ANALYSIS GROUP

NYISO Climate Change Phase II Study

Continued Modeling Discussions

NYISO ESPWG

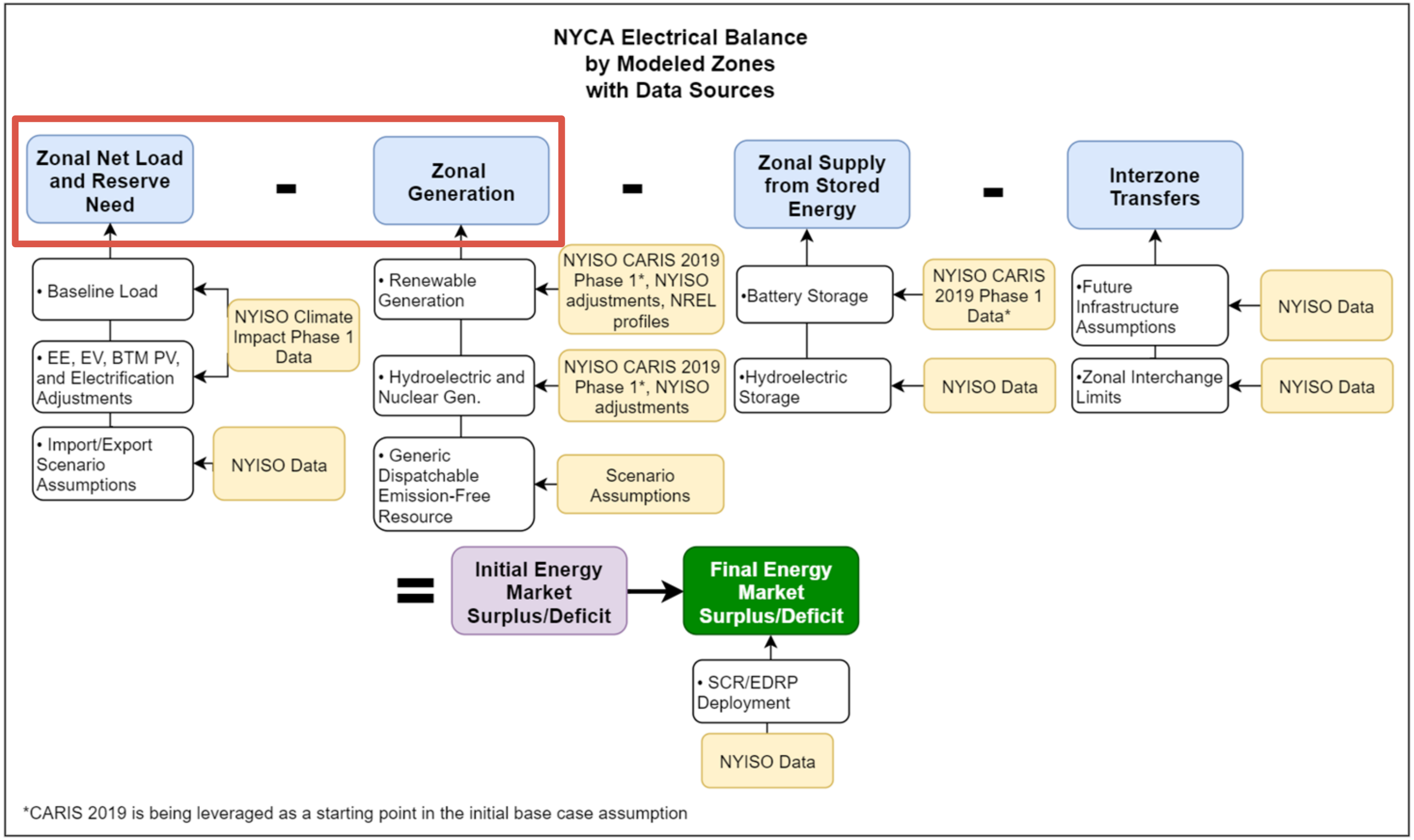
April 23, 2020

Today:

