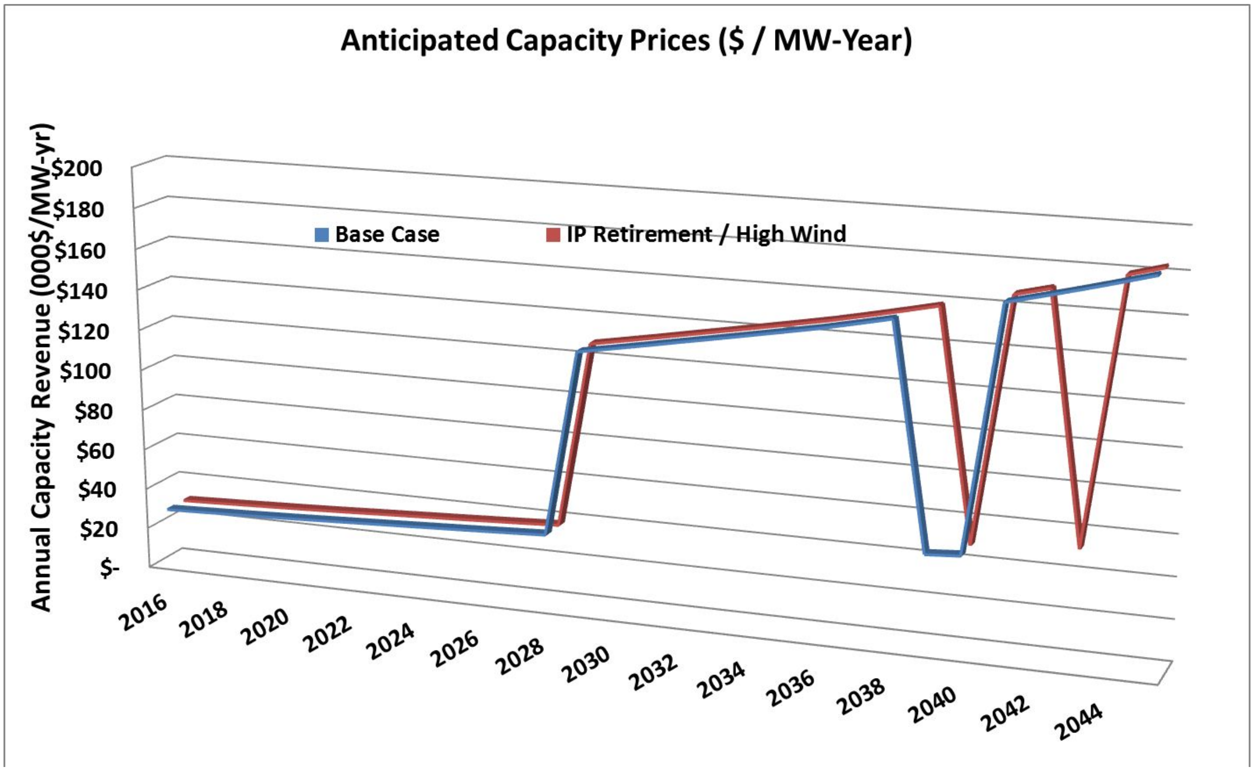

Figure 7: Capacity price forecast under base case and Indian Point Retirement scenario

4 Dispatch Modeling

4.1 Background

There are two CAES plants currently operating in the world. The McIntosh CAES plant in Alabama was designed to store as compressor air the lower cost excess coal power that is available in the off peak periods and then release the stored energy in the compressed air to generate electricity during the higher cost energy periods during the peak periods of the day. The Huntorf CAES plant in Germany is mainly used for peak shaving and operating reserve.

For the NYSEG Seneca CAES Project, the charging of the compressed air storage area, in this case the salt cavern, is accomplished in the off peak periods of the weekday and over the weekend periods when energy prices are low. This mode of operation help supports the electric system where the off peak loads may not be large enough to maintain the supply fleet operational for the following day's peak load requirements. This is especially important in systems that have a considerable amount of nuclear or other types of generation that can only be backed down to a certain level of operation or need to taken off line.

For the Seneca CAES Plant, the facility is intended to support the system during all periods of the day to the full extent of the stored energy and the operating flexibility of the facility. The CAES Dispatch Model was developed to determine the net revenues from the operation of the CAES plant and to keep track of the environmental emissions from the plant. The model is based on previous studies and research conducted by Customized Energy Solutions to determine the revenue opportunities for energy storage in the organized energy markets. [1] The model used in this effort has been upgraded from previous versions to include the flexibility in modeling provided by the Lumina Decision Systems Corporation in their Analytica Software for incorporation of ancillary service revenues to optimize the profitability of the CAES plant and maximizing the benefits to the NY Grid.

4.2 CAES Dispatch Model

The model utilizes the technical parameters of the CAES design including energy ratio, input and output power ratings (including auxiliary power), heat rate and emissions at different operating points (10%, 25%, 50%, 75% and 100%). Using all these parameters, the model estimates the marginal dispatch cost for the CAES plant, and then uses inputs including hourly energy and ancillary services revenue opportunities to determine the optimal operating pattern. The operational pattern can be calculated for daily as well as weekly operation. For the Base Case scenario, the CAES operations have been optimized for the weekly operational cycle.

The CAES Dispatch Model was refined using actual hourly energy, ancillary service prices and natural gas daily price data for the period from 2005 through 2010. The historical model optimizes the CAES plant's operation over the course of a week starting with Friday night at beginning at 10:00 PM. The model matches the highest LBMP for the week with the lowest LBMP and continues to do this until there is no net revenue benefit when considering the energy ratio between the cost to charge the cavern and the revenue gained by dispatching the generators from the facility. The model keeps track of the cavern inventory so that the maximum capacity and minimum capacity levels are not exceeded at anytime during the week evaluated. The model then determines the cost and revenues from the operation of the various CAES designs that will maximize the net revenues to the facility from energy arbitrage and the ancillary services.

Given the proposed unit sizes of 135 to 210 MW, the analysis assumed that the facility is not large enough (considering the 40 GW installed capacity in NY) to significantly change the pricing that occurred in the State or Zone C, the NYISO Market region where the plant would be located. Based on the market size for the ancillary services, the amount of ancillary services has been limited 40 MWs for regulation service, 50 MW for spinning

[1] The New York State Energy Research and Development Authority, Electric Energy Storage Market Analysis Study in New York Report 2006, NYSERDA PON Contract No. 8722

reserve service and 20 MW for non-spinning reserve service to avoid a situation of price collapse in ancillary service markets.

During the optimization, the model stores sufficient air to provide energy and ancillary services during the selected optimization period based on the optimization algorithm. The optimization algorithm ensures that for all hours when the plant is discharged, the unit was profitable to operate. Also, during each hour of operation the model compares the profitability of energy arbitrage versus the profitability of providing frequency regulation or synchronous reserves. For any hour when ancillary services are more profitable, the plant is dispatched for both energy and ancillary services as shown in an example of the weekly duty cycle chart below.

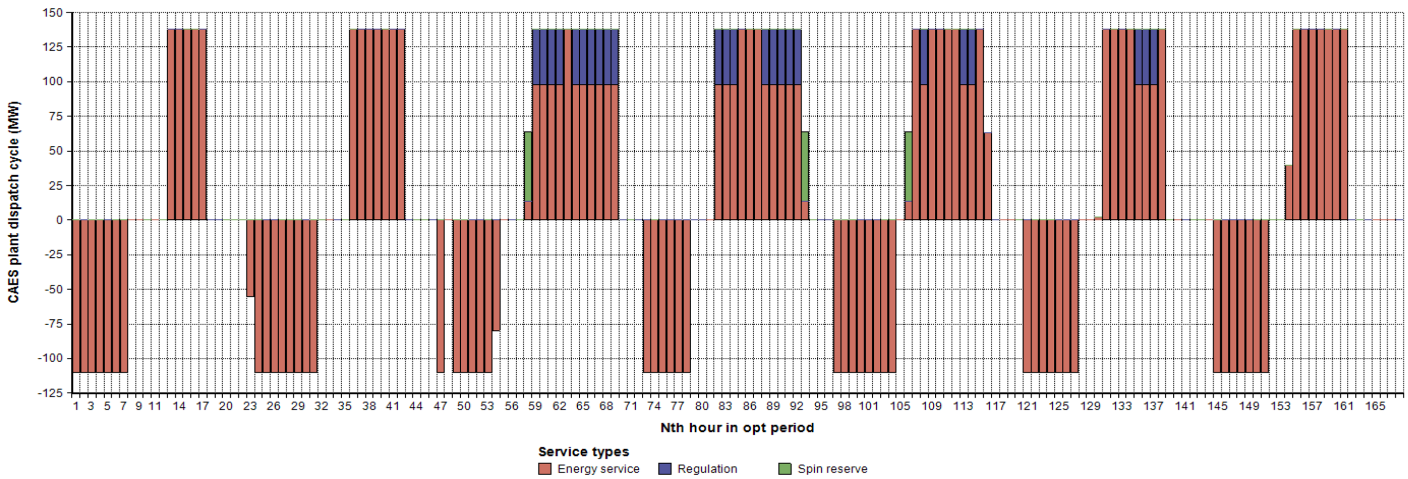

Figure 27: Example CAES dispatch cycle, showing the hours of operations and different modes of energy and ancillary services provided during a sample summer week.

