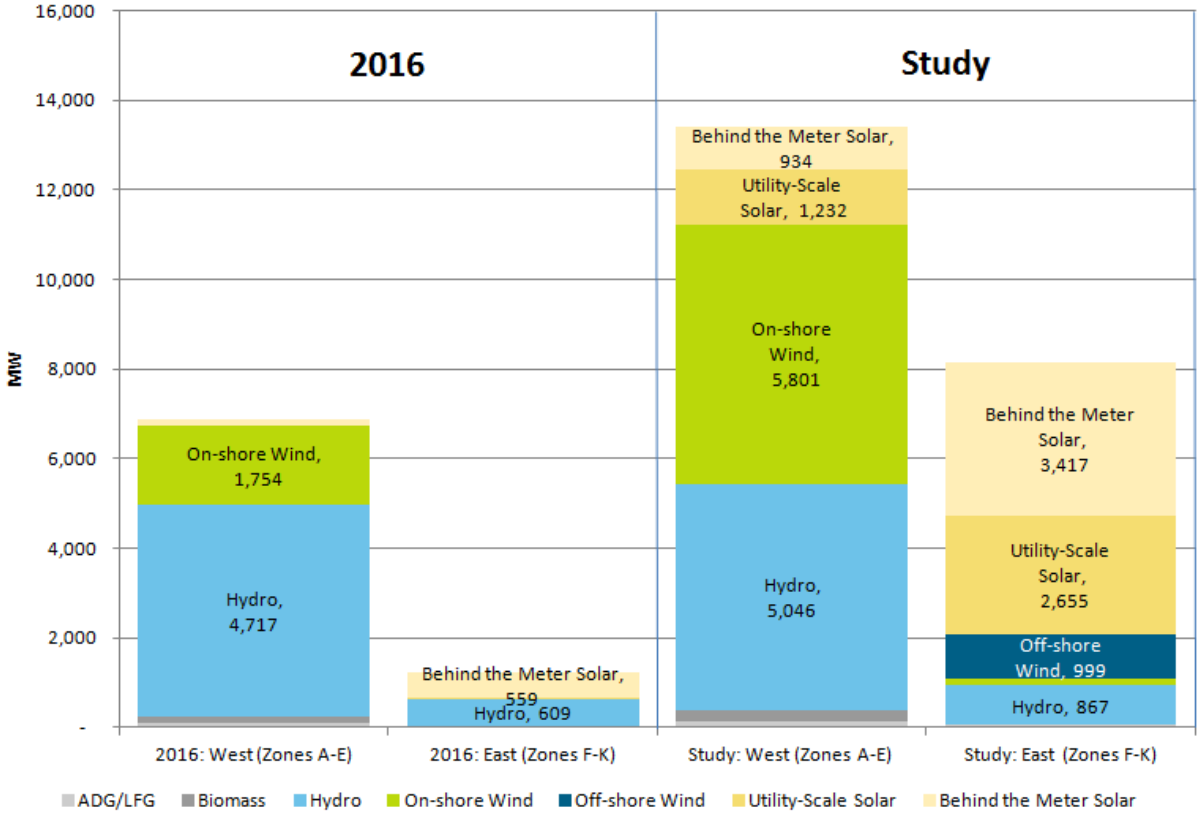
Today's renewables and study renewables



❖ The "study" case represents NYDPS Final Supplemental EIS installed megawatt (MW) projections.

❖ ADG/LFG = anaerobic digester/landfill gas generators.

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Energy Market Days Modeled

Day Ahead Date	Peak Load Forecast (MW)	Peak Hour	High-Low Temp. ALB/LGA	Gas Prices TNZ6/TZ6NY	Other
Tuesday, January 19, 2016	22,168	18:00	23-13/29-18	$4.20/$6.25	Winter Peak
Tuesday, March 22, 2016	18,638	20:00	51-27/55-35	$2.02/$1.30	Indian Point 2 Refueling
Monday, July 25, 2016	31,401	16:00	89-68/91-81	$2.91/$2.83	Summer
Thursday, November 10, 2016	19,131	17:00	51-32/57-43	$2.45/$1.90	High Wind

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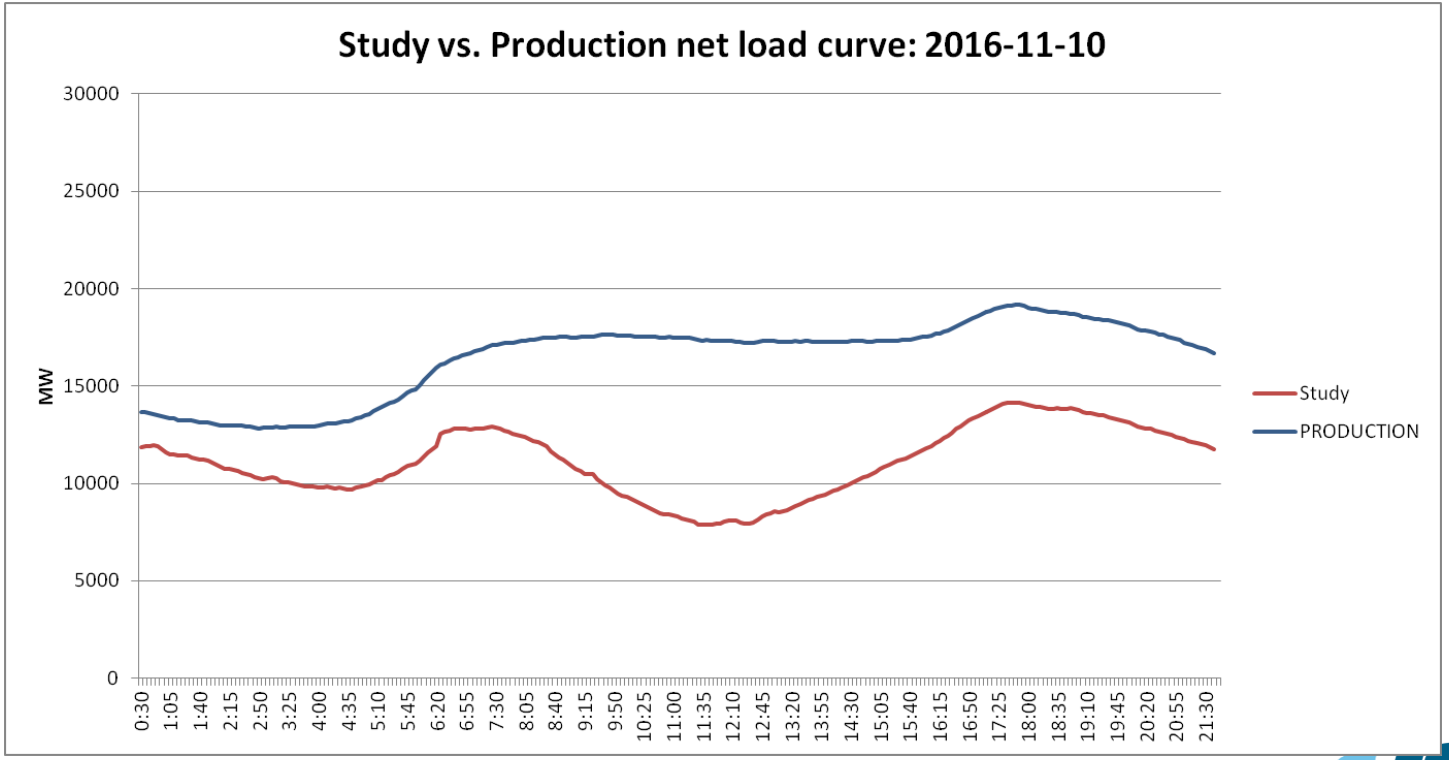
Study vs. Production net load curve: 2016-11-10