- Review of Initial Load and Generation Inputs
- Initial Aggregate Load/Generation Balance
- Initial Transmission Limitations
- Options for Balancing Load and Generation
- Reference Case Reliable Starting Point Results
- Next Steps

Review of Initial Load and Generation Inputs

Review of Model Setup



- Initial focus today will be on patterns in hourly balance between aggregate load and generation

Review of Load Inputs

- Three 30-day modeling periods: Winter (January 2040), Summer (July 2040), and Off-peak (April 2040)
- 4 Phase I scenarios:
  - *Reference Case* – Load growth based on Gold Book 2019 Estimates with 0.7° F per decade average temperature increase
  - *Accelerated Climate Change Case* – Reference case with assumption of 1.4° F per decade average temperature increase
  - *State Policy Case* – Increased energy efficiency to meet NY Clean Energy Standard goals; increased BTM PV, EV, and heating electrification
  - *CLCPA Case* – 85% reduction in overall GHG by 2050, large scale electrification in residential and commercial sectors; 85% reduction in transportation GHG

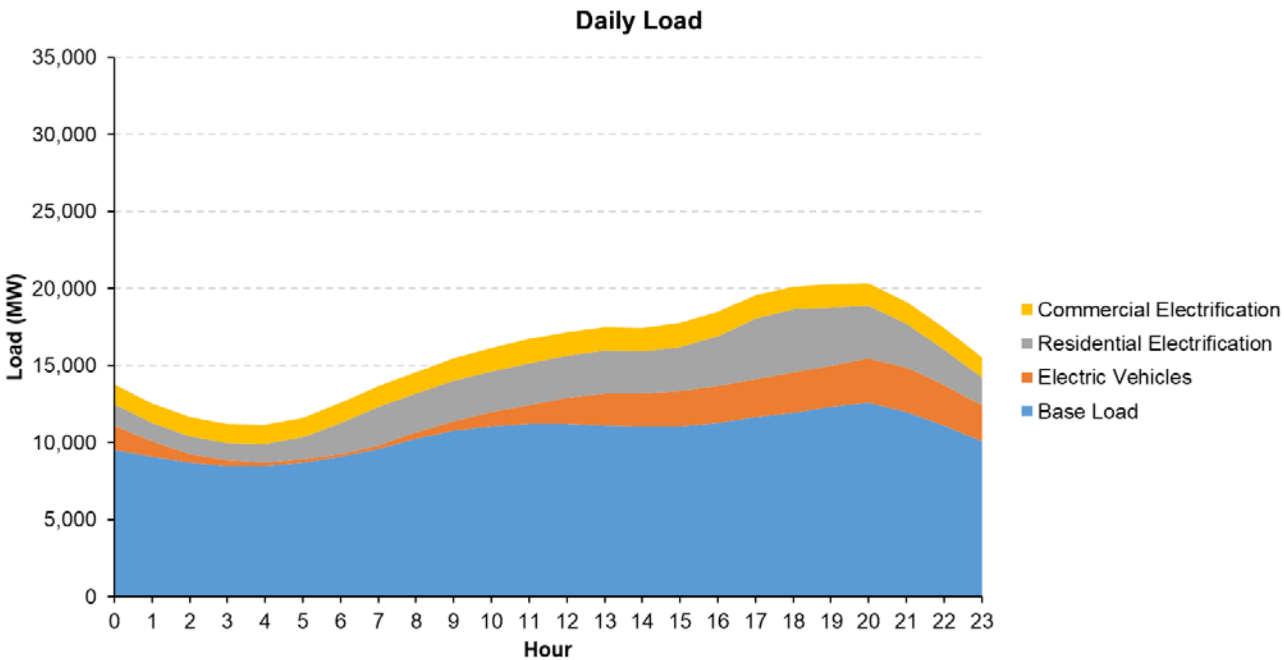
Shoulder Modeling Period (April 2040) Load Summary

