NORTHEAST POWER MARKETS

ENERGY WATCH

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EXECUTIVE SUMMARY

In this issue of *Energy Watch*™, ESAI discusses energy storage technologies with a particular focus on battery technology. Lithium-ion batteries have emerged as the technology of choice, although other technologies such as the more expensive flow batteries have characteristics that may be more desirable for highly active operations such as regulation. ESAI discusses current market rules that apply to storage resources and provides an overview of recent additions and queue activity in the three Northeast pools.

ESAI's natural gas outlook has been updated to reflect expectations for lower price escalation in the longer term. Technological advances will continue and are likely to keep production costs from advancing above inflation. Increased renewable penetration and completion of LNG export facility buildouts by 2022 will reduce the need for significant production increases, thereby increasing competitive pressures. In addition, Permian basin associated gas constraints will be relieved as up to 12 Bcf/d of new pipeline capacity is added to the region, largely targeting USGC demand from LNG export facilities.

ESAI's energy price and spark spread forecasts for each region are provided, along with details of assumptions that drive the individual regional and zonal forecasts.

In This Issue

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Energy Storage

INTRODUCTION

Fluctuating demand combined with the difficulties of storing electricity has long been recognized as a fundamental challenge for achieving efficient outcomes in electricity markets. Unlike most other goods, for which inventories can be maintained allowing for variations in production that are not contemporaneous with consumption, electricity generally must be produced at the time it is consumed. Increasing amounts of intermittent generation from renewable resources has exacerbated the challenges of efficient system operations, by requiring flexible generation resources to respond to not only fluctuations in demand, but also swings in supply.

This increase in renewable capacity, along with technological improvements related to the feasibility and cost of storage, has led to increased interest in storage among suppliers and system operators, leading to policy initiatives that encourage storage. This study begins a series of ESAI research related to energy storage. In this issue, we focus on the storage technologies, the commercial arrangements and product markets available to suppliers, the queues of new storage projects, and policy initiatives to expand storage capacity. In future pieces, we will address the economic issues associated with storage, such as:

- What are the economics and where are/should be decisions made to get to the optimal amount and use of storage?
  - Could the competitive market get us there?
  - If not, what is the market failure preventing that from happening?
  - If done through contracts, what incentives need to be set in order to get to an optimal outcome?
- Why is storage valuable to the system, to society, to producers, and to consumers?

TECHNOLOGY OVERVIEW

This study focuses on battery storage, but in the following section we present an overview of other key storage technologies for comparison purposes. While grid-scale battery applications are relatively new, other storage technologies have been operating in the Northeast markets for many years. In particular, pumped storage hydro facilities have been operating in each of the three Northeast power markets since the 1970's. Many hydro facilities are equipped with dams that can store several hours to several days worth of energy. More recently, flywheel operations commenced in New York and PJM.

There are three main categories of energy storage outlined below; chemical, mechanical and thermal. The performance characteristics of each of the key chemical and mechanical technology options are presented in Table 2, along with the markets that can be served by each technology.

Table 2: Performance Characteristics & Markets Served

	Chemical (Batteries)		Mechanical			
	Li-Ion	Flow	Pumped Storage Hydro	Reservoir Storage Hydro	Flywheels	Compressed Air
Characteristics						
Capacity	<1MW to >100 MW	up to 200 MW	3,000 MW[1]	3,000 MW	up to 20 MW	110 MW
Discharge Time, hrs	4[2]	4[2]	6-8	4+	0.25	26
Charge/Disch Efficiency	80-91%	75-85%	65-82%	N/A	85-88%	60-80%
Charging High/Low	85% / 15%	95% / 5%	100% / 0%	100% / 0%	100% / 0%	100% / 0%
Cycles per day	1-2	1-4	1	1	Unlimited	1
Lifetime cycles	3,000-5,000	Unlimited	Unlimited[3]	Unlimited[3]	Unlimited	Unlimited[3]
Degradation, Capacity at 10 yrs[4]	70-85%	95%	99%	99%	100%	99%
Markets Served						
Energy	x	x	x	x		x
Capacity	x	x	x	x		x
Regulation	x	x	x	x	x	x
Operating Reserves	x	x	x	x		x
Voltage Support	x		x	x	x	x
Black Start	x	x	x	x		x

1 - Bath County Pumped Storage; PJM
2 - Typical spec is 4 hrs, varies from 1 to 8 hrs
3 - Pumped Storage, Hydro with Storage & Compressed Air require major maintenance over the long term
4 - Percentage of original capacity

Chemical

Chemical energy storage includes a wide array of batteries, from the traditional lead-acid batteries to the state-of-the-art Lithium-ion (LI-ion) and Nickel-Cadmium batteries. Li-ion batteries are currently commanding the most attention for investment and represent over 90 percent of current installations worldwide. Flow batteries are gaining attention because of their resistance to capacity degradation. Fuel cells and electric vehicle-to-grid schemes are also in the chemical energy storage category. The following provides a brief overview of Li-ion batteries and chemical flow batteries.

Lithium Ion Batteries

Li-ion batteries have benefited from extensive development efforts for mobile phone and laptop computer applications, resulting in higher power deliveries with lower volumetric and weight requirements. Li-ion batteries have also been the technology of choice for electric vehicles, driving advances in larger scale batteries where weight and power delivery are critical. Li-ion batteries deliver a high energy density, which represents the available power to weight (or volume) ratio. Within the Li-ion sphere of batteries are various combinations of chemical technologies for the cathodes, anodes and electrolytes. Most projects are utilizing Lithium iron phosphate (LiFePO4) cathodes, graphite anodes and a gel polymer electrolyte.