The model is run in the same manner through the life of the CAES Facility, where the economic dispatch model predicts the LBMP and ancillary service costs for each of the scenarios from the inputs assumptions without the CAES in service. Then the CAES dispatch model is used for determining the operation of the CAES facility 30 years forward from 2016. The same weekly optimization is conducted as in the historical model for every hour for every week for the 30 year period of operation.

4.3 Dispatch Modeling Results for Base Case Scenario for CAES 1, CAES 1A and CAES 2

This section provides a summary of the final three configurations evaluated under the base case operations. The three configurations included:

CAES 1: A Dresser Rand CAES Facility with 135 MW Generation Output and 170 MW Compression.

CAES 1A: A Dresser Rand Facility with a dual train with 210 MW Output and 170 MW Compression

CAES 2: A CAES unit from ESPC/MDT with 210 MW Output and 170 MW Compression

The table below provides summary of the key technical parameters used in the dispatch modeling for each configuration.

	CAES 1A (DR-170/210)				
Operating level	10%	25%	50%	75%	100%
Gross power output (MW)	32.508	53.225	106.45	159.675	212.9
Auxiliary power for generation (MW)	1.793	1.943	2.313	2.645	2.956
Net specific generation power (lbs/kW-hr)	20.63	16.71	12.69	11.19	10.6
Heat rate (BTU / kW-hr)	4968	4692	4565	4450	4376
Energy ratio	1.45	1.18	0.9	0.79	0.75
Compressor capacity (MW)	171.369	171.36	171.36	171.36	176.36
Auxiliary power for compression (MW)	3.06	3.06	3.06	3.06	3.06
Average net specific compression power (lbs/kW-hr)	14.18	14.18	14.18	14.18	14.18
	CAES 1 (DR-170/135)				
Operating level	10%	25%	50%	75%	100%
Gross power output (MW)	14.05	34.47	68.93	103.4	137.87
Auxiliary power for generation (MW)	1.07	1.36	1.61	1.85	2.07
Net specific generation power (lbs/kW-hr)	23.59	15.76	12.16	11.15	10.6
Heat rate (BTU / kW-hr)	5152	4775	4512	4396	4335

Energy ratio	1.72	1.15	0.88	0.81	0.77
Compressor capacity (MW)	168.2	168.2	168.2	168.2	168.2
Auxiliary power for compression (MW)	2.89	2.89	2.89	2.89	2.89
Average net specific compression power (lbs/kW-hr)	13.74	13.74	13.74	13.74	13.74
	CAES 2 (ESPC-170/210)				
Operating level	10%	25%	50%	75%	100%
Gross power output (MW)	0	53.94	106.35	159.35	212.09
Auxiliary power for generation (MW)	0	1.3	1.64	1.94	2.23
Net specific generation power (lbs/kW-hr)	0	3.56	8.94	10.37	10.13
Heat rate (BTU / kW-hr)	0	12,300	6181	4439	4267
Energy ratio	0	0.26	0.65	0.75	0.74
Compressor capacity (MW)	0	168	168	168	168
Auxiliary power for compression (MW)	0	2.89	2.89	2.89	2.89
Average net specific compression power (lbs/kW-hr)	0	13.76	13.76	13.76	13.76

The O&M cost are calculated based on costs associated with using demineralized water and ammonia that is required during the CAES operation.

The chart below shows the average anticipated energy revenues during the on peak operation of CAES 1 facility and the average charging costs during compression cycle for each year of operation. Note that the energy prices predicted are in nominal values for period 2016 through 2045.

Figure 28 represents the On Peak and Off Peak LBMP prices when the CAES unit is predicted to be operating. The graphic shows that there are periods in the future during high load and/or low load periods where the price differential is significant to support arbitrage. What not evident here is that the opportunity for these

differentials to exist diminish. With so much of the generation in the later years coming from Gas Fired Combined Cycle Units, there are smaller differentials in the On Peak and Off Peak prices, except for extreme system conditions.

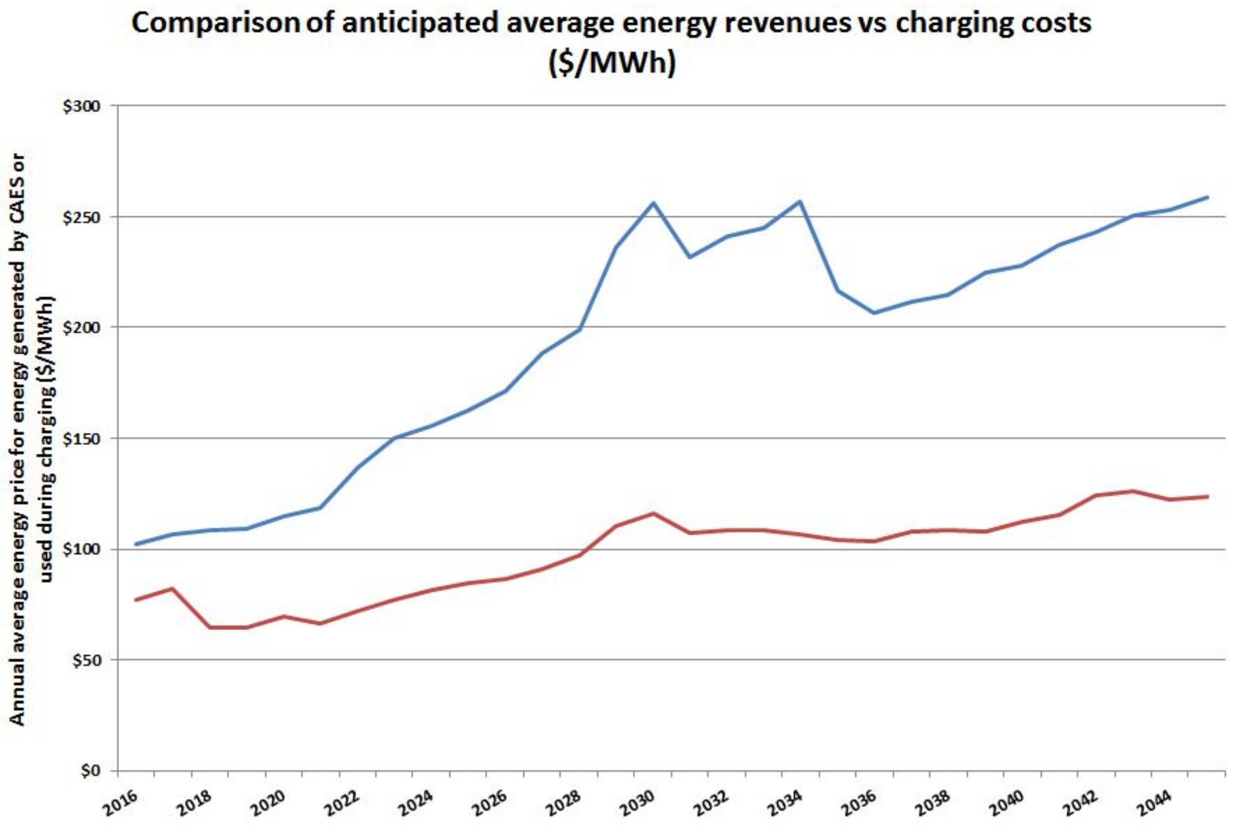

Figure 28: Anticipated average revenues vs. charging costs for the CAES plant during the 30 year operational period.

