Appendix G Carbon Free Electric Supply

The Integration Analysis description of the Carbon-Free Electric Supply in Appendix G Section I starts at page 42. This document reproduces the text from Appendix G and adds the values associated with the figures describing the projected installed capacity and annual generation.

To meet rapidly growing electricity demand while decarbonizing electricity supply, New York must significantly expand its generation and transmission infrastructure. Coupled with New York's existing clean firm resources, all pathways require major investments in wind, solar, and battery storage, which serve as the foundational resources to achieve New York's 70x30 and 100x40 goals.

To achieve 70% renewable electricity by 2030, New York must continue to increase its Clean Energy Standard procurements for large-scale renewables, part of which involves scaling up Offshore Wind procurements on the path to the 9 GW target by 2035. Although partially offset by investments in the New Efficiency: New York program, the large increases in electricity demand by 2030 and beyond will place additional pressure on the amount of new renewable resources needed to meet and maintain the 70% target over time. Behind-the-meter solar resources play a critical role in meeting the 70x30 targets, and the modeled pathways include the achievement of the recently-announced 10 GW BTM PV goal by 2030.

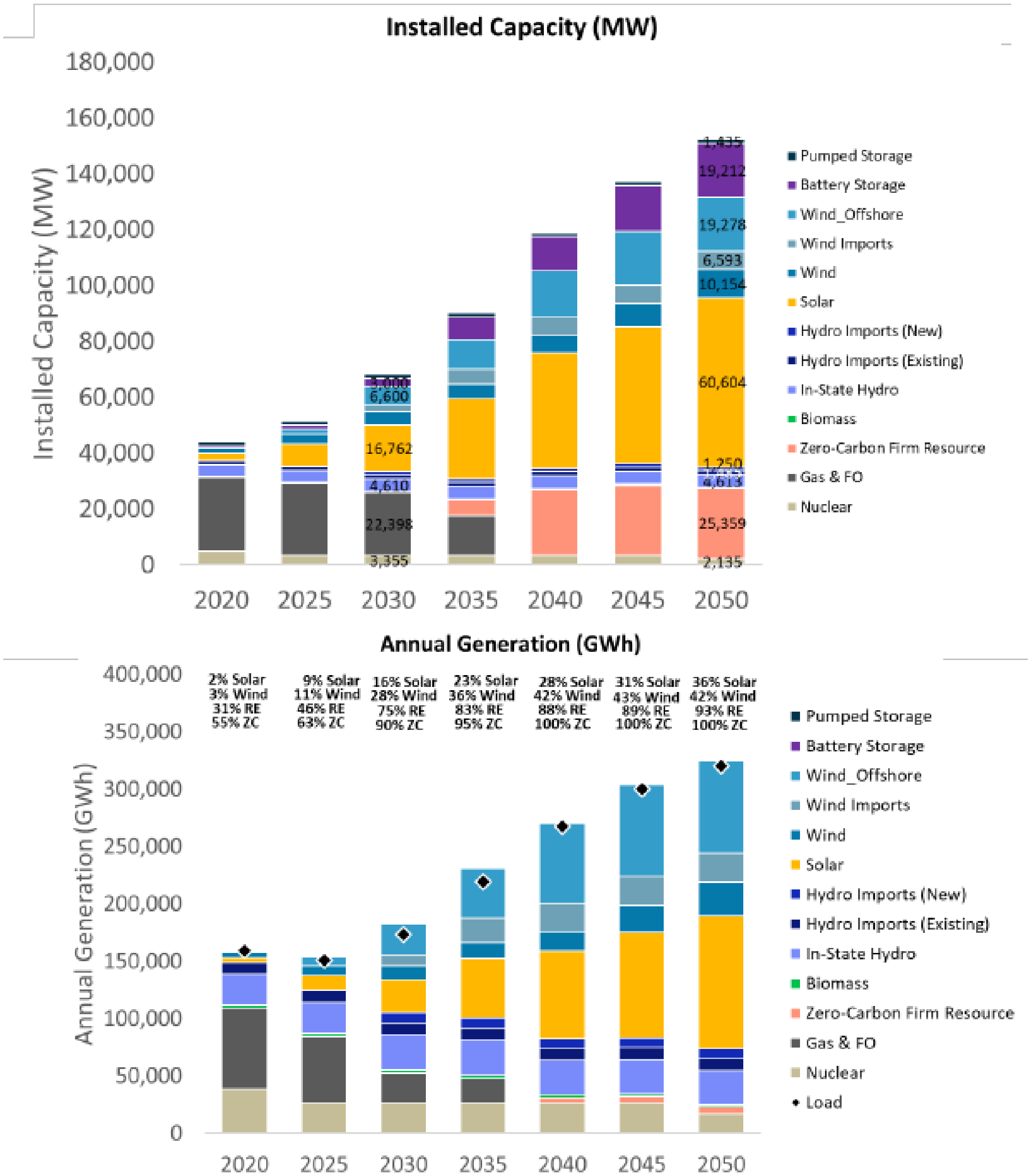
New transmission infrastructure is also expected to be an important part of the State's 70x30 and 100x40 goals. The pathways include the development of a 1250 MW line from Hydro-Quebec to New York City, as well as a 1300 MW line from upstate New York to New York City, both of which support the State's decarbonization efforts and in particular help reduce the need for fossil generation in Zone J. In addition to new bulk transmission infrastructure, multiple studies have found that investments in local system upgrades will be critical to reducing congestion and ensuring that new renewable generation can be delivered to load centers.[28,29] This analysis assumes that all new large-scale renewable projects are accompanied by investments in local transmission upgrades to "unbottle" renewables and ensure that new resources are fully deliverable. Between 2030 and 2050, New York must accelerate the build-out of new renewable resources to meet the 100% zero-emissions target and as electrification loads are added to the system. Figure 29 demonstrates the transformation of the New York capacity and generation mix over the 2020-2050 period.