The key battery specifications are capacity (max output) and duration (hours). The capacity of Li-ion batteries is highly flexible as battery units can be combined in buildings or containers with no specific limits on capacity. For utility scale projects, typical project sizes are 5-20 MW, although projects well in excess of 100 MW are under development. Because capacity increases are gained through incremental combinations of battery units, costs do not necessarily go down with increasing size. However, economies of scale can be gained in the balance of plant costs to achieve reductions in overall $/kWh costs for a facility.

The duration, or sustained energy output, of a battery facility can be tailored to the needs of a particular application and can range from 0.5 to 8 hours. A four-hour duration has more recently become the typical spec for grid-scale applications although worldwide installations to date have average durations of approximately two hours. A typical specification would be for a battery with a 20 MW capacity with a four hour duration that is therefore capable of 80 MWh of energy output (see Table 2 and further discussions on performance metrics below). Li-ion batteries degrade over time based largely on the number of charge/discharge cycles employed as well as the typical depth of discharge (deep discharge is detrimental to Li-ion battery longevity). After ten years, a Li-ion battery would be expected to lose at least 15 percent of its capacity.

Flow Batteries

Flow batteries employ liquid electrolytes stored in tanks that exchange electrons via a membrane that separates the two electrolyte solutions (one positive solution and one negative). Flow batteries are currently more expensive than Li-ion batteries, but the battery costs themselves can be reduced through larger sizes through the construction of larger tanks. Larger scale flow battery installations will also combine individual units to gain increases in capacity.

Although flow batteries are more expensive than Li-ion batteries, they have performance characteristics that may be more advantageous for specific applications. Flow batteries can operate with deeper discharge ratios and increased cycling without significant impacts to degradation rates (see Table 2).

EV to Grid

As the electric vehicle market grows and smart grid applications become more prevalent, the batteries within electric vehicles have the potential to be accessed by the grid as another source of storage. Given the low penetration of electric vehicles currently, this source of storage for the grid is unlikely to gain traction much before 2030.

Mechanical

Pumped Storage Hydro

Pumped storage facilities consist of an upper storage reservoir and a lower reservoir or river with a reversible turbine. The turbine can be used to pump water from the lower to the upper reservoir which can later be used to generate power when water is released from the upper reservoir to the lower reservoir. Pumped storage has been employed in the U.S. since 1930 and currently there are over 42 operating pumped storage facilities in the U.S. with a total capacity of over 21 GW.

Capacities of pumped storage in the U.S. range from 20 MW to almost 3,000 MW (Bath County in Virginia). Table 3 below provides an overview of pumped storage facilities currently operating in the Northeast power pools. Most began commercial operations in the 1960's and 1970's.

Pumped storage facilities provide tremendous operating flexibility to system operators due to their sheer size and quick response times. Pumped storage facilities typically cycle once per day, pumping overnight when prices are low and generating during peak hours the following day. Round-trip cycle efficiencies range from 65 – 82 percent, with 70-75 percent being typical. A 75 percent efficiency would represent 8 hours of pumping and 6 hours of discharge.

Table 3: Pumped Storage Hydro Facilities in the Northeast

Plant Name	Nameplate Capacity	ISO	State	COD
Bath County	2,770	PJM	VA	1985
Muddy Run	1,050	PJM	PA	1967
Seneca	470	PJM	PA	1970
Smith Mountain	250	PJM	VA	1965
Yards Creek	450	PJM	NJ	1965
Blenheim Gilboa	850	NYISO	NY	1973
Lewiston Niagara	235	NYISO	NY	1962
Bear Swamp	600	ISO-NE	MA	1974
Northfield Mountain	1,170	ISO-NE	MA	1973
Total	**7,845**			

Reservoir Storage (Run of River Hydro)

All hydro facilities include a dam that provides a difference in elevation between the surface of the reservoir behind the dam and a lower turbine and generator set. This difference in elevation drives the flow of water that spins the turbines. At a minimum, the dam maintains a reservoir height that maintains the required head (pressure) required to spin the turbines. For facilities with small reservoirs, maintaining the reservoir height when river flows are low may require a reduction in water flow through the turbines - resulting in generation that is below capacity. When river flows are high, these facilities will spill water past the dam, bypassing the generator which is already operating at its maximum capacity. Facilities with small reservoirs have limited flexibility and their energy output is directly correlated to the flow conditions of the river.

Facilities with larger reservoir storage capabilities can operate in ways that mimic pumped storage operations. It is possible for these facilities to limit the flow of water to the turbines overnight in order to preserve water height in the reservoir. The following day, the turbines can operate at higher levels and sell energy into the higher priced on-peak markets. Depending on the reservoir size, water can be stored to optimize energy output in terms of hours or days. Thus, pumped storage facilities are not alone in their capabilities to store water during off-peak periods for use later during on-peak periods.

HydroQuebec – The Canadian province of Quebec has vast potential for hydro resources. Currently, HydroQuebec operates 63 hydro facilities with a nameplate capacity of over 37 GW. For many of these facilities, the reservoir storage capabilities are enormous and measured in months, not hours or days.