Although historically during the years 2005-10, the CAES dispatch model predicts that the CAES units would have been dispatched for energy arbitrage between 1100-1500 hours of energy discharge operations, for the future analysis, the model predicts that the operations will be limited to less than 900 hours during the initial years due to the staged cavern development schedule. Under the cavern development schedule, it is assumed that only 33% of the air volume is available during 2016 and 2017, 66% available during 2018-2020 and 100% volume is only available after 2021. This assumption mainly limits the revenues from energy and ancillary services, as with the 1/3rd volume and with compressors sized at 170 MWs the cavern is expected to have only sufficient capacity to allow compression for 2.5 hrs before becoming full. This limitation does not reduce the capacity revenues, as even with the limited capacity, the plant is anticipated to provide at least four hours of energy due to the additional energy generated with the natural gas.

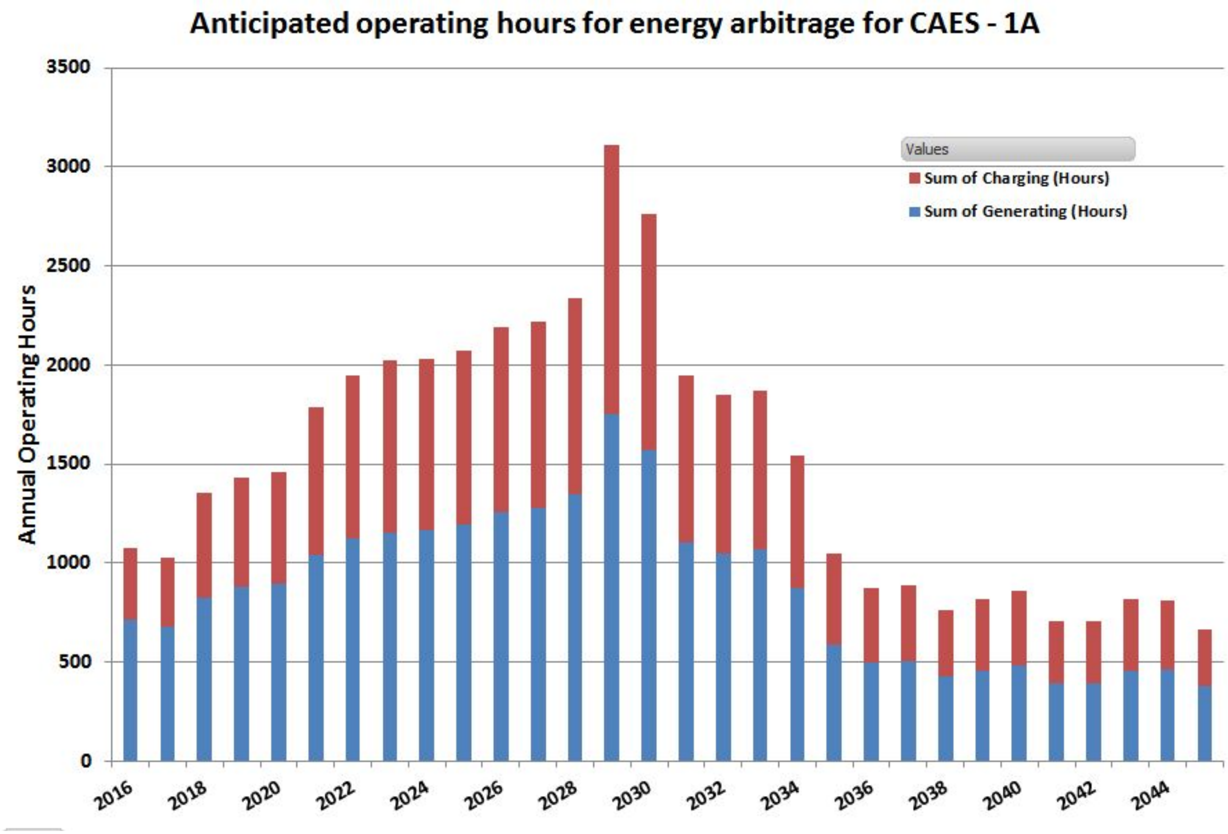

Figure 29: Anticipated operating hours for CAES 1A

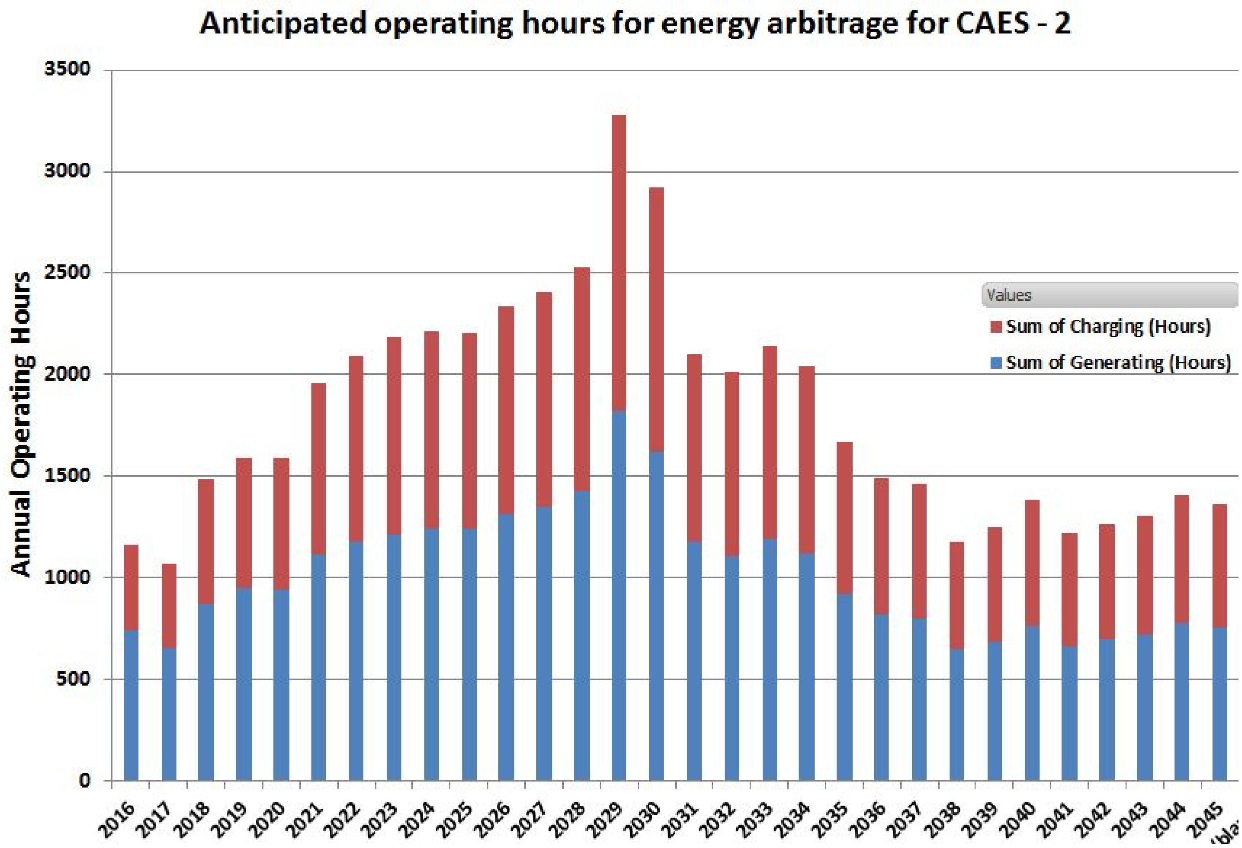

Figure 30: Anticipated operating hours for CAES 2

This impact of cavern capacity can be seen in the following anticipated dispatch cycles during the years 2017 and 2021. The example used is for the CAES 2 facility. Similar trends exist for all of the CAES configurations.