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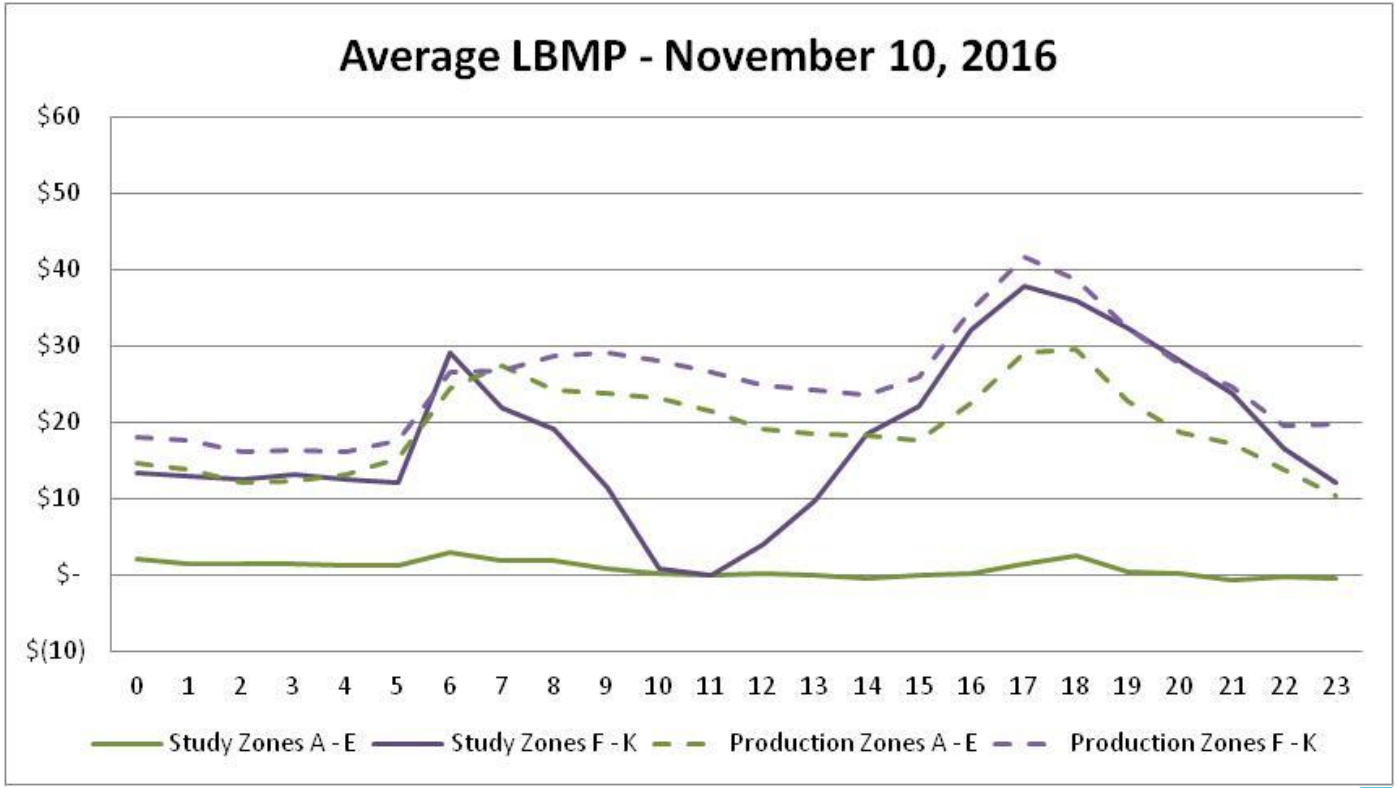
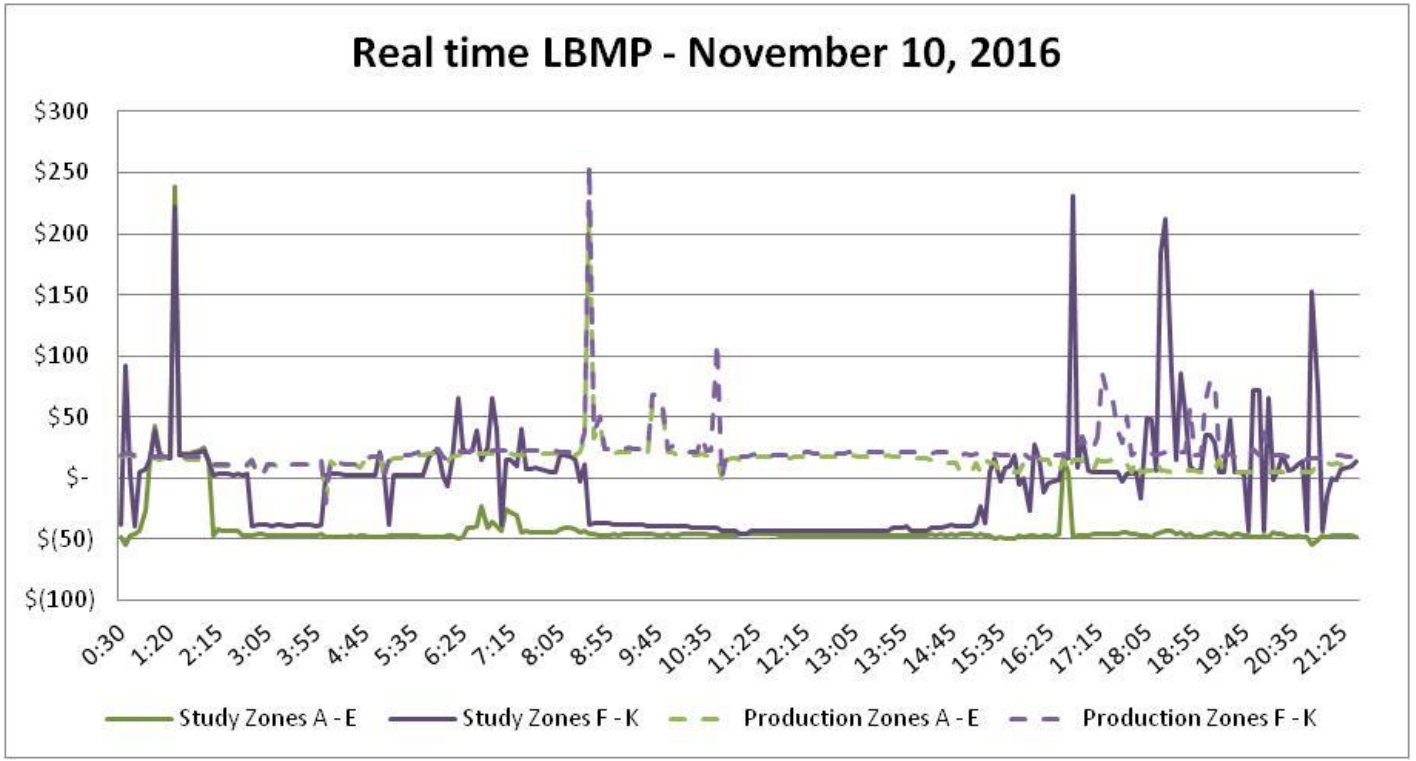
DAM Prices: 2016-11-10