Because of the HydroQuebec system's vast storage capabilities and flexibility as well as their ties to New York and New England, HydroQuebec can serve as a giant 'pumped storage' facility for the Northeast power markets. If an excess of renewable generation in New York or New England drives prices low (or negative) overnight, HydroQuebec can purchase power at these low prices to serve their local needs in Quebec, saving the water to be released for generation during higher demand and higher priced hours during on-peak hours. In this way, HydroQuebec can provide much needed balancing services to its neighbors to the south as the intermittancy of renewable production becomes harder to manage in the future.

More importantly, HydroQuebec has the storage capability to optimize generation and storage on a seasonal basis, not just daily. Generation can be reduced during the shoulder season months to conserve water for generation and energy exports to the south during the higher priced summer months.

HydroQuebec is expanding its export capabilities through its support for the construction of the 1,200 MW New England Clean Energy Connect (NECEC). The NECEC line will bring additional clean, hydro energy to New England via its interconnection in Maine and will add to the potential balancing and storage capabilities that will be beneficial to the New England grid.

Flywheels

Flywheels are mechanical batteries that store kinetic energy in a high-speed rotating mass that spins at its highest speed when fully charged. When discharging, the speed of the rotating mass slows as it powers a generator that provides energy to the grid. When charging, the generator serves as a motor to bring the rotating mass back up to full speed.

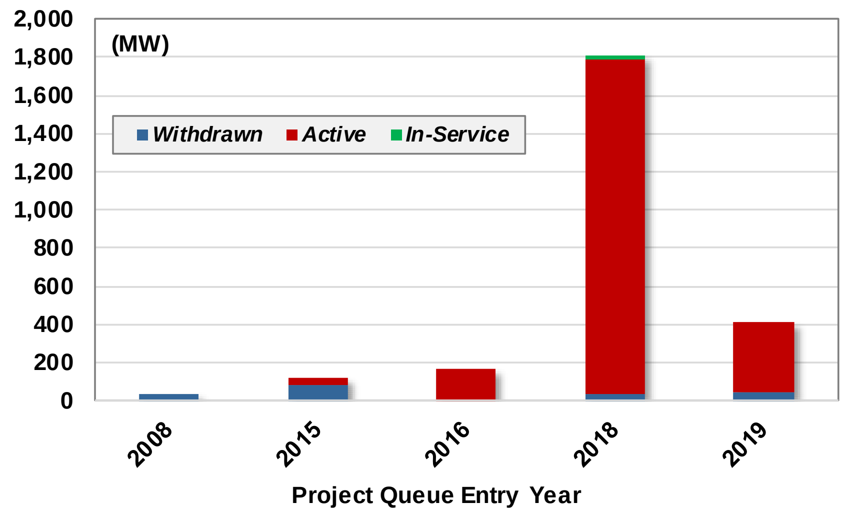
Beacon Power built the only operating flywheel facilities in the Northeast. The 20 MW Stephenstown, New York facility commenced operations in 2011 and the 20 MW Hazle Township facility in Pennsylvania commenced operations in 2014. Each facility is comprised of 200 flywheels, each of which contains a five-ton steel and carbon fiber rotating mass (see Figure 3 for a diagram of the flywheel). Both facilities are now owned by Convergent Energy and Power.

New York

Approximately 50 MW of energy storage capacity is installed in New York.[4] This amount is expected to increase significantly in response to the state's 3,000 MW by 2030 target and NYSERDA's Market Acceleration Bridge Incentive Program which is expected to incentivize two-thirds of the capacity needed to meet the 2025 interim goal of 1,500 MW.

The NYISO interconnection queue contains over 2,300 MW of energy storage projects, of which the queue reports approximately 100 MW is expected to enter service this year, 620 MW in 2020, 1,160 MW in 2021 and 450 MW in 2022. The amount of energy storage projects in the queue has increased significantly as almost all of the energy storage projects were added in 2018 (1,750 MW) and 2019 (365 MW). Between 2008 and 2019, 204 MW of energy storage projects withdrew from the queue.

Figure 9: NYISO Generation Interconnection Queue (Battery Storage Projects)



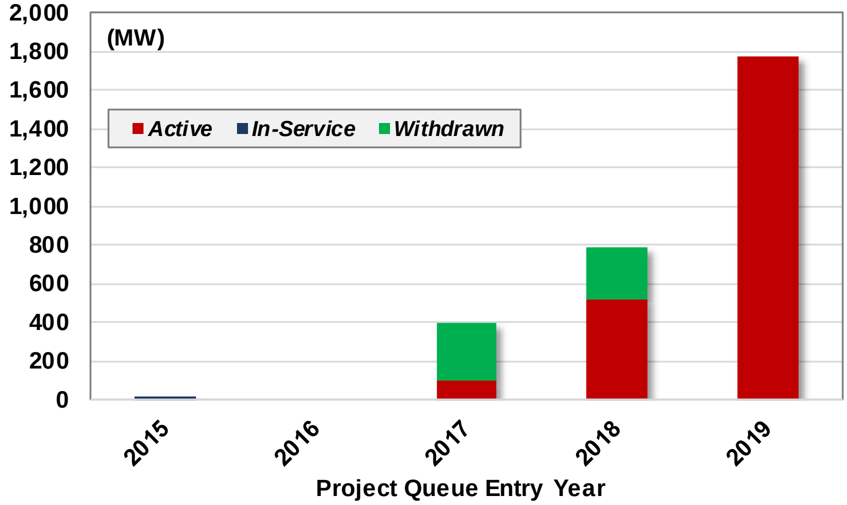
New England

In the six New England states, there is approximately 65 MW of installed energy storage capacity[5]. As shown in Figure 10, of the nearly 2,400 MW of active energy storage projects in the queue, the queue reports that 20 MW will enter service in 2020, 500 MW in 2021, 500 MW in 2022 and 1,355 MW in 2023. 1,700 MW (74 percent) of all active storage projects under development in New England are located in Massachusetts (the only state in the New England footprint with a mandatory standard). Virtually all of the energy storage projects entered the queue between 2017 and 2019 (100 MW; 2017, 520 MW; 2018, and 1,771 MW in 2019). Since 2015, 560 MW of energy storage projects have withdrawn from the queue.