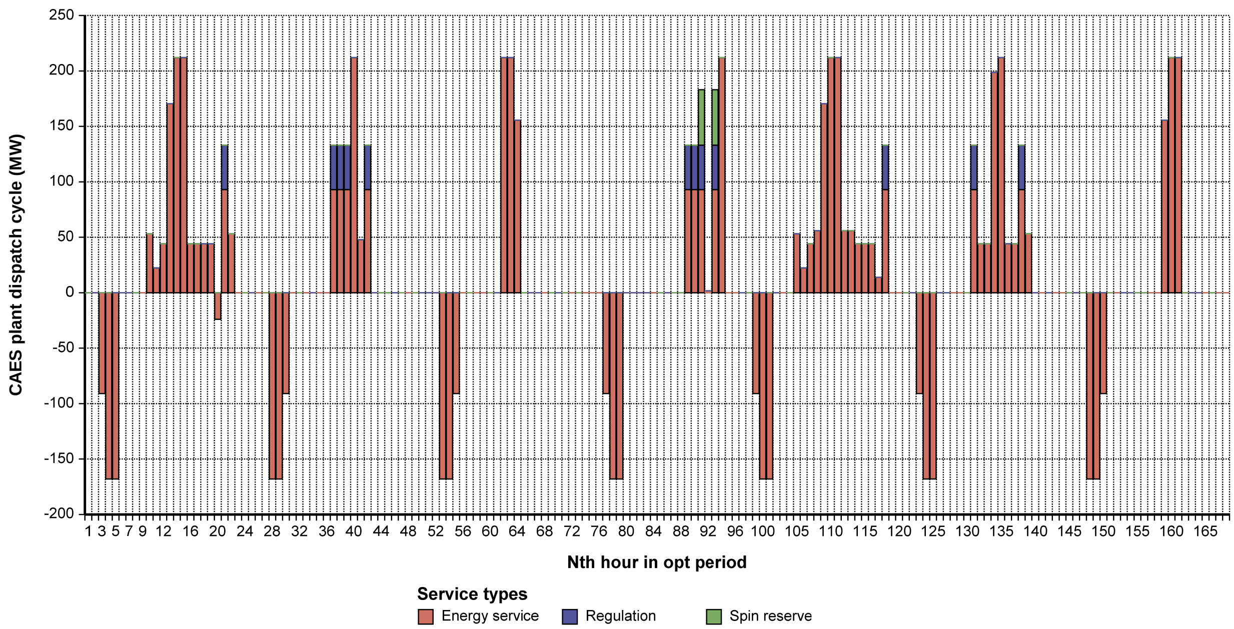

Figure 8: Anticipated dispatch cycle during summer of 2017 with 33% cavern deployed

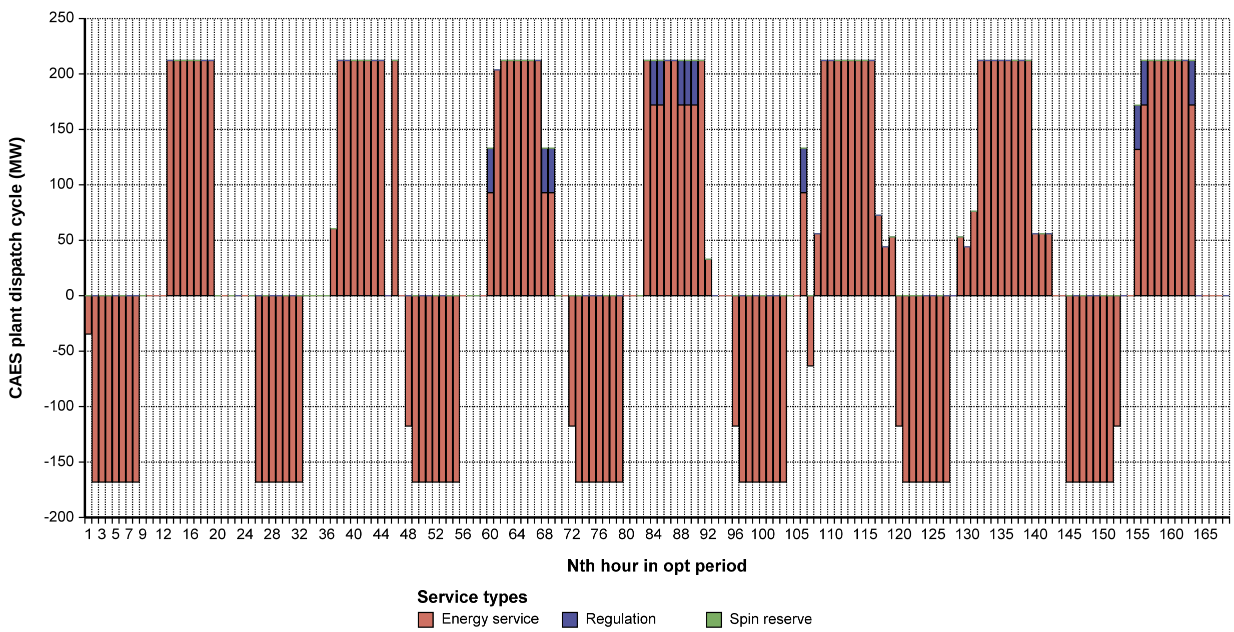

Figure 32**: Anticipated dispatch cycle during summer of 2021 for same unit with 100% cavern deployed**

The chart below shows the comparison of the annual net revenues anticipated for each of the configurations under the base case.

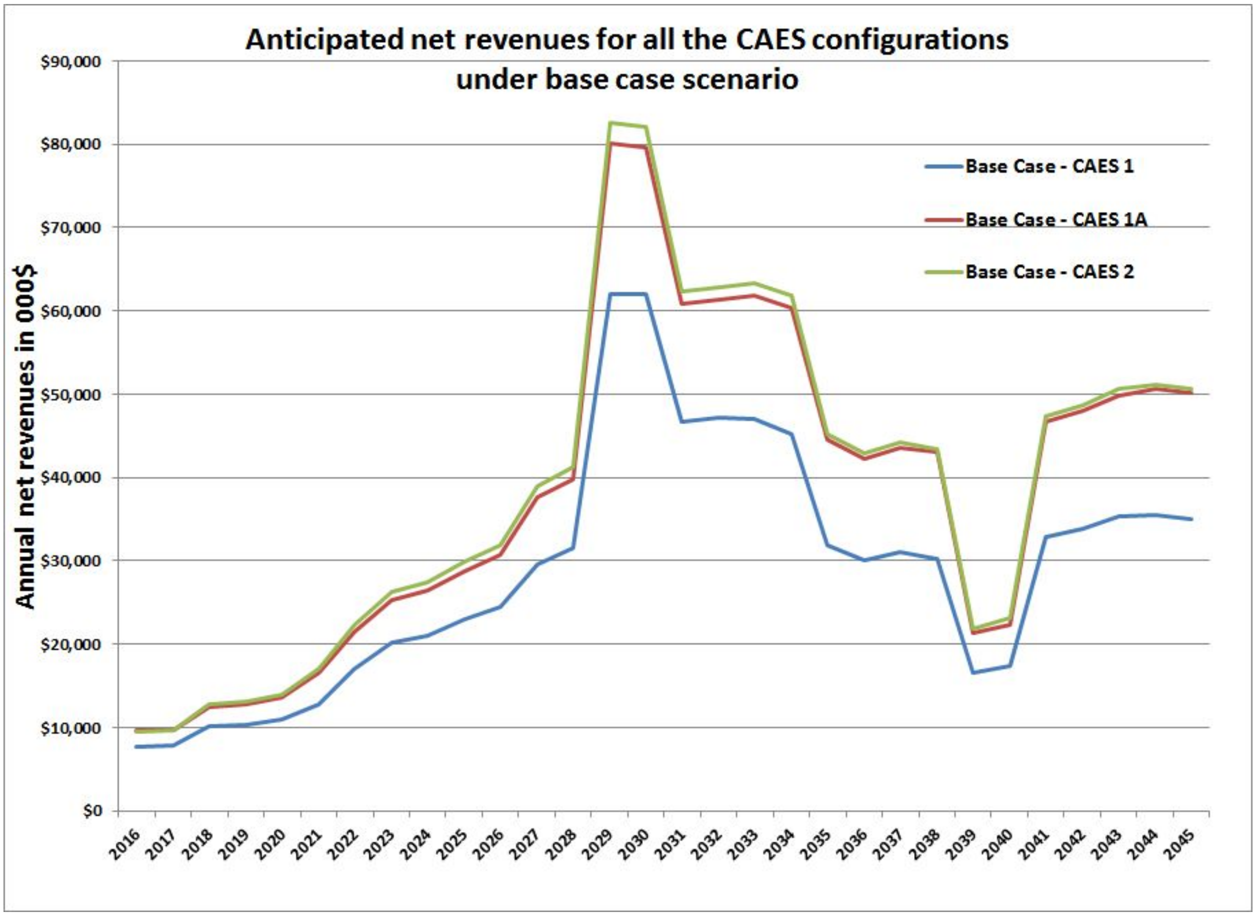

Figure 933: Anticipated net revenues for each CAES configuration under base scenario (revenues in 000$)

Once all the caverns are developed, the revenues start to rise from 2021 due to a combination of rising fuel prices, load growth, and planned generation retirements, without any addition in new generation capacity (except wind) until 2029. The big jump in revenues around 2029-30 is mainly due to the planned generation retirements and lag in the anticipated addition of new combined cycle units. These reserve margins are above 15%. In these years, the anticipated hours of energy generation also rise to close to 1700 hours. Once full caverns are available, considering the charging hours of operation the plant typically operates for 2000-3000 hours till 2035 as shown in figures 26 & 27. Apart from this, due to the fast response capability of the plant we also consider that the plant participates in the Non Synchronous Reserve market when the CAES facility is not being used for charging or discharging.