RTD Prices: 2016-11-10



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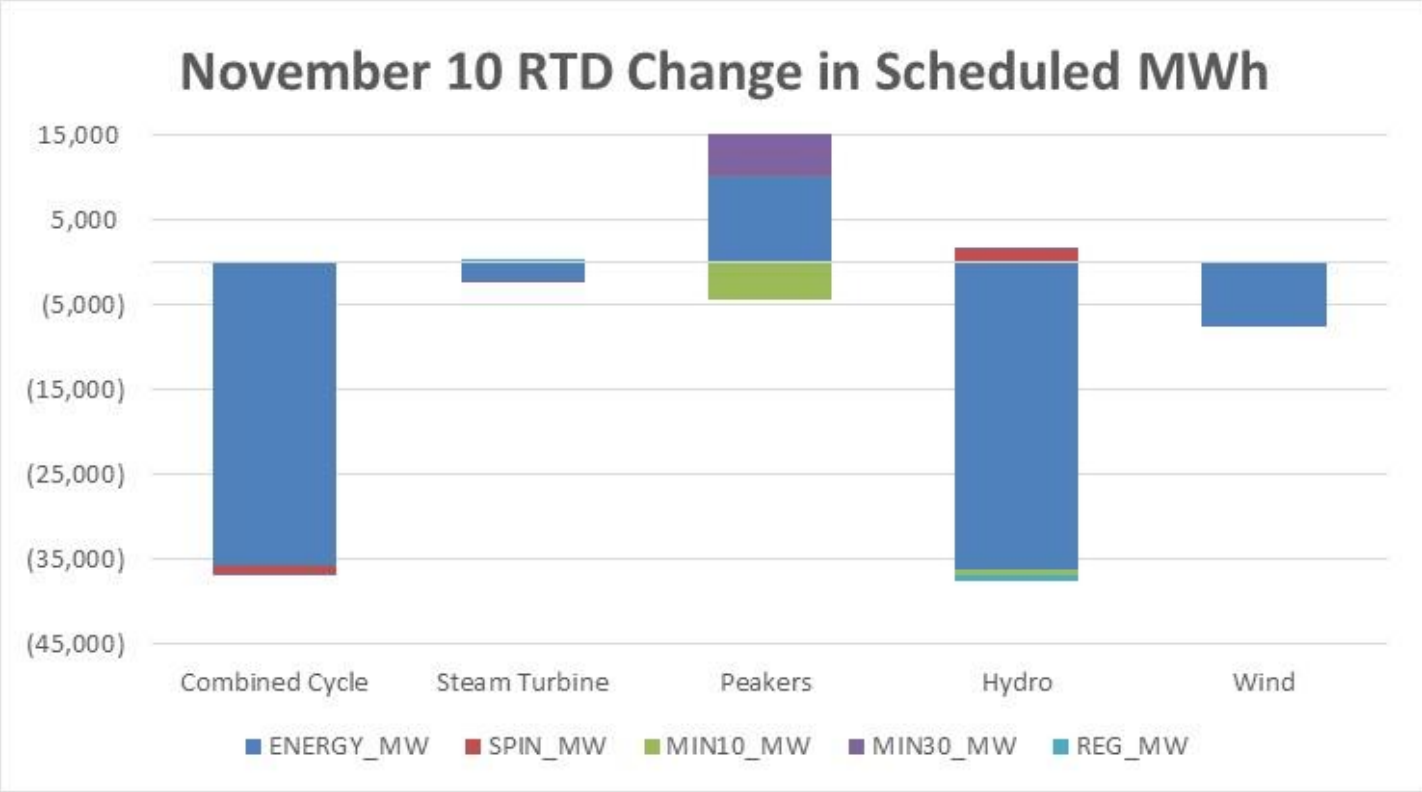
Overall Observations

- **In general, flexible resources currently connected to the grid were dispatched down, replaced by both the behind the meter resources and the renewables modeled as virtual supply**
  - Units dispatched down include Conventional Hydro, Combined Cycle, Fossil Fuel Steam Turbine and existing wind resources.

Schedule Changes of Existing Resources



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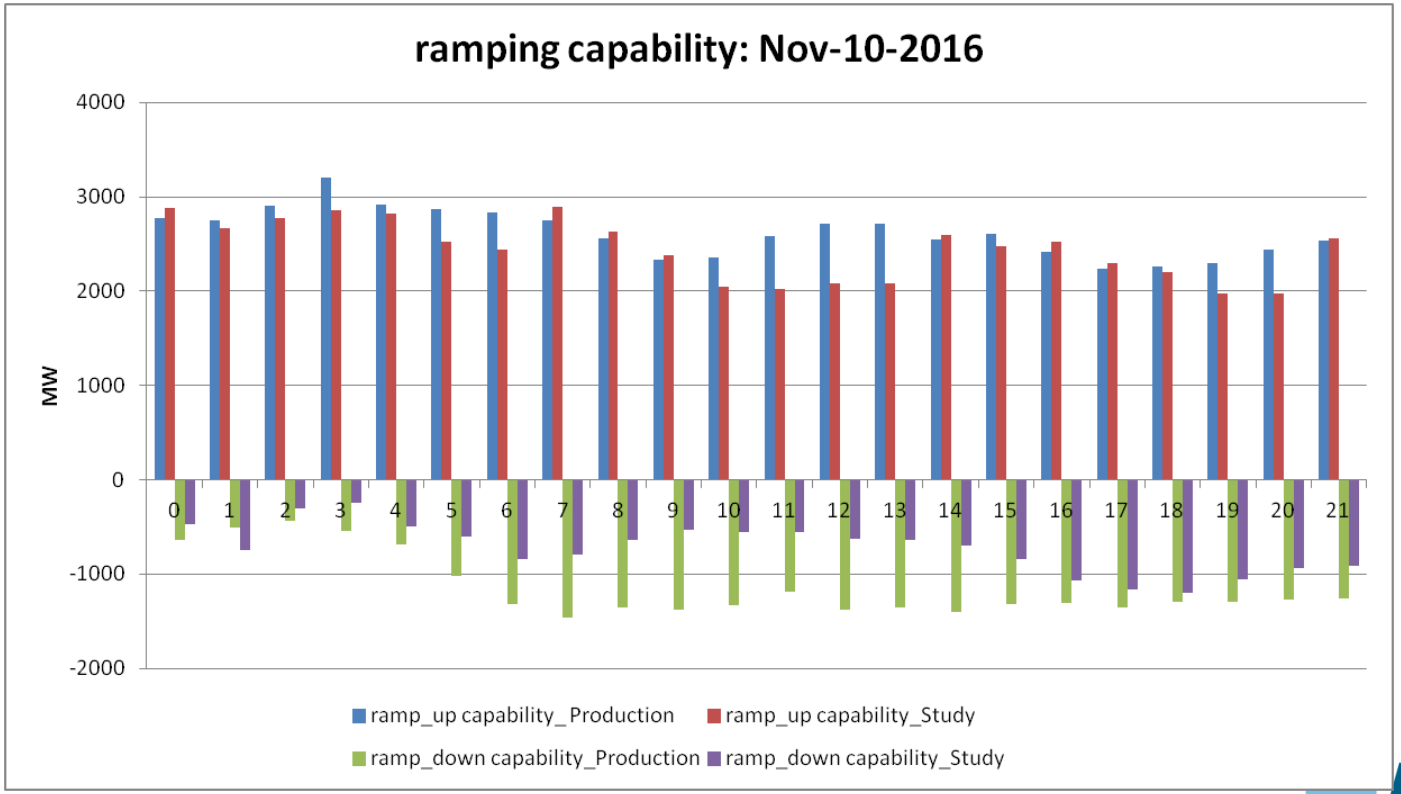
System ramp capability: 2016-11-10



Market Study - Capacity

50% Renewable Resource Penetration

Modeling the effect of additional renewable resources on the ICAP market

- ✓ **Identify the additional resources**
  - Quantity
  - Location
  - Characteristics (e.g., Unforced Capacity as a percentage of ICAP)
- ✓ **Model the effect of these resources on resource adequacy requirements**
  - Installed Reserve Margin (IRM)
  - LCRs
  - http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={039DE249-C6D9-4A80-8183-349261546F1B} (NYISO comments in the NYS Clean Energy Standard Docket, including IRM discussion)
- ✓ **Model the effect of these resources on peak demand**
  - ICAP Load forecast
- ✓ **Model the effect of these resources on Demand Curve parameters**
  - Demand Curve reference points
    - Net Energy and Ancillary Services revenues of the Demand Curve peaking unit (i.e. assumed to be $0/kW-y)
    - Winter-to-Summer ratio
  - NYCA and Locality translation factors