[4] There is 50 MW of installed energy storage in New York. The queue shows 20 MW installed. This difference is attributed to BTM projects that are not included in queue.

[5] There is 65 MW of installed energy storage in New England. The queue shows 16 MW installed. This difference is attributed to BTM projects that are not included in queue.

Figure 10: ISO-NE Generation Interconnection Queue (Battery Storage Projects)



New England

NEW ENGLAND ENERGY MARKET OUTLOOK

Forecast Assumptions

Demand assumptions for New England are based on ISO New England's final 2019 CELT forecast, published in April 2019 and updated from the preliminary values used for ESAI's Q1 2019 forecast. ISO New England's latest load projections reflect the expectation of lower system peak loads and increased annual energy consumption, as discussed in the Q1 2019 issue of *Energy Watch*™. While demand assumptions are similar to those underlying the Q1 forecast, expected changes in supply are more significant.

Table 6 and Table 7 provide assumptions for retirements and new capacity additions in New England. Major generator additions include PSEG's 576 MW Bridgeport Harbor combined-cycle project in CT that is slated to commence operations in June this year, and NTE's 650 MW Killingly project (also in CT) with an announced target commercial online date of June 2022. In addition to gas-fired generation additions, ESAI's outlook also reflects the addition of substantial amounts of renewable energy resources, including offshore wind facilities that are expected to come online in 2024 and beyond as a result of clean energy solicitations in MA, RI and CT. Relative to the Q1 forecast, ESAI has assumed a substantially higher success rate for offshore projects, based on continued progress and financial commitments through state procurement processes. Our current forecast includes 2,900 MW of nameplate offshore wind additions by 2031, up from 2,100 MW included in our Q1 forecast.

Also, by 2024, Avangrid's 1,200 MW New England Clean Energy Connect (NECEC) HVDC transmission project is expected to become operational, creating additional access to hydro-generated power in Canada. The NECEC HVDC project was selected in response to Massachusetts' 83D solicitation and recently received approval of its PPA by the Massachusetts DPU.

Major capacity retirements in New England include the recent retirement of Entergy's 670 MW Pilgrim nuclear power station in SEMA, the decommissioning in 2021 of PSEG's remaining 400 MW coal-fired power plant at Bridgeport Harbor, and the retirement of Exelon's 617 MW Mystic 7 unit in NEMA. As discussed in detail in the Q2 2019 issue of *Capacity Watch*™, ESAI is now assuming that Mystic Units 8 and 9 will be retired in June of 2024, after continuing to operate based on retention of the by ISO-NE for transmission security (2021/22) and fuel security needs (2022/23 and 2023/24). Mystic Units 8 and 9 will operate under a FERC-approved cost-of-service agreement starting in June 2022. ISO-NE recently announced that the retention will extend one additional year, through May 2024. The plant could be shut down as soon as June 2023 if Exelon does not accept the terms of its cost of service agreement for 2023/24, however, ESAI has assumed operation through June 2024.

Table 6: New England Retirement Assumptions

Unit	Nameplate (MW)	Summer ICAP (MW)	Unit Type	Month	Year	Status	Location	Included in ESAI Base Case
Pilgrim	670	677	Nuclear	Jun	2019	Slated	SEMA	Yes
Front Street Diesels	8	8	Oil	Jun	2019	Slated	WMA	Yes
L Street Jet	19	16	Oil	Jun	2020	Slated	NEMA	Yes
Highgate Falls	3	3	Hydro	July	2021	Slated	VT	Yes
Attleboro Landfill	0	0	Landfill Gas	July	2021	Slated	SEMA	Yes
Bridgeport Harbor (Unit 3)	400	383	Coal	July	2021	Slated	CT	Yes
Pawtucket Power	69	60	Nat Gas	Jun	2022	Slated	RI	Yes
Mystic (Unit 7)	617	574	Oil	Jun	2022	Slated	NEMA	Yes
Mystic (GT1)	14	9	Oil	Jun	2022	Slated	NEMA	Yes
Mystic (Unit 8)	872	703	Nat Gas	Jun	2024	Slated	NEMA	Yes
Mystic (Unit 9)	872	714	Nat Gas	Jun	2024	Slated	NEMA	Yes
Economic Retirements ('24)	1,050	1,050			2024	At-Risk	ME / NH	Yes
Economic Retirements ('27)	1,250	1,250			2027	At-Risk	ME / CT / WMA	Yes
Total At-Risk	***2,300***	***2,300***						
Total Slated [1]	***3,544***	***3,148***						
Total	***5,844***	***5,448***						
Total in ESAI Base Case	***5,844***	***5,448***						

Note: For additional historical data, please reference ESAI PEP file.