Once the new combined cycle units get added, then energy prices will drop off, but the revenues do not drop back proportionally as higher capacity revenues for those years are obtained when new units are being added in the supply stack. For the years beyond 2029, almost $30M is projected as the annual capacity revenue based on the base value of ~$90K / MW-Yr revenue requirement was used to justify capacity additions. Following charts show the components of the annual net revenues for energy arbitrage, capacity, regulation, synchronous and non-synchronous reserves for both CAES1A and CAES 2 facilities.

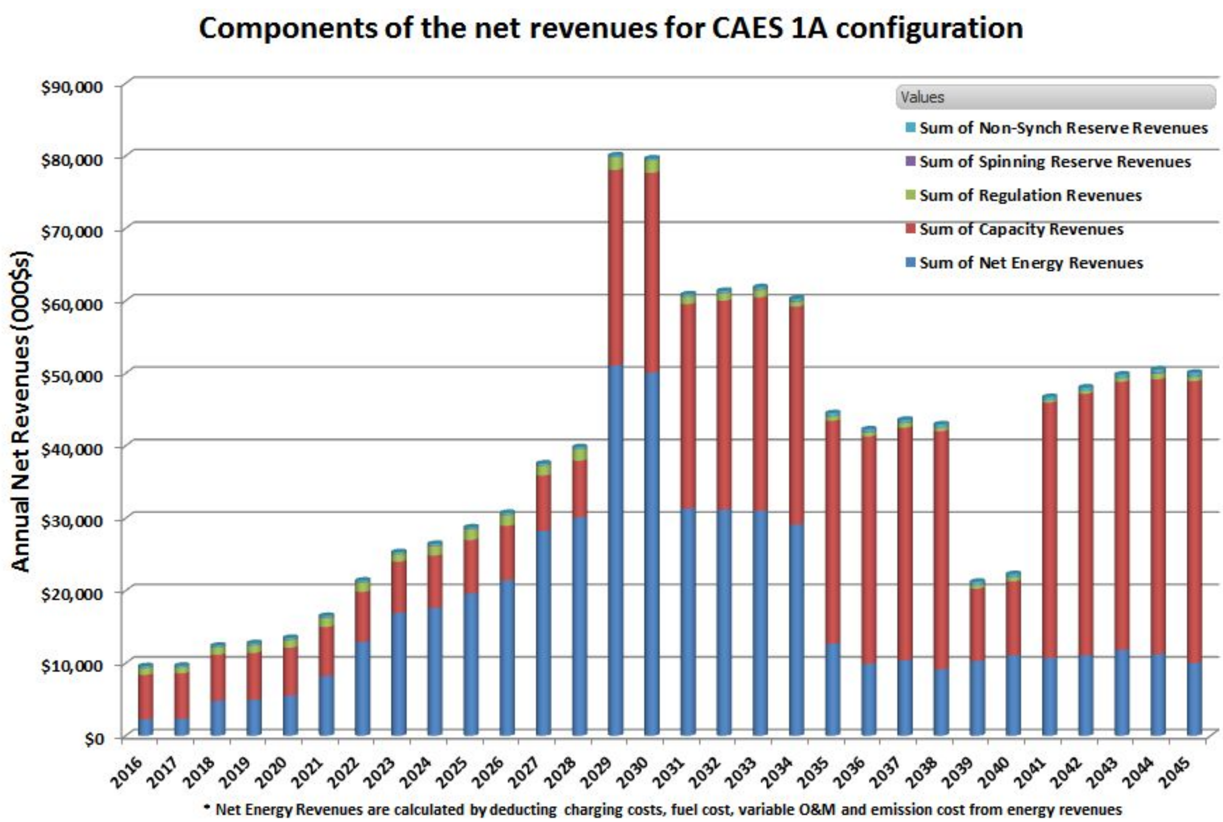

Figure 34: Components of the net revenues for the CAES 1A facility including net revenues from energy arbitrage, regulation, synchronous and non synch operating reserves and capacity revenues during 2016-45.

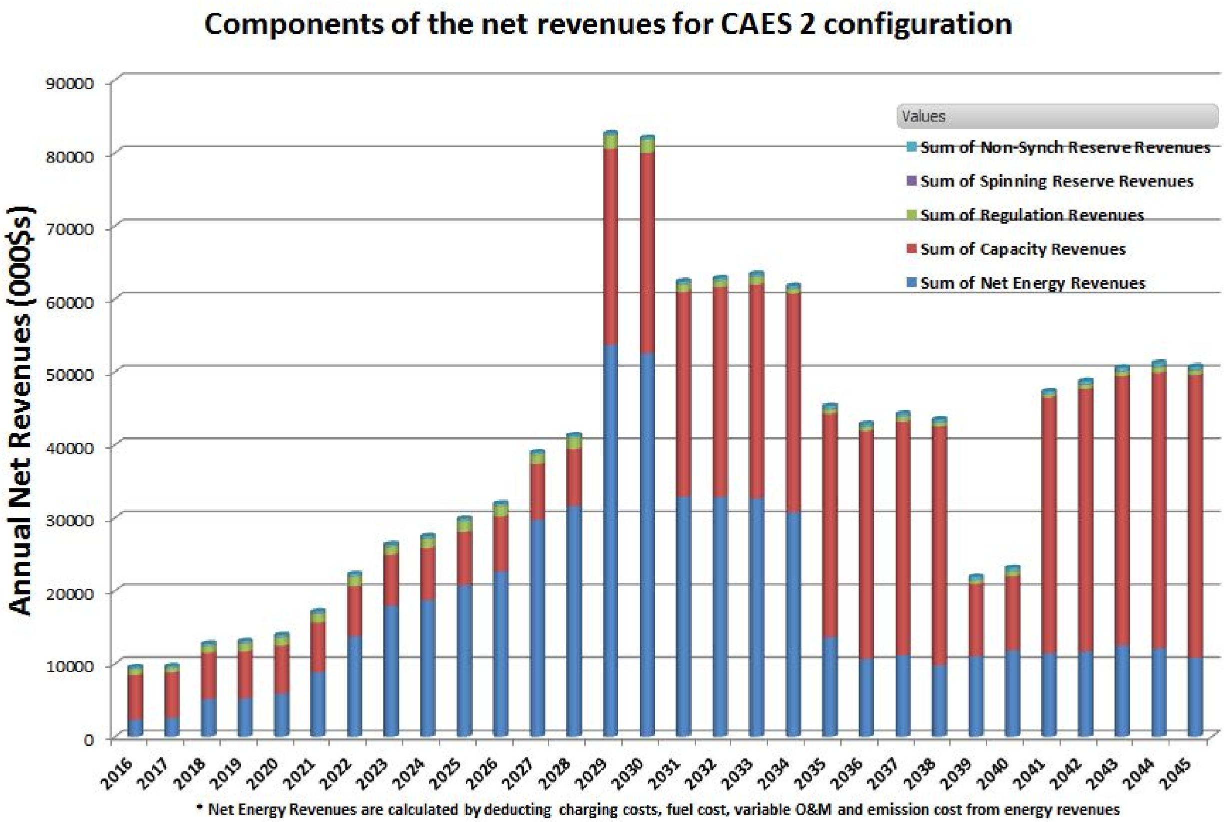

Figure 1035: Components of the net revenues for the CAES 2 facility including net revenues from energy arbitrage, regulation, synchronous and non synch operating reserves and capacity revenues during 2016-45.