Renewable Capacity Added by Zone

Zone(s)	Nameplate MW added
A-F	8,978
GHI	905
J	1,235
K	2,326
A-K (NYCA)	13,444

Effect of Incremental Renewable Resources – ICAP Demand Curves

- **ICAP reference points increased**
  - Driven by the use of the assumption that the Demand Curve peaking plant receives 0$/kW-y net EAS (see the sensitivity analysis for alternate assumptions)
- **ICAP minimum requirements increased for the NYCA, remained nearly flat for the Localities**
  - Adding renewable resources increases the derating factor (locational EFORd) and thus increases the requirement
  - Adding BTM solar decreases peak load and thus decreases the requirement
- **Demand Curves became steeper**
  - Driven by higher reference points
- **The NYCA results are shown on the next slide**
  - Locality results are shown in the spreadsheet posted with this presentation
  - Results did not change from the 7/13 preliminary results presentation, except minor rounding changes

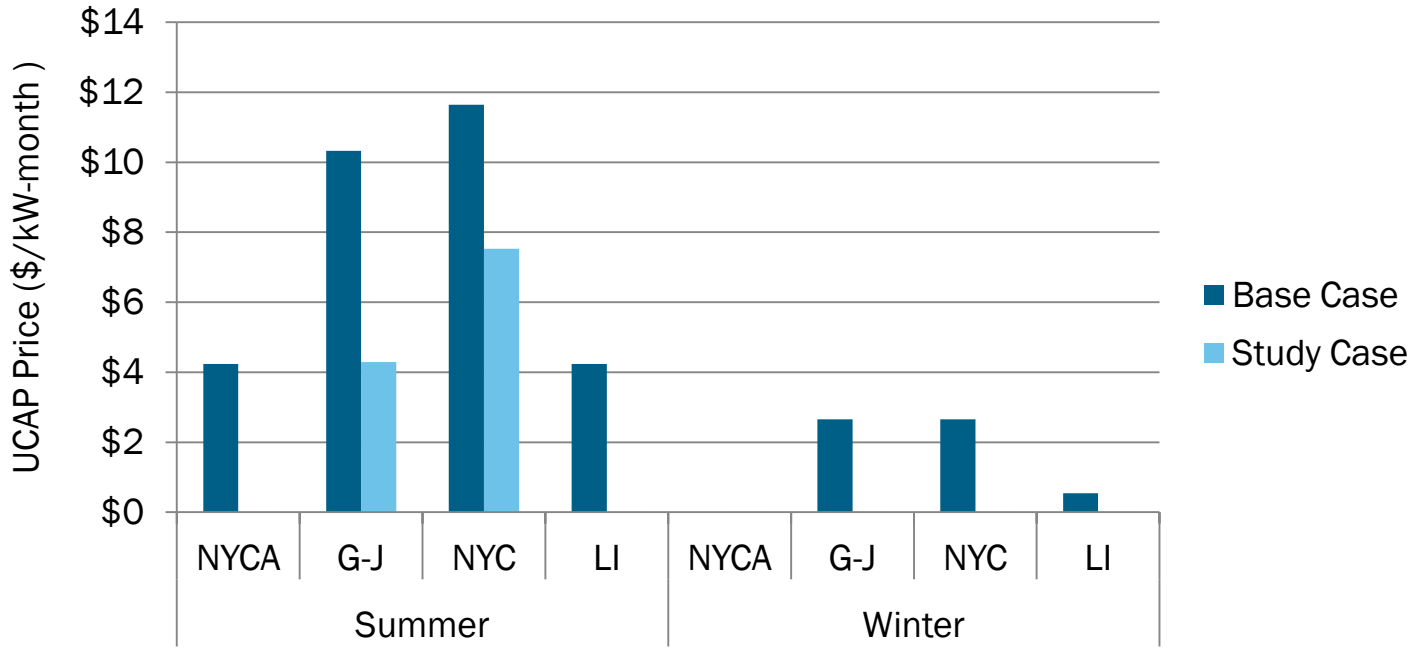
NYCA Final Results

NYCA Results *MW values, except load, are in UCAP MW*	Base Case		Study Case		Difference	
	Summer	Winter	Summer	Winter	Summer	Winter
Spot Auction Price ($/kW-Month)	$4.24	$0.00	$0.00	$0.00	-$4.24	$0.00
Load Forecast 2017	33,177.8	33,177.8	31,503.5	31,503.5	-1,674.3	-1,674.3
LCR/IRM Percentage	118.00%	118.00%	138.80%	138.80%	20.80%	20.80%
Demand Curve ICAP Ref Point	$9.08	$9.08	$12.19	$12.19	$3.11	$3.11
ICAP/UCAP derating factor	9.68%	7.90%	21.64%	20.95%	11.96%	13.06%
UCAP Ref Point	$10.05	$9.86	$15.56	$15.42	$5.51	$5.56
UCAP Requirement	35,361.4	36,058.8	34,264.2	34,565.0	-1,097.2	-1,493.8
Demand Curve Zero Crossing	112.00%	112.00%	112.00%	112.00%	0.00%	0.00%
UCAP at $0	39,604.8	40,385.9	38,375.9	38,712.8	-1,228.9	-1,673.1
Demand Curve Slope	(0.0024)	(0.0023)	(0.0038)	(0.0037)	(0.0014)	(0.0014)
Generation/SCR UCAP Available**	36,647.7	39,805.0	39,617.9	41,971.9	2,970.2	2,166.9
Imports	1,413.7	1,172.9	1,413.7	1,172.9	0.0	0.0
Exports	138.3	146.1	138.3	146.1	0.0	0.0
Unoffered MW	101.7	177.5	101.7	177.5	0.0	0.0
Unsold MW	4.6	164.1	4.6	164.1	0.0	0.0
Total MW Cleared***	37,816.8	40,490.2	40,787.0	42,657.1	2,970.2	2,166.9
MW Cleared Above Requirements	2,455.4	4,431.4	6,522.8	8,092.1	4,067.4	3,660.7
% Cleared Above Requirements	6.94%	12.29%	19.04%	23.41%	12.10%	11.12%

Overall Observations

- **Summer supply and demand balances shift most dramatically in the NYCA and Long Island**
  - Due to additional MW of renewable capacity (both wholesale and BTM) in these locations
- **Winter supply exceeds the zero crossing point in all locations**

UCAP Price in the Base and Study Cases



Market Concepts

50% Renewable Resource Penetration

General Themes driving Market Concepts

- Availability
- Dispatchability (Ramping)
- Predictability (Accuracy of Forecasts)
- Flexibility (Cycling)

Number of Starts by Unit Type							
Study	*22-Mar*	*25-Jul*	*10-Nov*	**Production**	*22-Mar*	*25-Jul*	*10-Nov*
Combined Cycle	23	30	20	*Combined Cycle*	9	18	6
Combustion Turbine	16	77	24	*Combustion Turbine*	15	76	7
Jet Engine	31	49	58	*Jet Engine*	18	39	19
Internal Combustion	2	1	3	*Internal Combustion*	1	1	0
Steam Turbine (Fossil)	2	12	0	*Steam Turbine (Fossil)*	2	9	0
Conventional Hydro	0	3	4	*Conventional Hydro*	0	3	4
Pumped Storage Hydro	7	10	8	*Pumped Storage Hydro*	2	3	0

- Let's not forget the need for transmission!

Energy Market Potential Concepts

- **Concepts for new energy market products:**
  1. Separate products for regulation up and regulation down
  2. Ramping product to cover forecast error
- **Energy market products or rules that could be modified or enhanced:**
  1. Revisions to offline fast start pricing
  2. More dynamic ancillary service requirements and shortage pricing levels

Capacity Market Potential Concepts

- **Capacity market products or rules that could be modified or enhanced:**
  - DA bidding obligations
  - Output duration requirements
  - Initial performance factors for new resources

Next Steps

Whitepaper

Questions?