[28] NYISO, 2019 CARIS Report, June 2020, available at: https://www.nyiso.com/documents/20142/13246341/2019_CARIS_Report_v20200617.pdf/fa44a341-786d-2b83-0c00-22951bb112a0, accessed December 2021

[29] New York Utilities, Utility Transmission and Distribution Investment Working Group Report, November 2020, available at: https://www.nyserda.ny.gov/About/Publications/New-York-Power-Grid-Study (App C), accessed December 2021

Footnote[30]

Figure 29. Installed Capacity and Annual Generation for Scenario 3: Accelerated Transition away from Combustion[30]



By 2050, across all modeled pathways, New York installs over 60 GW of solar capacity (both utility-scale and distributed resources), between 16-17 GW of new land-based wind capacity (including imported wind from neighboring ISOs), and between 16-19 GW of offshore wind resources, illustrated in Figure 30.

---

[30] In Scenario 3, the "zero-carbon firm resource" represents a combustion-free resource, and is modeled as a hydrogen fuel cell.

Footnote[31]

Figure 30. Installed Capacity in 2050, All Scenarios[31]

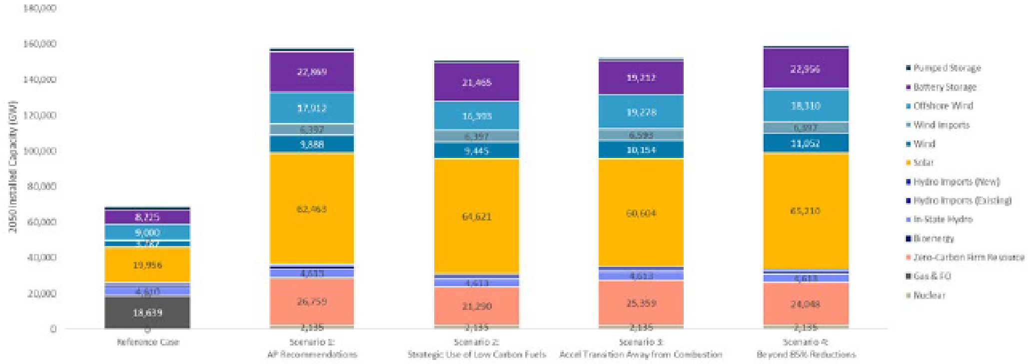
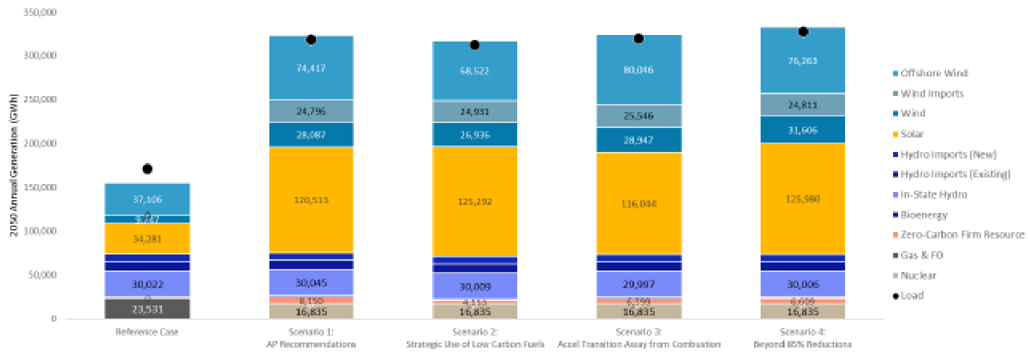


Figure 31. Annual Generation in 2050, All Scenarios



To integrate large quantities of intermittent resources into the New York electricity system, wind and solar output must be balanced with customer demand on multiple timescales, with different resources providing integration value over each timescale.