Although the CASE1 Configuration was reviewed in the initial runs of the model, the vendor proposed an alternate cycle, CAES 1A. CAES 1 was dropped from further consideration with all the remaining model runs focused on the CAE0S 1A.

.

The following chart shows the result of the CAES 1A facility under all the scenarios.

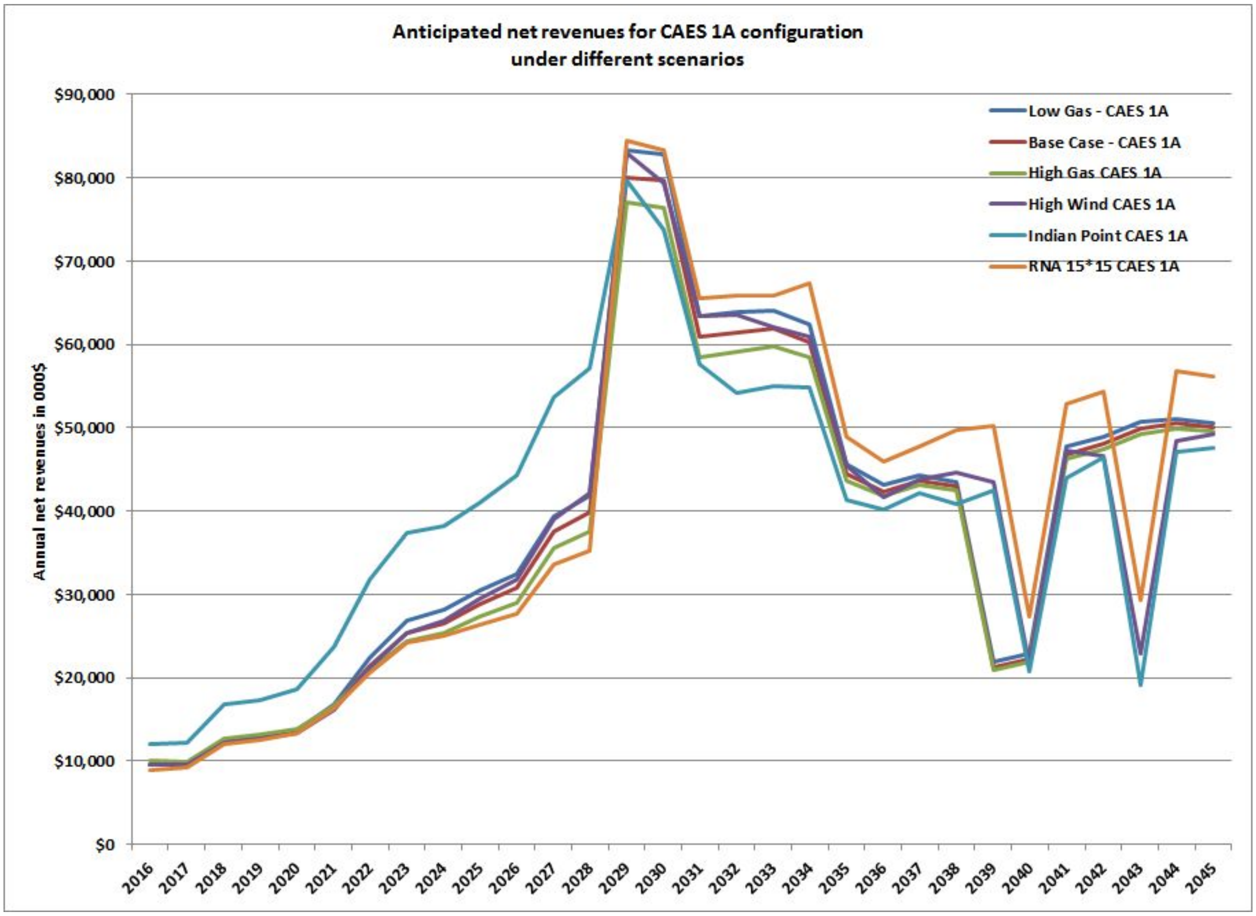

Figure 36: Comparison of anticipated net revenues for all scenarios for CAES 1A configuration

The figure provides some interesting insights into the impact of various scenarios. Overall the CAES facility is anticipated to provide relatively stable revenues each year under all the scenarios.. The Indian Point retirement scenario does result in higher revenues in the initial years, but results in lower revenues than other scenarios, beyond 2031 due to the higher addition of combined cycle units under that scenario as compared to other scenarios during 2029-31. The drop in revenues in the 2040 and 2043 is attributed to the scenarios where there is no new capacity addition required in those years, based on the projected load growth and available capacity.

A similar trend is seen also for the CAES 2 facility; although the CAES 2 facility is anticipated to provide slightly higher net revenues than the CAES 1A facility.

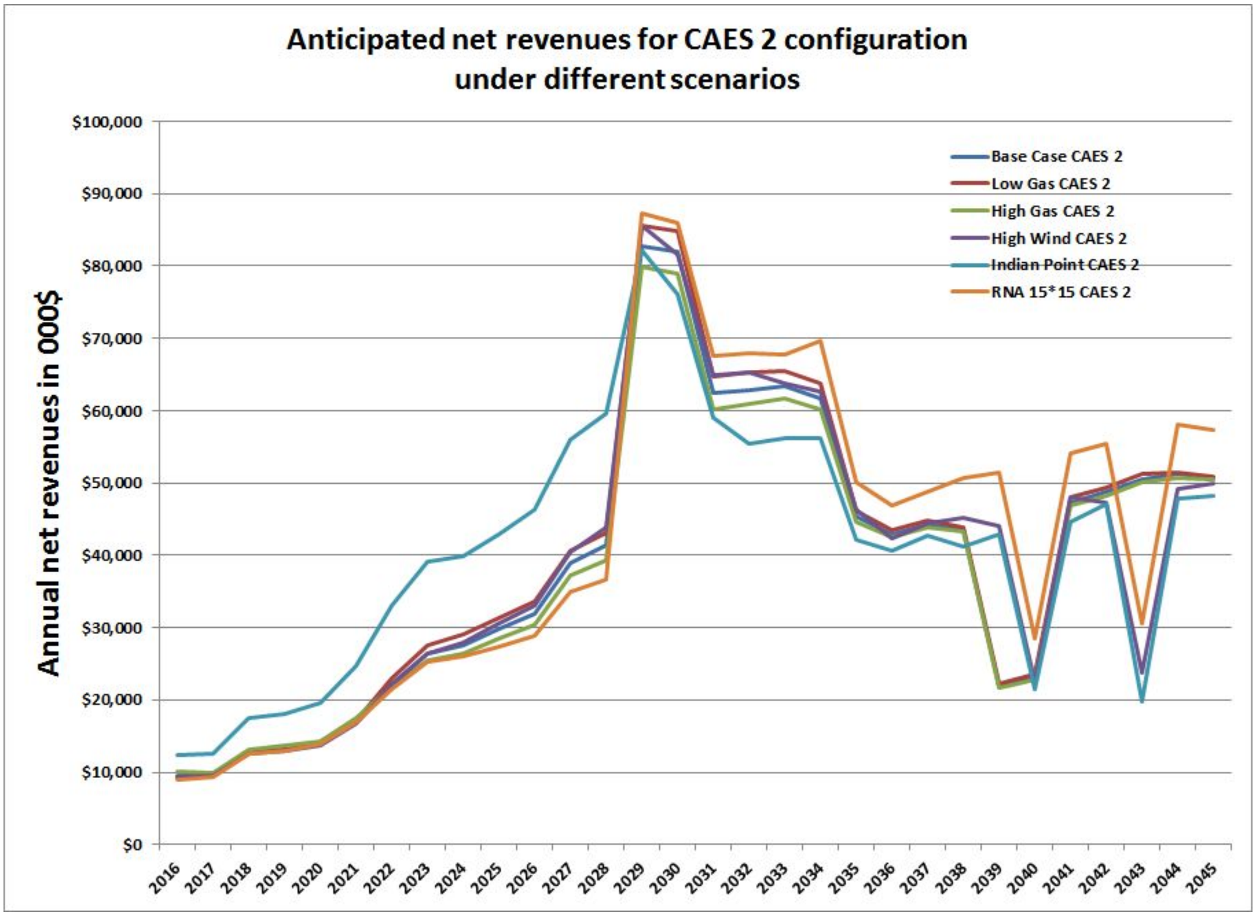

Figure 37: Comparison of anticipated net revenues for all scenarios for CAES 2 configuration

4.4 CAES Project Impact on Statewide Emissions

The Seneca CAES facility is anticipated to be a renewable resource enabler. The method to illustrate the statewide reduction in CO2, NOx and SOx emissions resulting from the CAES facility operations was to identify the marginal plant from the economic dispatch and then account for the emissions difference between the CAES plant and that marginal plant for the number of hours that the CAES plant is expected to run. It was assumed that the CAES plant will use off peak non-emitting renewable energy sources for charging energy, and thus no emissions were accounted for in the compression cycle.