We are here to help. Let us know if we can add anything.

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The Mission of the New York Independent System Operator, in collaboration with its stakeholders, is to serve the public interest and provide benefits to consumers by:

- Maintaining and enhancing regional reliability
- Operating open, fair and competitive wholesale electricity markets
- Planning the power system for the future
- Providing factual information to policy makers, stakeholders and investors in the power system

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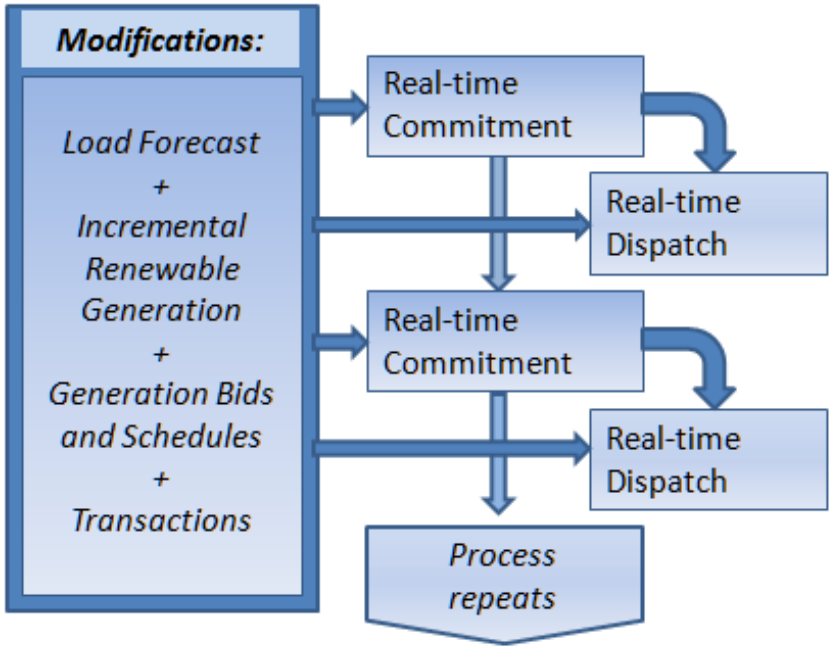
Appendix: Modeling Assumptions

Real-Time Market Simulation Process

- Hourly commitments from DAM simulations passed to the real-time simulation
- Modifications are read into the solver for each RTC and RTD evaluation
  - Behind-the-meter solar modifies zonal load forecast
  - Incremental Renewable Generation
  - Commitment Schedules for existing Generation
  - Lost-opportunity cost bids modified for some resources
  - Fixed Transaction Schedules
- Note that the simulation covers hours 1 through 20 and part of hours 0 and 21 because other hours depend on the prior/next day's bids.



Modeling Assumptions

- **Bid pass & forecast pass**
  - New Behind The Meter (BTM) Solar resources are modeled as fixed load modifiers
  - New utility-scale renewables are modeled as virtual supply (with -$47/MWh incremental bid in the bid pass)
  - Existing resources and existing virtuals are modeled as bid in production, except for resources bidding opportunity costs
- **External Transactions**
  - All interfaces but HQ are fixed at production cleared quantities. HQ is economically evaluated in the simulation.
- **Regulation, reserves**
  - Current production requirements
- **Resources bidding**
  - Bids from selected resources bidding based on opportunity costs were adjusted to account for different RT LBMPs (scaled by the peak hour ratio of preliminary study LBMP to production LBMP).
  - Selected resources bidding a higher RT Lower Operating Limits (LOL) than DAM LOL had their RT LOL in the study changed to their DAM LOL so their study DAM schedules were achievable within their RT operating range.

Modeling Assumptions (cont.)

- Incremental Renewable Resources by Zone (MW)

	A	B	C	D	E	F	G	H	I	J	K
Wind (On-shore)	981	238	947	851	1,031	141					
Wind (Off-shore)										408	591
Utility-Scale Solar	841		391			1,812	431	7			373
Hydro	8	30	72		219	213	28	17			
Biomass	57		65								
Landfill Gas	5	4	2			2			3	34	3
BTM Solar	193	117	287	10	174	577	584	91	118	419	1,069
Total	**2,085**	**389**	**1,764**	**861**	**1,424**	**2,745**	**1,043**	**115**	**121**	**861**	**2,036**

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Modeling Assumptions (cont.)

- **For wind, solar and hydro, both the installed capacity (MW) and the annual production (GWh) are needed to form the profiles**
- **Wind**
  - On-shore wind profiles based on forecasts in DAM and metered performance in RT
    - Total MWs from EIS, Exhibit 4-1. Zonal distribution based on current NYISO Interconnection queue.
    - Day Ahead wind profiles from actual production forecasts for the study day.
    - Zone F profile based on Zone C.
    - Real-time wind profiles based on actuals
    - Total GWh in EIS requires a capacity factor 50% higher than historical average for wind generators in NYCA. To match GWhs to MWs installed profiles were scaled up MW-hour profiles, respecting upper operating limits, using the following scalar:
    - MWhscaled = (2 * MWhactual) – (MWhactual * (MWhactual /MWnameplate))
  - Off-shore wind profiles are based on NREL data,
    - The error modeled in the DA forecast is based on the error from on-shore wind.
    - Total MWs for J and K based on EIS, Exhibit 5-20.
    - Daily profiles from NREL Wind Prospector, 2012 case
    - Site south of NYC chosen for Zone J, and a site chosen off the Eastern tip on Long Island for Zone K.
    - Hourly MWs scaled to annual GWh projection in the EIS
  - Profiles and forecasts are zonal

Modeling Assumptions (cont.)

- **Large-Scale Solar**
  - Using actual profiles for Jan 19, March 25 and November 10 for both the Day-Ahead and Real-Time Markets
    - Better simulates day-ahead bidding of utility-scale solar and virtual supply on a normal day
  - Using “clear sky” zonal profiles in the DAM for July 25, and the actual, more variable, profiles in real time for that day
    - Better simulates day-ahead bidding of solar resources and virtual supply on a day with a weather front and thunderstorms moving across New York state
    - Hourly profile shape estimated with a 27% axis tilt, due south orientation.
  - Profile shapes based on actual metered output provided by a vendor
- **Behind-the-meter Solar**
  - MWs scaled to Final EIS assumption of 5,000 GWh
  - Profile shape based on actual metered output from vendor
  - July 25 to uses a“clear sky” profile in the DAM
  - Zonal distributions based on current zonal distributions provided by NYSERDA, net of existing BTM solar