On the intraday timescale, battery storage plays a critical role in providing flexibility and balancing renewables with customer loads on both an hourly and subhourly basis. At the hourly level, batteries can charge during times of high renewable output and discharge during times of lower renewable output or high customer demand, and batteries can also help meet subhourly reserve requirements. New York installs between 19-23 GW of battery storage across our modeled pathways. Dynamic end-use flexibility also has similar potential to help meet hourly balancing needs, if customers are incentivized to shift their demand to times of highest renewable output. The impacts of end-use flexibility on electricity system resource needs and system costs are examined in Section 3.5.

[31] In Scenarios 1, 2, and 4, the "zero-carbon firm resource" represents a combination of existing and new combustion-based resources (i.e. combustion turbines and combined cycle gas turbines) that convert to utilizing hydrogen as a zero-carbon fuel. In Scenario 3, firm zero-carbon capacity represents a combustion-free resource, modeled as hydrogen fuel cells.

Scenario 2: Summary Fuel Mix Capacity (MW)

Scenario 2	2020	2025	2030	2035	2040	2045	2050
Nuclear	4,860	3,355	3,355	3,355	3,355	3,355	2,135
Gas & FO	26,388	25,775	21,579	18,078	-	-	-
Zero-Carbon Firm Resource	-	-	-	-	21,015	21,576	21,290
Biomass	327	327	327	327	327	275	178
In-State Hydro	4,269	4,269	4,610	4,610	4,613	4,613	4,613
Hydro Imports (Existing)	1,485	1,485	1,485	1,485	1,485	1,485	1,485
Hydro Imports (New)	-	-	1,250	1,250	1,250	1,250	1,250
Wind	1,917	3,292	3,814	4,263	5,845	7,781	9,445
Wind Imports	-	-	1,760	5,796	6,397	6,397	6,397
Wind_Offshore	-	1,826	6,200	9,906	14,364	16,393	16,393
Solar	2,592	8,201	18,852	28,994	43,432	53,089	64,621
Battery Storage	750	1,500	3,000	5,791	10,713	17,046	21,465
Pumped Storage	1,435	1,435	1,435	1,435	1,435	1,435	1,435
Total	44,023	51,467	67,667	85,292	114,232	134,694	150,707

Scenario 2: Summary Annual Energy Fuel Mix (GWh)

Scenario 2	2020	2025	2030	2035	2040	2045	2050
Nuclear	38,318	26,452	26,452	26,452	26,452	26,452	16,835
Gas & FO	70,449	58,305	24,562	19,651	-	-	-
Zero-Carbon Firm Resource	-	-	-	-	3,342	3,675	4,153
Biomass	2,721	2,721	2,721	2,721	2,721	2,288	1,480
In-State Hydro	27,121	27,011	30,857	30,963	30,045	30,021	30,009
Hydro Imports (Existing)	10,361	10,361	10,361	10,361	10,361	10,361	10,361
Hydro Imports (New)	-	-	8,760	8,760	8,760	8,760	8,760
Wind	4,796	8,238	9,873	11,229	16,035	21,854	26,936
Wind Imports	-	-	6,944	22,810	25,130	24,916	24,931
Wind_Offshore	-	7,611	25,657	41,016	59,778	68,287	68,522
Solar	3,908	13,087	32,965	52,781	80,620	100,948	125,292
Battery Storage	(16)	47	(774)	(1,543)	(2,196)	(3,406)	(4,319)
Pumped Storage	(74)	(50)	(233)	(123)	(348)	(380)	(476)
Imports*	**4,694**	**3,827**	**2,309**	**4,573**	**13,545**	**14,266**	**14,818**
Exports	**(3,320)**	**(6,628)**	**(10,716)**	**(13,458)**	**(13,545)**	**(14,266)**	**(14,818)**
Load	**158,963**	**150,985**	**169,744**	**216,201**	**260,708**	**293,786**	**312,488**

Scenario 3: Summary Fuel Mix Capacity (MW)