The following chart shows the anticipated emissions impact of CAES 1A and CAES 2 (210 MW) configurations. Please note that these results are very heavily influenced by the assumptions about the generation retirements, as well as, the emissions of the new more efficient and less polluting units added in the generation mix. Since by 2029, a large number of existing units do retire, the anticipated emissions impact is significantly lower in scenarios after that as more efficient natural gas units are anticipated to replace the older units.

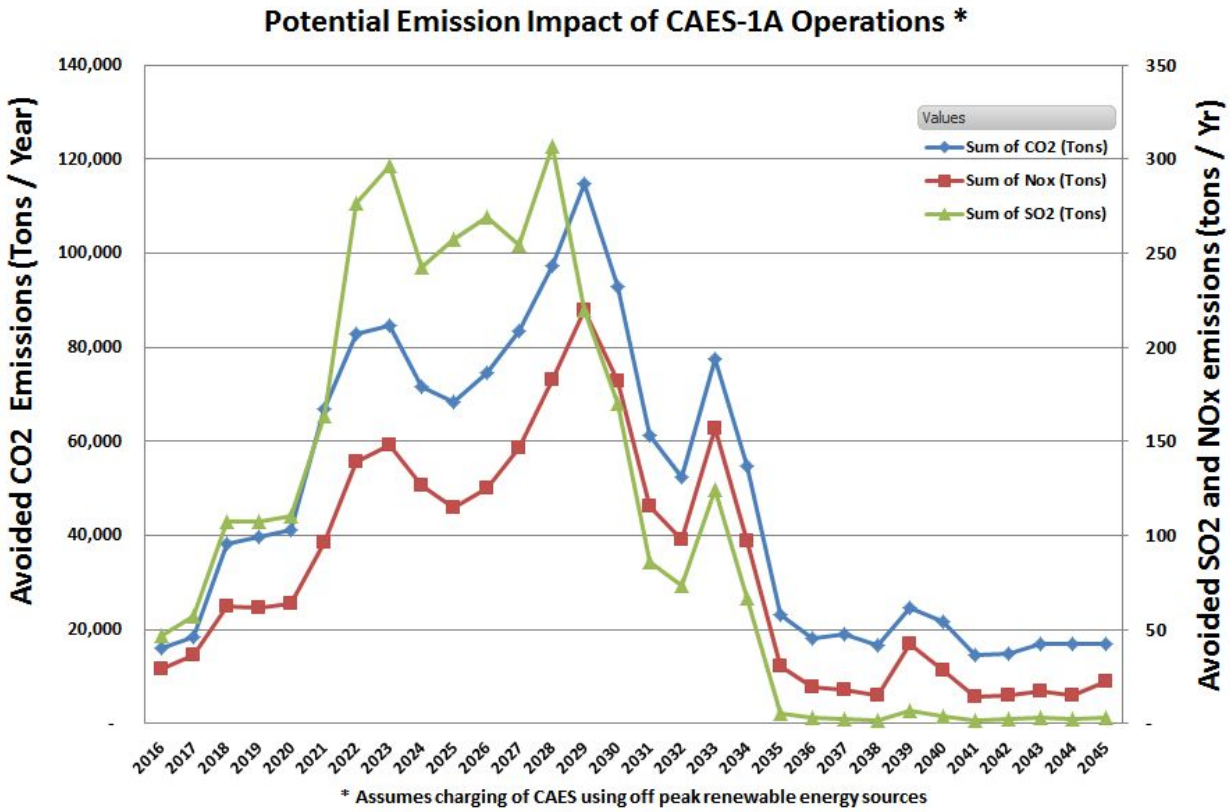

Figure 11: Emission Impact of CAES 1A configuration

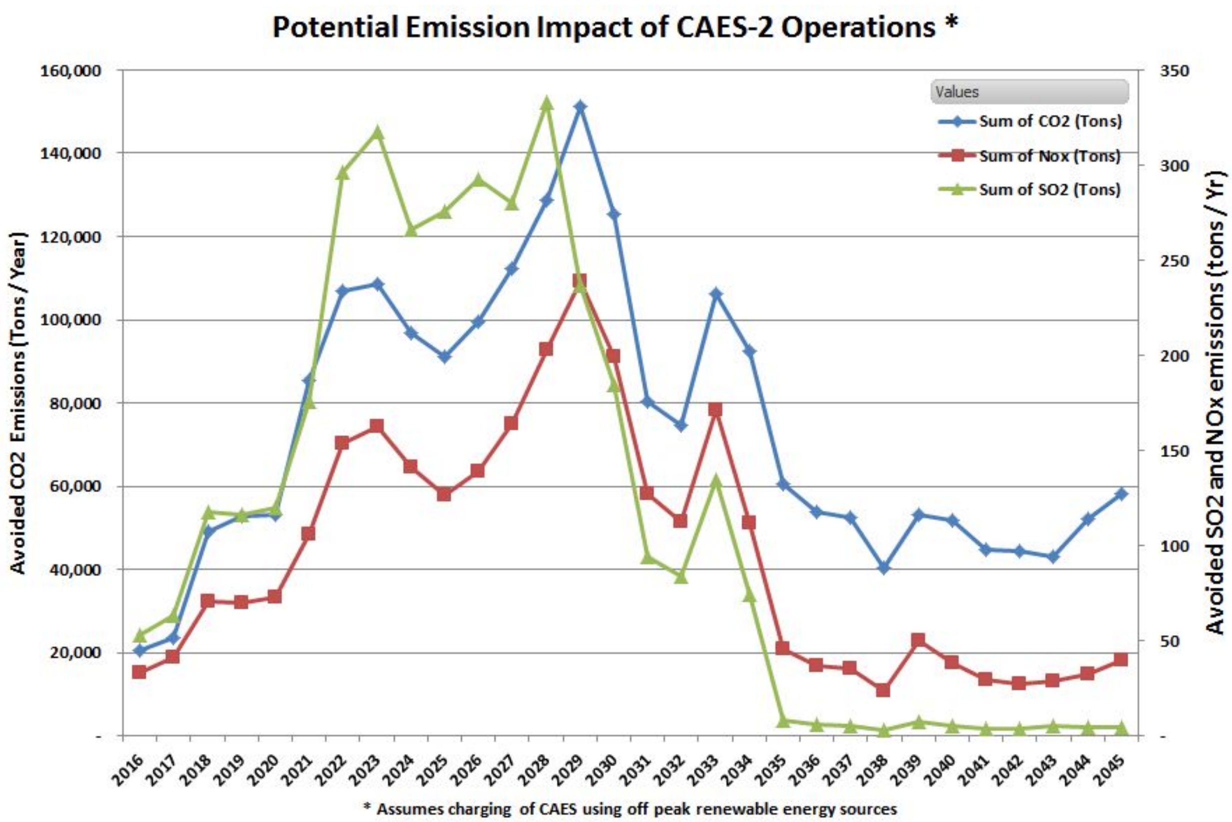

Figure 39: Emission Impact of CAES 2 configuration

Following charts show the $ value of the avoided emissions based on the emission pricing forecasts used for the analysis.