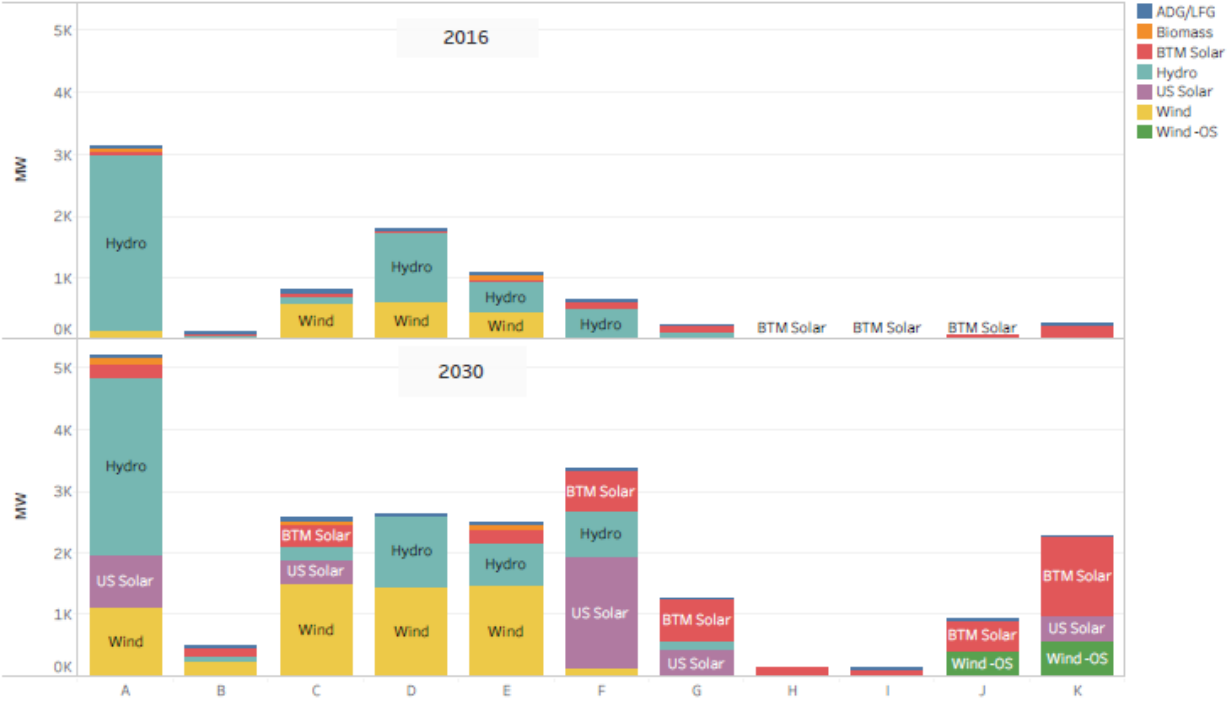
Modeling Assumptions (cont.)

- **Run of River Hydro**
  - Zonal MWs based on Final EIS, Exhibit 5-24.
  - Profiles based on like-days
- **Anaerobic Digesters/LFG**
  - Zonal MWs from Final EIS, Exhibit 5-27.
  - Flat profiles based on average actuals
- **Biomass**
  - New Zonal MWs from Final EIS.
  - Profiles based on existing facilities

Modeling Assumptions (cont.)

- **Transmission**
  - No topology changes in the system. System considered “as is”.
- **Real Time**
  - Incremental renewable generation added as zonal virtual supply (-$47)
  - Simulated DAM commitment overwrites real-time unit bid mode
    - Fast Start units re-evaluated using their RTM bids and non-fast-start units set to either “must run” or “unavailable” based on day-ahead commitment
    - Simulations are not linked to the prior day or the next day, therefore Real-time simulations can only calculate LBMPs from 00:30 to 21:40
  - All resources are assumed to follow real-time commitment and dispatch perfectly

Distribution of Renewable Capacity



- "2030" case represents NYDPS Final Supplemental EIS installed megawatt (MW) projections.

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Distribution of Renewable Capacity (cont.)

- Summary of Final EIS GWh used in Modeling Assumptions

Incremental Energy GWh in Assumptions from Final EIS 2030 Blend Case						
	Incremental		Existing		Total	
	GWH	MW	GWH	MW	GWH	MW
Land-based Wind	14,326	4,188	3,984	1,754	18,310	5,942
Utility-scale Solar	4,582	3,855	52	32	4,634	3,887
Hydro	2,720	587	26,704	6,727	29,424	7,314
Biomass/ADG	1,179	175	422	148	1,601	323
Offshore Wind	4,275	1,000	-	-	4,275	1,000
BTM Solar	5,000	4,350	811	712	5,811	5,062
Total	**32,082**	**14,155**	**31,973**	**9,372**	**64,055**	**23,527**
"Existing" here is based on 2016 Gold Book. Existing in Final EIS uses 2015 Gold Book						

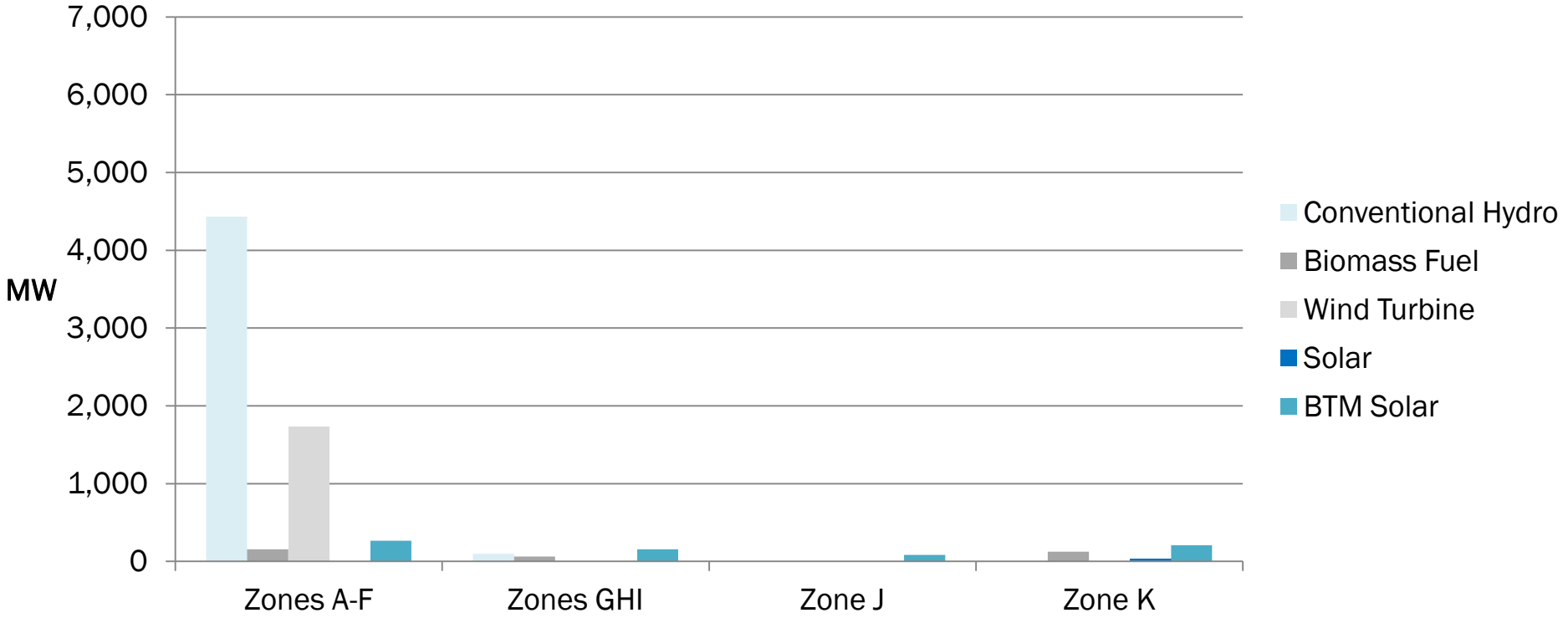
ICAP Base Case Assumptions

- **Market parameters and conditions representative of current market conditions**
  - 2017 ICAP reference points, NYCA Minimum Installed Capacity Requirement, Locational Minimum Installed Capacity Requirements (LCRs), ICAP Load forecast, ICAP Demand Curves' respective zero crossing points
  - Estimated ICAP to UCAP translation factors
  - Representative levels of Generation, SCRs, UDRs, imports and exports, unoffered and unsold ICAP