Table 7: New England Generation Additions

Unit	Nameplate (MW)	Summer ICAP (MW)	Unit Type	Month	Year	Location	Included in ESAI Base Case
Footprint Power (Salem CC)	798	730	Nat gas	May	2018	NEMA	Yes
Wallingford Peaker Expansion	100	90	Nat gas	May	2018	CT	Yes
Towantic Energy Center	842	822	Nat gas	May	2018	CT	Yes
Lake Road Uprate	50	42	Nat gas	Jun	2018	CT	Yes
Medway Peaking	200	195	Nat gas	Jun	2019	SEMA	Yes
Bridgeport Harbor CC	576	510	Nat gas	Jun	2019	CT	Yes
Canal 3	330	330	Nat gas	Jun	2019	SEMA	Yes
Milford (MA) Power (Units 1 & 2)	53	53	Nat gas	Jun	2020	WMA	Yes
Newington Energy Center (ST)	38	37	Nat gas	Jun	2020	NH	Yes
Killingly Energy Center	650	632	Nat gas	Jun	2022	CT	Yes
Clear River Energy Center - I	485	485	Nat gas	Jun	N/A	RI	No
NE Clean Energy Connect (MA RFP Award)	1,200	1,000	HVDC	Dec	2023	ME	Yes
Revolution Wind (RI & CT RFP Award)	400	140	Offshore Wind	Jan	2024	SEMA	Yes
Revolution Wind (RI & CT RFP Award)	300	105	Offshore Wind	Jan	2025	SEMA	Yes
Vineyard Wind (MA RFP Award)	400	140	Offshore Wind	Jan	2024	SEMA	Yes
Vineyard Wind (MA RFP Award)	400	140	Offshore Wind	Jan	2025	SEMA	Yes
Other Renewables	72	31			2019		Yes
Other Renewables	112	37			2020		Yes
Other Renewables	416	100			2021		Yes
Other Renewables	343	32			2022		Yes
Other Renewables	168	33			2023		Yes
Other Renewables	173	33			2024		Yes
Offshore Wind	200	70			2028		Yes
Offshore Wind	400	140			2029		Yes
Offshore Wind	400	140			2030		Yes
Offshore Wind	400	140			2031		Yes
	9,505	***5,717***					
Total Fossil	**4,122**	**3,926**					
Total Imports	**1,200**	**1,000**					
Total Renewable*	**3,783**	**1,141**					
Total (2018-2027)	***9,105***	***6,067***					
Total (2018-2027), Included in ESAI Base Case	***8,620***	***5,582***					

**Does not include BTM.*

***For additional historical data, please reference ESAI PEP file.*

NYISO

NEW YORK ENERGY MARKET OUTLOOK

Forecast Assumptions

In late April 2019, NYISO published it annual Gold Book, including an update to its comprehensive annual load forecast. ESAI's Q1 2019 demand assumption for New York reflected NYISO's 2019 ICAP load forecast that was published at the end of last year. As the ICAP forecast only provides guidance for on-peak load expectations in 2019, ESAI had applied growth rates and load factors implied in last year's 2018 Gold Book forecast to extend the projections through our forecast horizon for both peak loads and annual energy. The final Gold Book forecast is shown in the figures below and includes more robust long-term growth in peak load for New York City than the 2018 forecast, but lower growth for the rest of the state. Outside of New York City, annual energy demand is projected to be lower in 2030 than 2019 due to energy efficiency gains more than offsetting low underlying demand growth.

Figure 14: NYISO Peak Load Forecasts

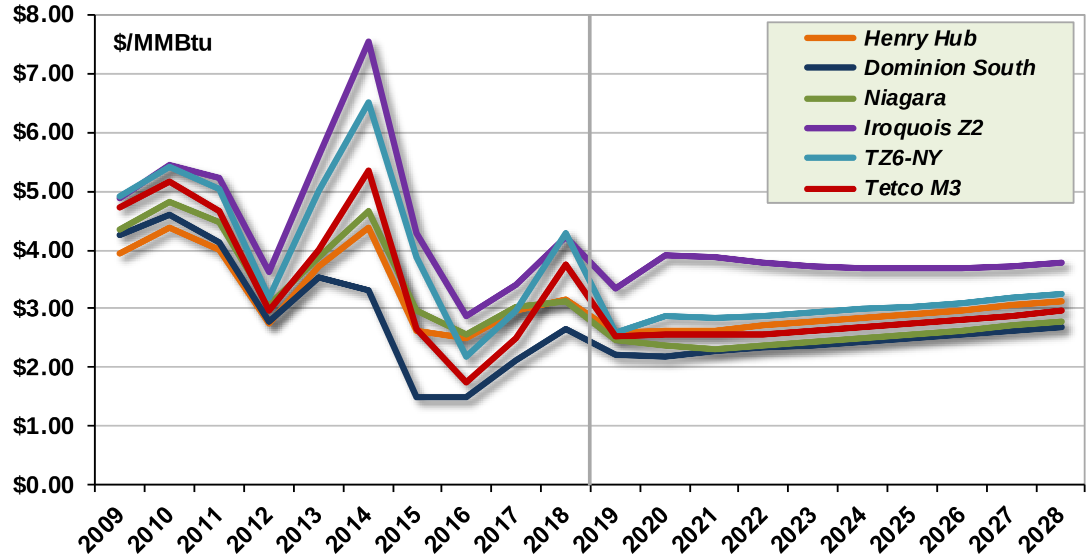
Non-Coincident Peak Load Forecast, by Zone (MW) 2019 Gold Book													
Year	A	B	C	D	E	F	G	H	I	J	K	NYCA	G-J
2019	2,732	1,983	2,847	569	1,351	2,425	2,249	640	1,407	11,608	5,240	32,382	15,883
2020	2,691	1,959	2,801	666	1,320	2,367	2,232	637	1,412	11,651	5,134	32,202	15,911
2021	2,672	1,953	2,779	663	1,301	2,342	2,210	637	1,417	11,695	5,056	32,063	15,937
2022	2,653	1,953	2,759	663	1,284	2,317	2,207	637	1,418	11,704	5,035	31,971	15,944
2023	2,625	1,947	2,735	662	1,264	2,291	2,213	635	1,407	11,608	4,969	31,700	15,841
2024	2,602	1,944	2,714	661	1,246	2,264	2,209	634	1,406	11,598	4,894	31,522	15,825
2025	2,582	1,940	2,695	658	1,229	2,242	2,206	635	1,408	11,616	4,823	31,387	15,843
2026	2,565	1,937	2,678	657	1,214	2,225	2,196	636	1,408	11,616	4,758	31,246	15,835
2027	2,548	1,937	2,666	654	1,203	2,208	2,184	636	1,406	11,598	4,719	31,121	15,803
2028	2,537	1,937	2,653	654	1,193	2,197	2,174	637	1,405	11,589	4,730	31,068	15,784
2029	2,530	1,941	2,646	652	1,184	2,191	2,170	639	1,404	11,580	4,815	31,115	15,772
2030	2,520	1,941	2,633	651	1,177	2,174	2,159	639	1,403	11,572	4,833	31,066	15,752