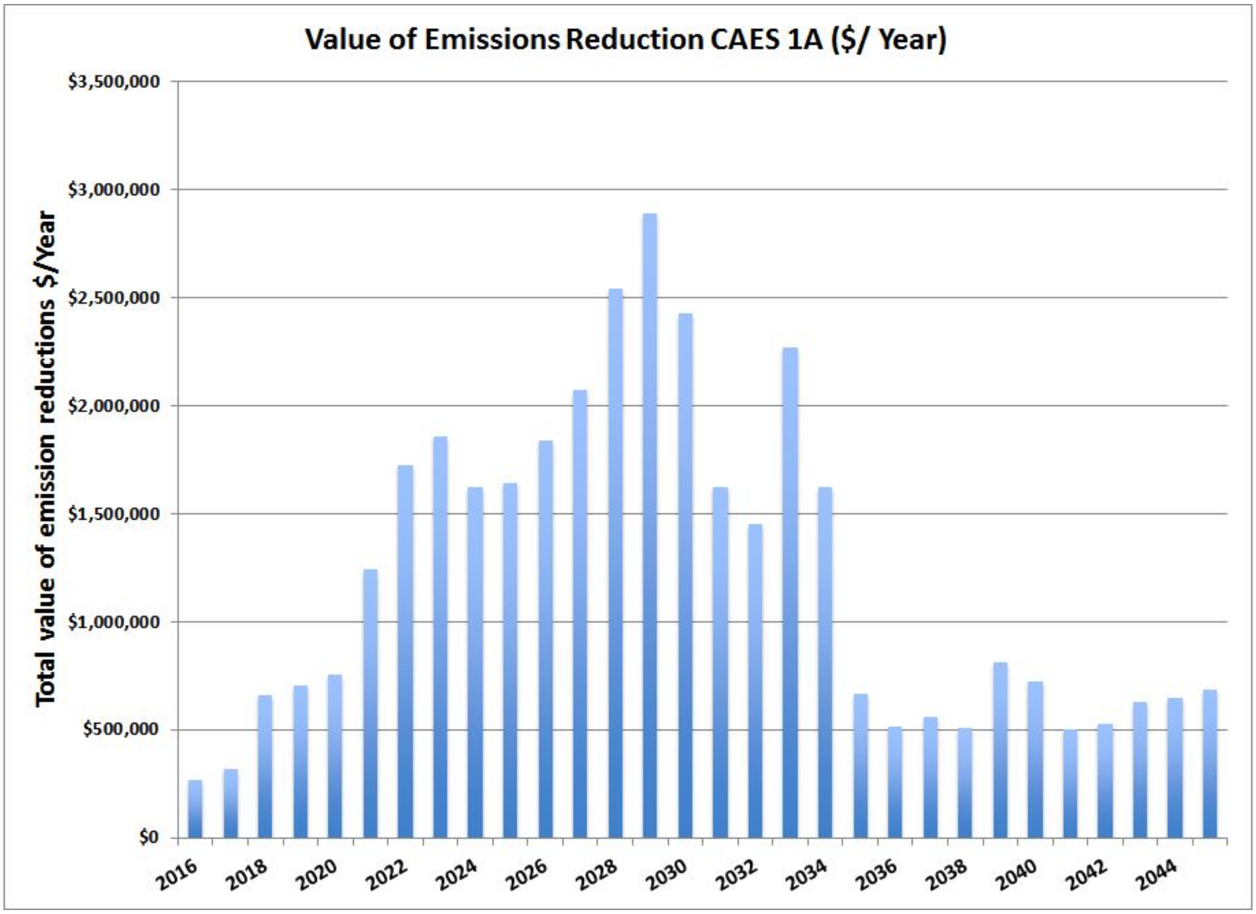

Figure 12: Value of the emission reductions for CAES 1A

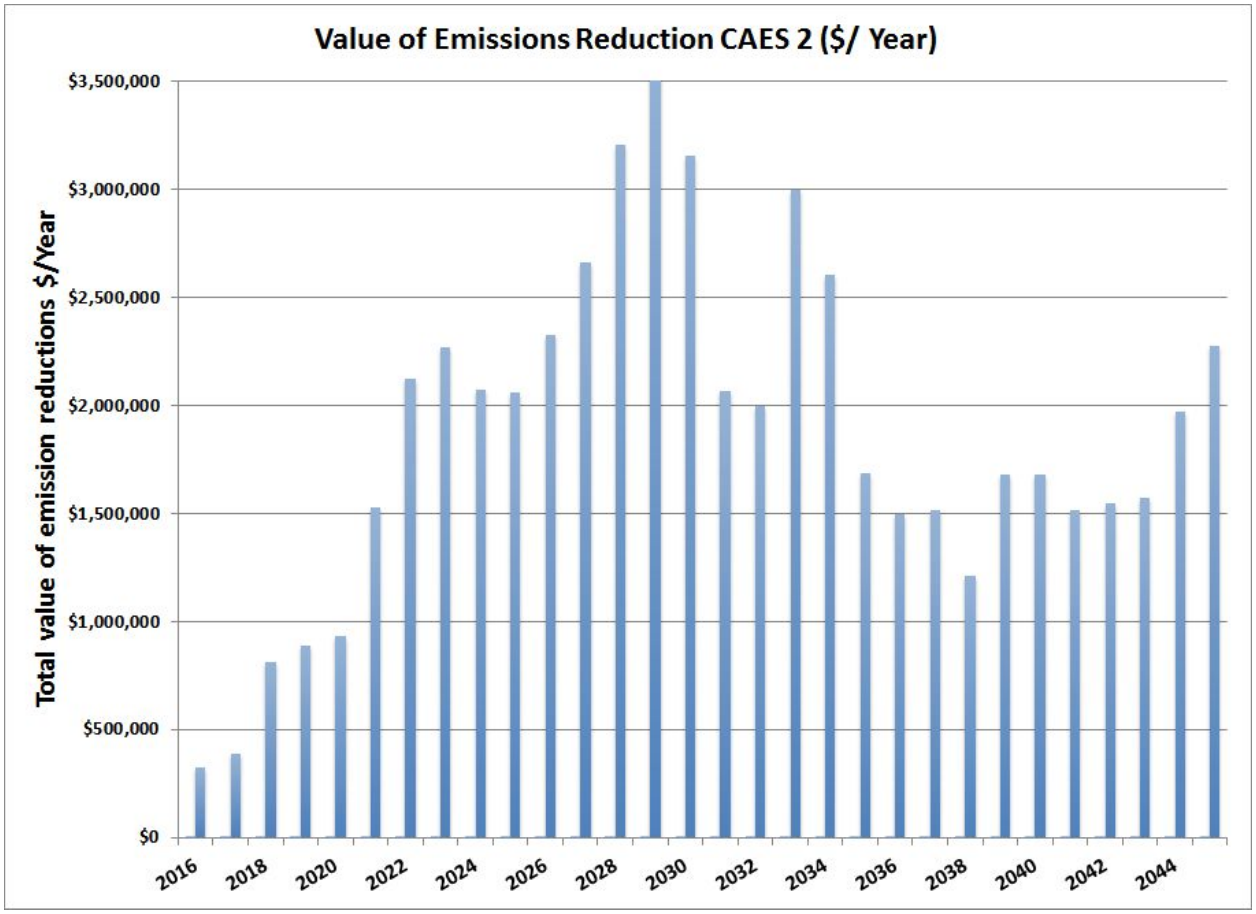

Figure 13: Value of the emission reductions for CAES 2

4.5 Other Operational and Reliability Benefits From CAES

Apart from the direct emissions impact, the proposed facility could also offer other system Operational and Reliability benefits, which were not captured by the analysis. These could include:

- Avoid or defer transmission system capital expenditures
- Reduce renewable energy source curtailment due to real time operational issues
- Increased ability of grid to rapidly respond to changes in renewable energy source production levels real time.

- Black Start capability to support local Reliability needs
- Additional revenues from Voltage Support Service
- As the development of new wind farms continue to come on line, they will have an impact on the NYISO operations, if the wind generation operates when it is not needed or changes in the wind generation occur rapidly.

Create an opportunity for wind farm owners to enter into bilateral contracts with the CAES plant to provide off peak energy at a low price, thus improving the economics of the CAES plant as well as providing additional revenue opportunity to the Wind Generator and improve use of renewable resources. Create an opportunity with Base Load Generators to enter into a bilateral contract with the CAES Plant to provide off peak energy to avoid frequent shutdowns

An extension of the model design has the capability to optimized the operation of a CAES facility given 3 of the 4 major variables in the CAES design, i.e., given the transmission limits and/or the Cavern storage limits, and/or the CAES, and/or the Compressor Size, and/or the Generation output capability

No Environmental credits were included in the evaluation while the EPA is still evaluating the CSAPR requirements or REC credits.