ICAP 'Study Case' Assumptions

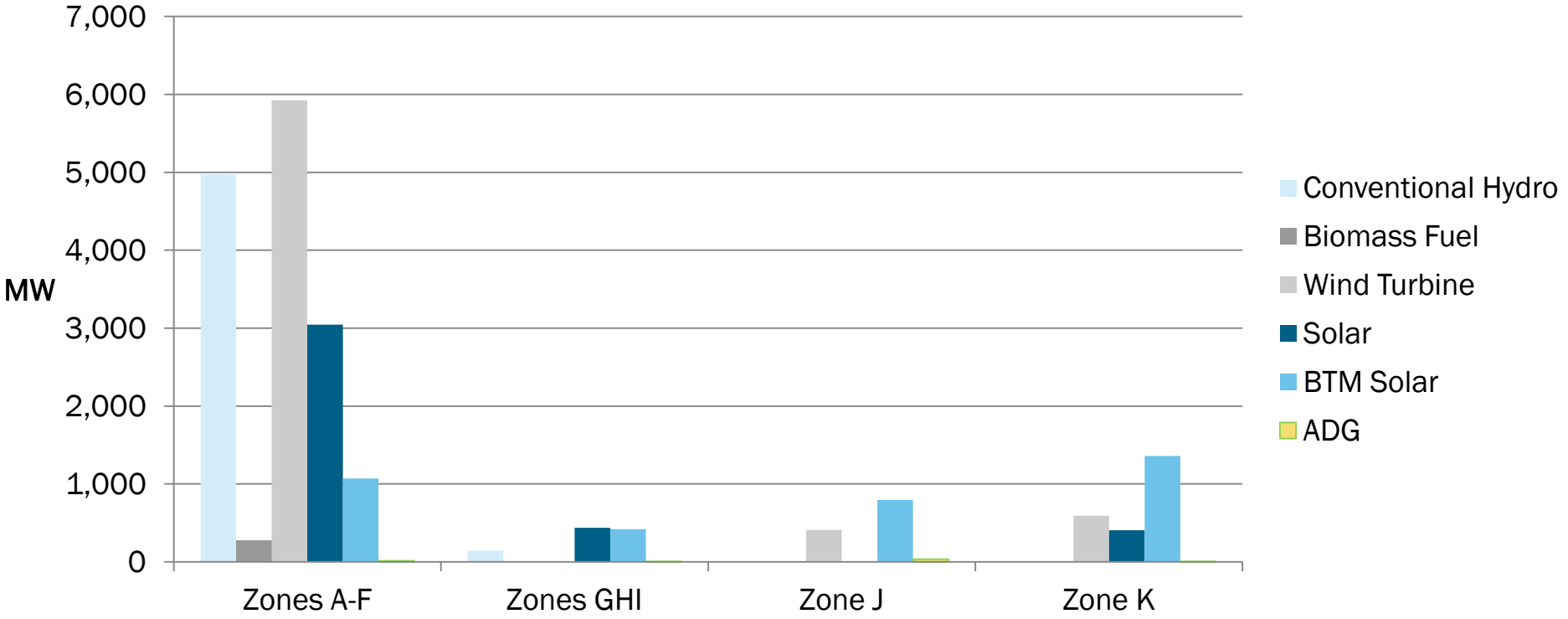
- **Keep the same existing generation, SCR, UDR, capacity imports, exports, and unoffered, unsold capacity as the base case**
- **Add incremental renewable capacity, similar to the approach in the IPP - energy market study**
  - The intent is to have the same resources modeled in both the energy market and capacity market studies
  - The primary source of projections for the quantity and location of qualified CES renewable generation is the NYSDPS Final Supplemental Environmental Impact Statement ("Final EIS") in CASE 15-E-0302 using the "Blend Base Case" http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={424F3723-155F-4A75-BF3E-E575E6B0AFDC}
  - Start with nameplate capacity values as ICAP and then convert into UCAP (*i.e.*, the product transacted in the NYISO ICAP market)

Renewable Capacity from the 2017 Gold Book (*i.e.*, Base Case)



BTM (i.e. retail level) solar MW are consistent with values presented at 3/28 and 4/24 MIWG meetings

Renewable Capacity in the ICAP Study Case



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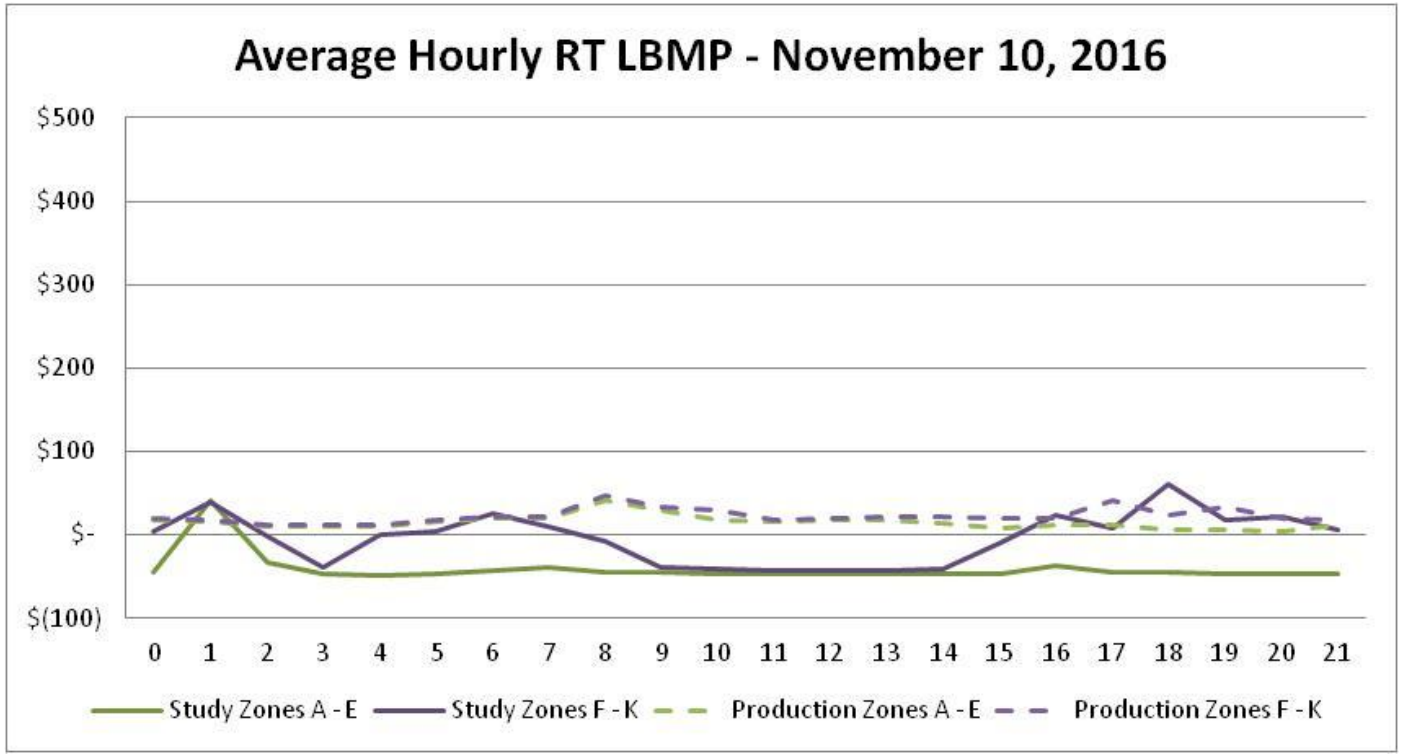
Study Case ICAP to UCAP derating factors