Figure 15: NYISO Annual Energy Demand Forecast

Annual Energy Demand Forecast, by Zone (GWh) 2019 Gold Book													
Year	A	B	C	D	E	F	G	H	I	J	K	NYCA	G-J
2019	15,550	9,975	16,213	4,845	7,815	12,117	9,793	2,739	5,895	51,874	20,643	157,459	70,301
2020	15,327	9,850	15,983	5,397	7,650	11,847	9,657	2,725	5,840	51,391	20,377	156,044	69,613
2021	15,172	9,781	15,830	5,386	7,536	11,705	9,568	2,719	5,805	51,080	20,018	154,600	69,172
2022	15,078	9,760	15,747	5,382	7,457	11,629	9,540	2,720	5,803	51,067	19,972	154,155	69,130
2023	14,955	9,724	15,649	5,373	7,368	11,540	9,509	2,728	5,807	51,102	19,817	153,572	69,146
2024	14,879	9,724	15,602	5,367	7,306	11,489	9,515	2,733	5,823	51,245	19,703	153,386	69,316
2025	14,738	9,676	15,485	5,355	7,214	11,390	9,475	2,742	5,824	51,248	19,492	152,639	69,289
2026	14,656	9,668	15,428	5,348	7,158	11,341	9,476	2,757	5,834	51,336	19,378	152,380	69,403
2027	14,596	9,666	15,385	5,341	7,112	11,304	9,492	2,782	5,852	51,494	19,347	152,371	69,620
2028	14,590	9,695	15,394	5,337	7,095	11,312	9,544	2,807	5,881	51,749	19,608	153,012	69,981
2029	14,535	9,689	15,348	5,328	7,059	11,278	9,563	2,828	5,902	51,934	19,783	153,247	70,227
2030	14,485	9,684	15,306	5,321	7,023	11,246	9,575	2,848	5,911	52,013	20,037	153,449	70,347

ESAI's gas price forecasts for New York are shown in Figure 17. As in New England, long-term gas price escalation is projected to be lower than forecasted in ESAI's Q1 2019 outlook.

Figure 16: NYISO Delivered Natural Gas Prices



ESAI's assumptions regarding generation retirements and additions remain largely unchanged from our Q4 2018 forecast and are shown in Table 11 and Table 12, respectively. ESAI's new generation and retirement assumptions are also mostly unchanged from our first quarter outlook.

Forecast Summary

ESAI's New York power outlook includes forecasts for Zone A (West), Zone G (Hudson Valley), Zone J (New York City), and Zone K (Long Island). Figure 18 shows ESAI's forecast for New York power prices, while Figure 19 shows our outlook for implied spark spreads. Detailed power outlooks for each of the four New York zones are included at the end of this section. As in New England, the long-term LMP forecast reflects the lower expected escalation in natural gas prices. Long-term escalation in spark spreads is expected for Zone J and Zone K, while spark spreads for the lower Hudson Valley and points north and west are expected to be flat, despite increases in CO_2 allowance costs through the RGGI program. Note that ESAI's forecast does not include the proposed carbon pricing rules for the NYISO market that are under discussion with stakeholders.