Scenario 3	2020	2025	2030	2035	2040	2045	2050
Nuclear	4,860	3,355	3,355	3,355	3,355	3,355	2,135
Gas & FO	26,388	25,775	22,398	14,292	-	-	-
Zero-Carbon Firm Resource	-	-	-	5,489	23,522	25,230	25,359
Biomass	327	327	327	327	327	275	178
In-State Hydro	4,269	4,269	4,610	4,613	4,613	4,613	4,613
Hydro Imports (Existing)	1,485	1,485	1,485	1,485	1,485	1,485	1,485
Hydro Imports (New)	-	-	1,250	1,250	1,250	1,250	1,250
Wind	1,917	3,292	4,600	5,220	6,126	8,250	10,154
Wind Imports	-	-	2,421	5,448	6,397	6,593	6,593
Wind_Offshore	-	1,826	6,600	10,423	16,756	19,278	19,278
Solar	2,592	8,201	16,762	28,625	41,420	49,042	60,604
Battery Storage	750	1,500	3,000	8,090	12,207	16,383	19,212
Pumped Storage	1,435	1,435	1,435	1,435	1,435	1,435	1,435
Total	44,023	51,467	68,244	90,054	118,894	137,190	152,297

Scenario 3: Summary Annual Energy Fuel Mix (GWh)

Scenario 3	2020	2025	2030	2035	2040	2045	2050
Nuclear	38,318	26,452	26,452	26,452	26,452	26,452	16,835
Gas & FO	70,461	57,869	25,668	21,231	-	-	-
Zero-Carbon Firm Resource	-	-	-	-	4,440	5,419	6,399
Biomass	2,721	2,721	2,721	2,721	2,721	2,288	1,480
In-State Hydro	27,121	26,995	30,870	30,993	29,982	29,996	29,997
Hydro Imports (Existing)	10,361	10,361	10,361	10,361	10,361	10,361	10,361
Hydro Imports (New)	-	-	8,760	8,760	8,760	8,760	8,760
Wind	4,796	8,238	12,296	14,130	16,799	23,200	28,947
Wind Imports	-	-	9,544	21,389	25,002	25,563	25,546
Wind_Offshore	-	7,611	27,293	43,153	69,388	79,540	80,046
Solar	3,908	13,087	28,596	51,328	75,966	92,094	116,044
Battery Storage	(16)	66	(822)	(1,875)	(2,443)	(3,249)	(4,081)
Pumped Storage	(74)	(64)	(223)	(115)	(288)	(310)	(395)
Imports*	**4,695**	**3,832**	**3,330**	**5,005**	**13,978**	**14,459**	**15,073**
Exports	**(3,319)**	**(6,657)**	**(11,480)**	**(14,461)**	**(13,978)**	**(14,459)**	**(15,073)**
Load	**158,973**	**150,512**	**173,371**	**219,076**	**267,143**	**300,115**	**319,942**

Scenario 4: Summary Fuel Mix Capacity (MW)

Scenario 4	2020	2025	2030	2035	2040	2045	2050
Nuclear	4,860	3,355	3,355	3,355	3,355	3,355	2,135
Gas & FO	26,388	25,775	21,579	20,326	-	-	-
Zero-Carbon Firm Resource	-	-	-	-	23,676	24,333	24,048
Biomass	327	327	327	327	327	275	178
In-State Hydro	4,269	4,269	4,610	4,613	4,613	4,613	4,613
Hydro Imports (Existing)	1,485	1,485	1,485	1,485	1,485	1,485	1,485
Hydro Imports (New)	-	-	1,250	1,250	1,250	1,250	1,250
Wind	1,917	3,292	3,859	4,491	6,282	8,305	11,052
Wind Imports	-	-	2,649	5,970	6,397	6,397	6,397
Wind_Offshore	-	1,826	6,600	9,967	15,875	18,066	18,310
Solar	2,592	8,201	18,060	29,841	41,623	53,450	65,210
Battery Storage	750	1,500	3,000	6,311	11,576	18,973	22,956
Pumped Storage	1,435	1,435	1,435	1,435	1,435	1,435	1,435
Total	44,023	51,467	68,210	89,373	117,896	141,938	159,070

Scenario 4: Summary Annual Energy Fuel Mix (GWh)