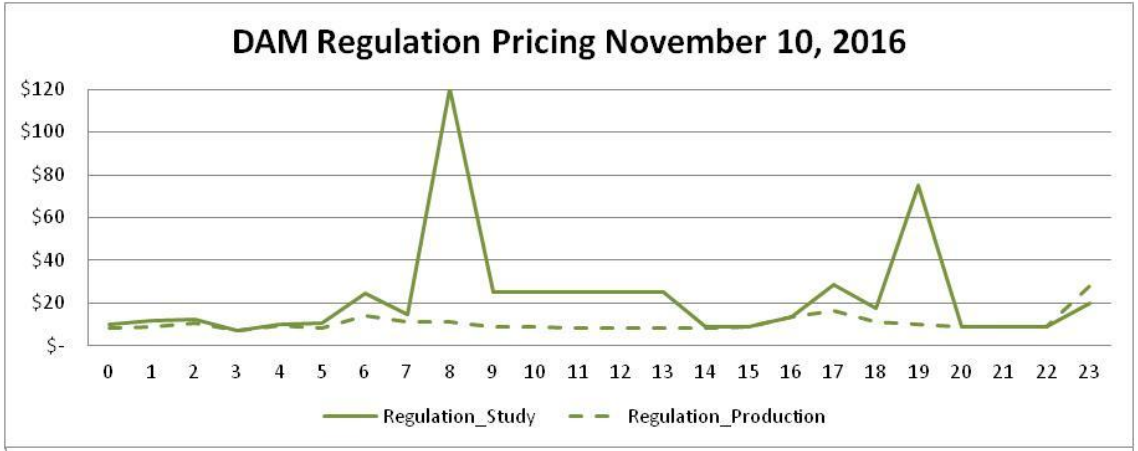
Resource	Summer DF	Winter DF	Source	Sensitivity performed?
On-shore wind	0.90	0.70	ICAP Manual, pg. 4-23	Yes
Off-shore wind	0.62	0.62	ICAP Manual, pg. 4-23	Yes
Solar (utility scale and BTM)	0.54	0.98	ICAP Manual, pg. 4-25	Yes
Run-of-River Hydro	0.50	0.40	Approximate NYCA average	No
Biomass/Landfill Gas	0.40	0.40	Approximate NYCA average	No

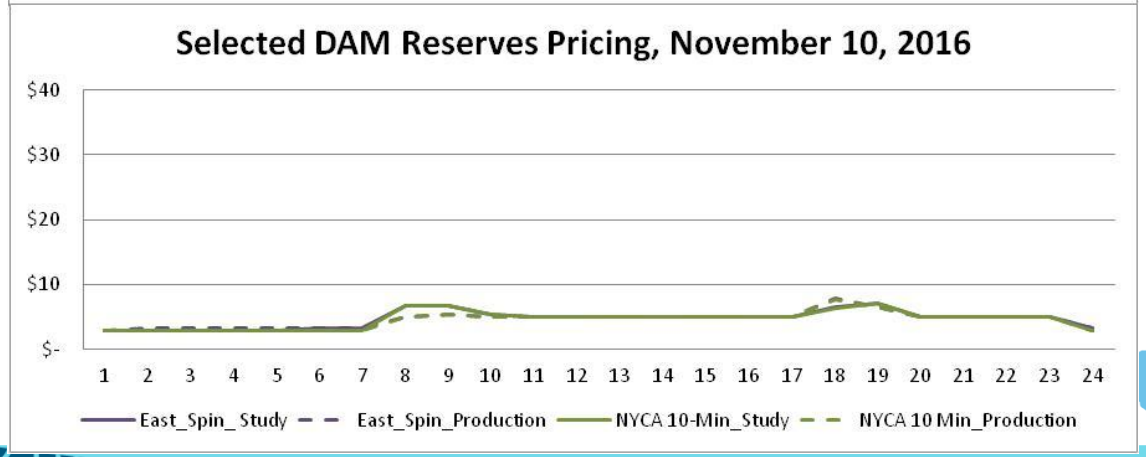
Appendix: Additional Results

Hourly RTM Results: 2016-11-10



DAM Reserve and Regulation Prices: 2016-11-10





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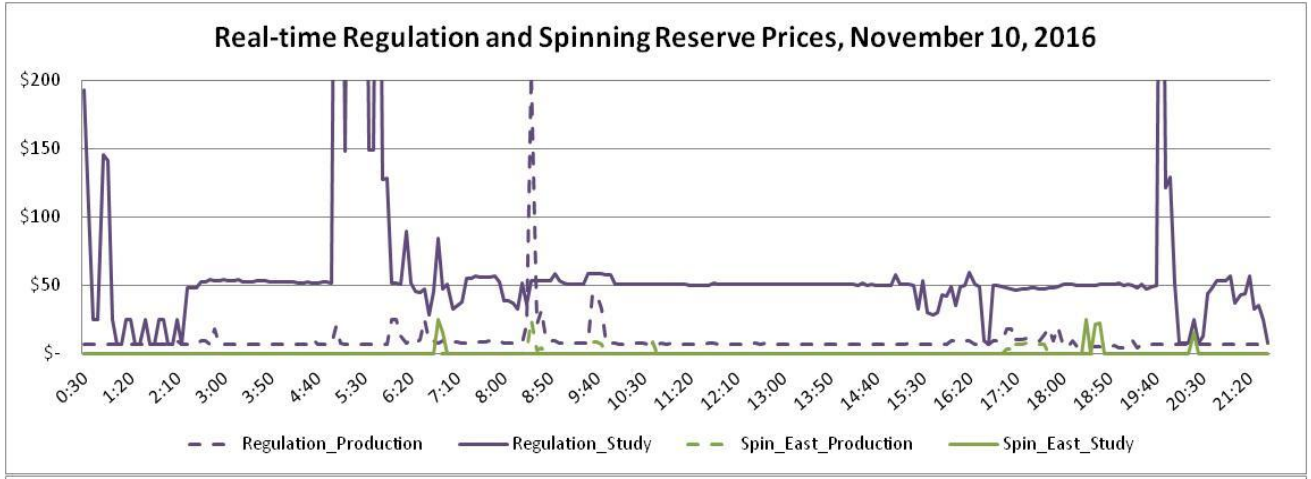
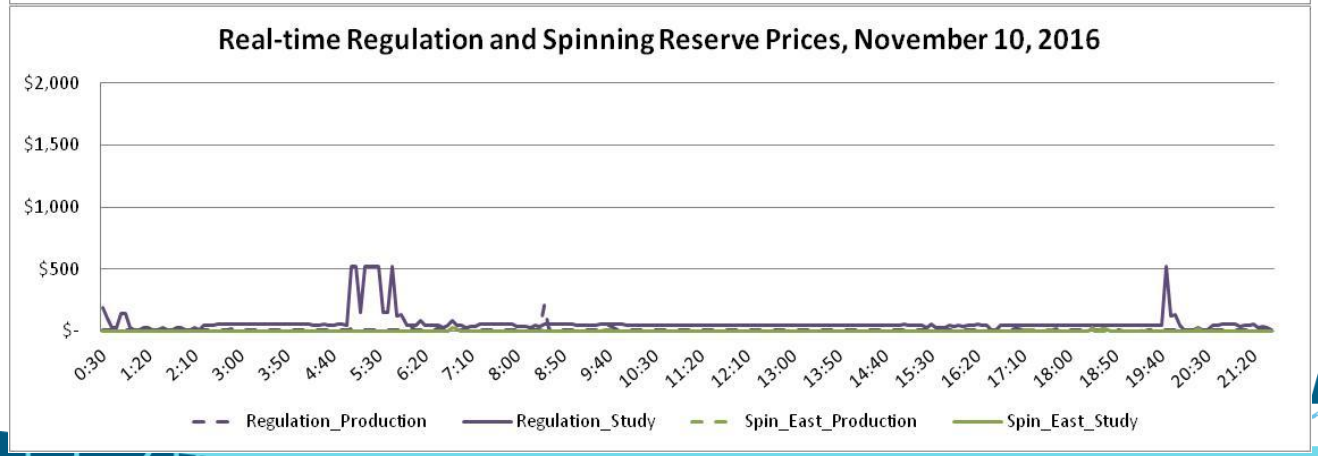
Real-time Reserve and Regulation Prices: 2016-11-10





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Real Time Hourly Average Bid MW Compared to Scheduled Front of the Meter Renewable MW - November