PJM

PJM ENERGY MARKET OUTLOOK

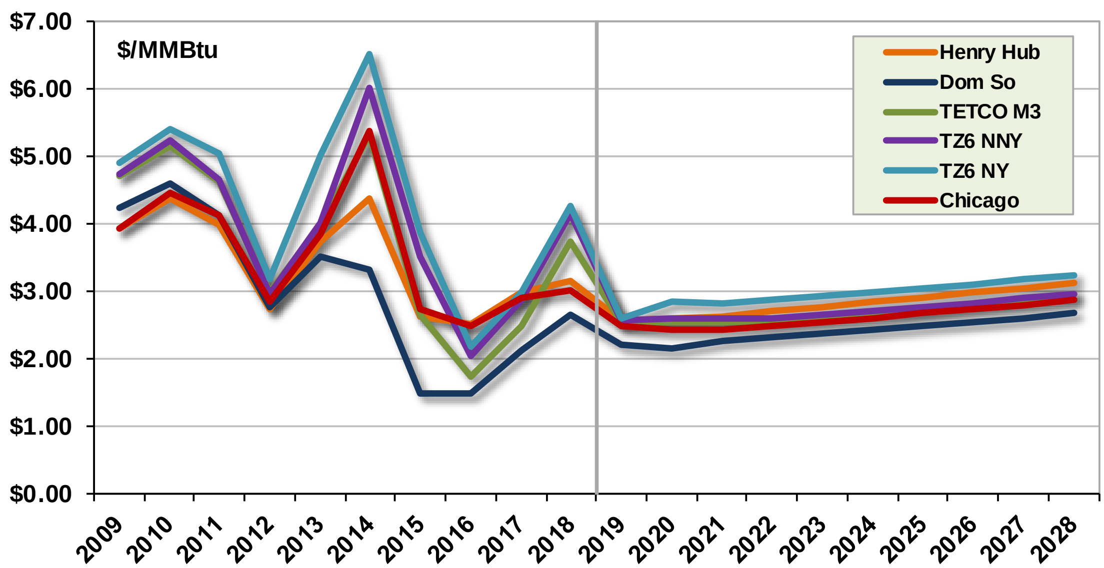
Forecast Assumptions

ESAI's demand assumptions reflect PJM's January 2019 Load Forecast Report and are unchanged from the assumptions used for ESAI's Q1 2019 PJM outlook. ESAI's retirement assumptions are also largely unchanged from the first quarter forecast assumptions. However, ESAI is now expecting more new gas-fired generating capacity to clear in the 2022/23 BRA than was reflected in the Q1 forecast. As discussed in ESAI Q2 2019 issue of *Capacity Watch*™, several projects have recently closed on debt financing or are expected to do so soon. The Jackson project in COMED and Niles project in AEP have both reached financial close since the last issue of *Energy Watch*™ was published. There are additional projects totaling over 2,500 MW that have ongoing active processes for commitments to be secured from lenders.

In total, ESAI has assumed approximately 7,500 MW of new additions by summer of 2022, up from 3,300 MW in the first quarter forecast assumptions.

The gas price forecasts for PJM are shown in Figure 29. As discussed in detail in the natural gas section of this issue, ESAI has revised our forecast for basis spreads between Marcellus production points and delivery locations near Chicago.

Figure 27: Delivered Gas Prices: PJM Regional Pricing Hubs



Forecast Overview

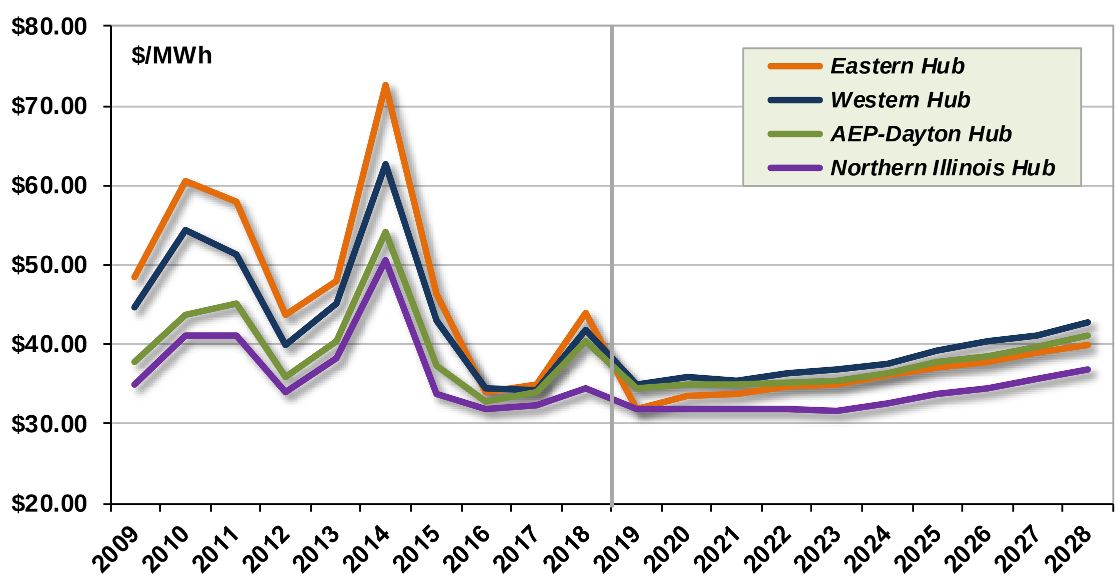
ESAI's forecast of power prices for the PJM regional hubs is shown in Figure 30 and Figure 31. The corresponding spark spreads are shown in Figure 32 and Figure 33. The forecast is shown for four hubs spanning PJM: Eastern Hub, Western Hub (PJMWH), AEP-Dayton Hub (AD Hub), and the Northern Illinois Hub (NI Hub). The spark spreads for each location are based on a proxy heat rate of 7,500 Btu/kWh and assumed gas pricing as follows:

- Eastern Hub: Transco Zone 6 Non-NY
- Western Hub: TETCO M3
- AD Hub: Dominion South Point
- NI Hub: Chicago Citygate

ESAI's base case power outlook reflects the convergence of power prices across the region commensurate with expected trends in the regional natural gas markets. Compared to the Q1 2019 forecast, increased new entry and lower natural gas price escalation results in lower escalation in Western Hub spark spreads, relative to other points in PJM.