Scenario 4	2020	2025	2030	2035	2040	2045	2050
Nuclear	38,318	26,452	26,452	26,452	26,452	26,452	16,835
Gas & FO	70,459	58,124	25,587	20,850	-	-	-
Zero-Carbon Firm Resource	-	-	-	-	4,644	5,614	6,609
Biomass	2,721	2,721	2,721	2,721	2,721	2,288	1,480
In-State Hydro	27,121	27,000	30,867	30,994	30,023	30,008	30,006
Hydro Imports (Existing)	10,361	10,361	10,361	10,361	10,361	10,361	10,361
Hydro Imports (New)	-	-	8,760	8,760	8,760	8,760	8,760
Wind	4,796	8,238	9,966	11,856	17,274	23,376	31,606
Wind Imports	-	-	10,449	23,455	25,035	24,849	24,811
Wind_Offshore	-	7,611	27,293	41,237	65,700	74,600	76,263
Solar	3,908	13,087	31,293	53,921	76,465	101,267	125,980
Battery Storage	(16)	61	(812)	(1,781)	(2,381)	(3,844)	(4,823)
Pumped Storage	(74)	(59)	(220)	(163)	(345)	(306)	(426)
Imports*	**4,694**	**3,834**	**3,303**	**5,017**	**14,006**	**14,780**	**15,101**
Exports	**(3,318)**	**(6,628)**	**(10,779)**	**(14,092)**	**(14,006)**	**(14,780)**	**(15,101)**
Load	**158,973**	**150,804**	**175,245**	**219,593**	**264,712**	**303,431**	**327,470**

Reference Case: Summary Fuel Mix Capacity (MW)

Reference Case	2020	2025	2030	2035	2040	2045	2050
Nuclear	4,860	3,355	2,135	1,287	1,287	1,287	-
Gas & FO	26,388	25,775	20,756	15,352	16,319	17,822	18,639
Zero-Carbon Firm Resource	-	-	-	-	-	-	-
Biomass	327	327	327	327	327	275	178
In-State Hydro	4,269	4,269	4,610	4,610	4,610	4,610	4,610
Hydro Imports (Existing)	1,485	1,485	1,485	1,485	1,485	1,485	1,485
Hydro Imports (New)	-	-	1,250	1,250	1,250	1,250	1,250
Wind	1,917	3,292	3,787	3,787	3,787	3,787	3,787
Wind Imports	-	-	-	-	-	-	-
Wind_Offshore	-	1,826	6,200	9,000	9,000	9,000	9,000
Solar	2,592	8,201	13,644	14,387	14,661	14,942	19,956
Battery Storage	750	1,500	3,000	4,655	4,872	5,123	8,225
Pumped Storage	1,435	1,435	1,435	1,435	1,435	1,435	1,435
Total	44,023	51,467	58,629	57,576	59,033	61,017	68,565

On the interday timescale, firm resources are needed to serve load and maintain system reliability during multi-day periods of low renewable output – periods in which the contributions of short-duration battery storage are limited. Our analysis identified a need for firm, zero-carbon capacity – in addition to the state's existing hydro and nuclear facilities – of between 21-27 GW to maintain system reliability while achieving a 100% zero-emissions grid.[32]

Ultimately, each resource category – renewables, battery storage, and firm zero-carbon capacity – will make important contributions to the state's achievement of a reliable carbon-free electric system. The reliability contributions of different resource types to statewide capacity requirements are detailed in Figure 32, which provides an alternative view of the 2050 resource mix in Scenario 3.[33] New renewable and storage resources provide significant reliability contributions, contributing over 21 GW towards statewide capacity requirements. However, at high penetrations of renewables and storage, the incremental reliability value of new resources is limited, because the most challenging periods for system reliability become times in which renewable output is low and storage is quickly exhausted. Firm zero-carbon capacity, including the existing nuclear and hydro facilities as well as new resources, contribute the remaining 34 GW of capacity requirements to ensure that the system is fully reliable, including during extended periods of low renewable output. The following section details the contributions of each resource type at more granular timescales.

---

[32] In Scenarios 1, 2, and 4, this firm capacity need is met by a combination of existing and new combustion-based resources (i.e. combustion turbines and combined cycle gas turbines) converting to hydrogen as a zero-carbon fuel. In Scenario 3, all existing fossil fuel resources are retired by 2040 and no new combustion-based (CCGT or CT) capacity is permitted. New firm capacity is provided by a combustion-free resource (modeled as hydrogen fuel cells).

[33] In all of the modeled pathways, the analysis ensures that the resulting electric system portfolios are reliable by enforcing the current statewide and local capacity requirements on a UCAP basis. The reliability contributions of intermittent and limited-duration resources (i.e. renewables and battery storage) towards New York's UCAP requirements are measured using an effective load carrying capability (ELCC) methodology. ELCC is the quantity of "perfect capacity" or UCAP that could be replaced with renewables or storage while providing equivalent system reliability. The analysis included loss of load probability modeling using E3's reliability model, RECAP, as detailed in Chapter 5.