As coal is expected remain on the margin during many peak periods in PJM, lower natural gas prices generally support higher spark spreads throughout the RTO.

Figure 28: Historical and Forecasted On-Peak PJM Power Prices



ESAI's longer term forecast has declined as a result of lower expectations for price escalation beyond 2022. In previous forecasts, the longer term nominal price escalation was close to 4.0 percent, reflecting a real price increase of 1.5 - 2.0 percent above inflation. Our current forecast utilizes a nominal price escalator beyond 2021 of 2.5 percent – just slightly above inflation. At a high level, the key drivers for the longer term 4.0 percent nominal price escalation utilized in previous forecasts were:

- A longer-term shift away from cheaper Marcellus and Utica production to higher cost basins for marginal volumes, particularly as future production again hits pipeline constraints;
- Slight increases in production costs over time as the best drilling sites are cherry-picked early and marginally higher cost sites are exploited over time;
- Demand from the power sector and for LNG exports continues to drive higher production; and
- Canadian imports decline and Mexican exports increase.

Over the past year, several developments have affected these longer term expectations, some of which we have described in previous issues of *Energy Watch*™. The following provides a high-level overview of developments that ESAI believes will moderate any escalation in natural gas prices.

Competing Basins Seeing Lower Production Costs

Other basins are applying advances in drilling technology to lower costs and compete with production in Marcellus and Utica. Other basins such as Haynesville and Cana-Woodford have made substantial gains in production over the past 18 months. For example, Haynesville production has increased from 7.0 Bcf/d to 9.1 Bcf/d since January 2018.

Associated Gas Production Will Increase Substantially

Associated gas from the Permian has risen from 6.7 to 9.7 Bcf/d since January 2018 as a result of stronger oil prices and increases in oil production. The increase in Permian gas production has strained pipeline takeaway capacity to the point where Permian production is now constrained at just below 10.0 Bcf/d until new pipeline capacity can be built.

Currently, over 15 Bcf/d of pipeline capacity is under various stages of development that will greatly enhance Permian's production potential. Roughly 12 Bcf/d of new pipeline capacity is under construction or in active development to would move Permian gas eastward to feed growing demand for LNG exports. Kinder Morgan's Gulf Coast Express pipeline is under construction and will add 2.0 Bcf/d of takeaway capacity for Permian production when completed in the fourth quarter of this year. Another 6.0 Bcf/d of capacity is expected on-line in the second half of 2020 (Permian Highway, Bluebonnet Market Express, and Permian to Katy). Further expected additions include the 1.85 Bcf/d Pecos Trail pipeline in July 2021 and the 2.0 Bcf/d Permian Global Access pipeline in July 2022.

ESAI expects Permian production to increase by about 50 percent by 2022, from just below 10 Bcf/d to 15 Bcf/d. This 5 Bcf/d increase in Permian production would be well below the potential 12 Bcf/d increase in Permian takeaway capability. As such, a few delays or cancellations would not likely have a big impact on the projection for a 5 Bcf/d increase by 2022. If the full 12 Bcf/d of pipeline capacity does get built, then there will be plenty of headroom for additional Permian growth.

Producers Have Plenty of Gas in Reserves at Suitable Locations

The top producers in Marcellus and Utica have reserves that will take many years to exploit. The reserves are ranked in tiers according to expectations of estimated ultimate recovery (EUR). Most producers will be able to exploit reserves in the highest recovery tier for the next three to five years before shifting to lower recovery reserves.

To place the amount of available reserves in context, at the end of 2018 Cabot had almost 650 producing wells operating in Marcellus. Their inventory includes proved reserves of 11.6 Tcf with a total of 2,900 remaining undrilled locations – more than five times their current number of operating wells. Similarly, Range Resources inventory includes proved reserves of 40 Tcf with a total of 3,700 undrilled locations.

Technology Gains Continue

Technology gains have continued to reduce unit costs for gas production. These technological advances have allowed top-tier producers to profitably exploit gas reserves at cost structures below $2.00/MMBtu. The recent pace of cost reductions has declined, but shifts to longer laterals and advances in proppant deployments will continue to reduce costs for the next several years at a rate that, at a minimum, will offset cost increases from inflation.

Canadian Imports Have Not Declined As Expected

Canadian imports were previously expected to decline from 5.5 Bcf/d to 5.0 Bcf/d by 2022. ESAI's current projections are holding Canadian imports steady at 5.5 Bcf/d through 2022. There are a number of proposed LNG export projects that could divert gas flows to the U.S. towards LNG exports, thus potentially reducing Canadian imports. However, this shift in flows would not likely occur before 2024. Most of the proposed LNG export projects are targeting British Columbia but two potential projects are under consideration in Nova Scotia.

Demand Increases Will Taper Off

The first wave of LNG export facilities will be largely complete by 2022, including portions of the 3-train Golden Pass facility. Golden Pass will be capable of exporting up to 2.1 Bcf/d of LNG and will complete its third and final train by 2024 (Train 1 is currently under construction).

A second wave of LNG export facilities is expected to gain traction, and thus may provide additional demand in 2025 and beyond. One example of next wave projects is the NextDecade Rio Grande project. NextDecade has signed an offtake agreement with Shell for