Total Demand (GWh)	Reference	Accelerated Climate Change	State Policy	CLCPA
Base Load	10,304	10,388	8,509	8,509
Electric Vehicles	1,081	1,081	1,342	1,342
Residential Electrification	0	0	303	1,410
Commercial Electrification	0	0	61	1,236
Total Adjusted Load	**11,385**	**11,469**	**10,216**	**12,497**

Example Daily Load Shape

CLCPA Scenario

April 1, 2040



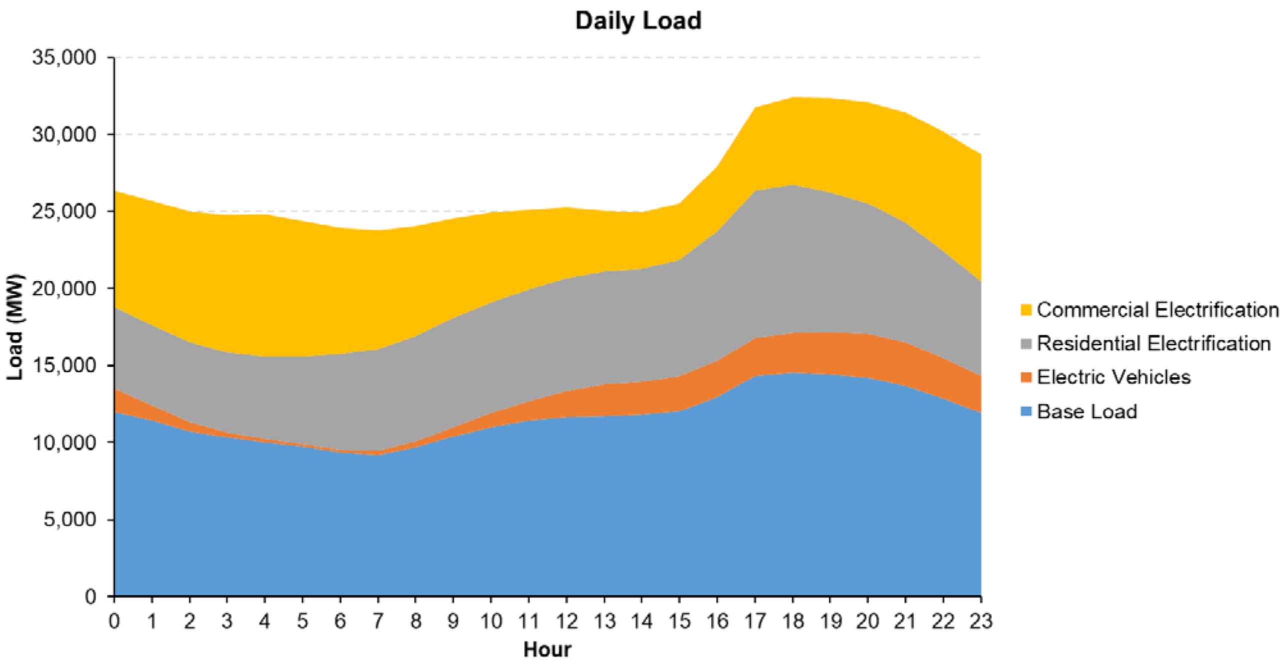
Winter Modeling Period (January 2040) Load Summary

Total Demand (GWh)	Reference	Accelerated Climate Change	State Policy	CLCPA
Base Load	13,464	13,192	11,190	11,190
Electric Vehicles	1,111	1,111	1,380	1,380
Residential Electrification	0	0	894	7,397
Commercial Electrification	0	0	673	8,129
Total Adjusted Load	**14,576**	**14,304**	**14,138**	**28,097**

Example Daily Load Shape

CLCPA Scenario

January 1, 2040



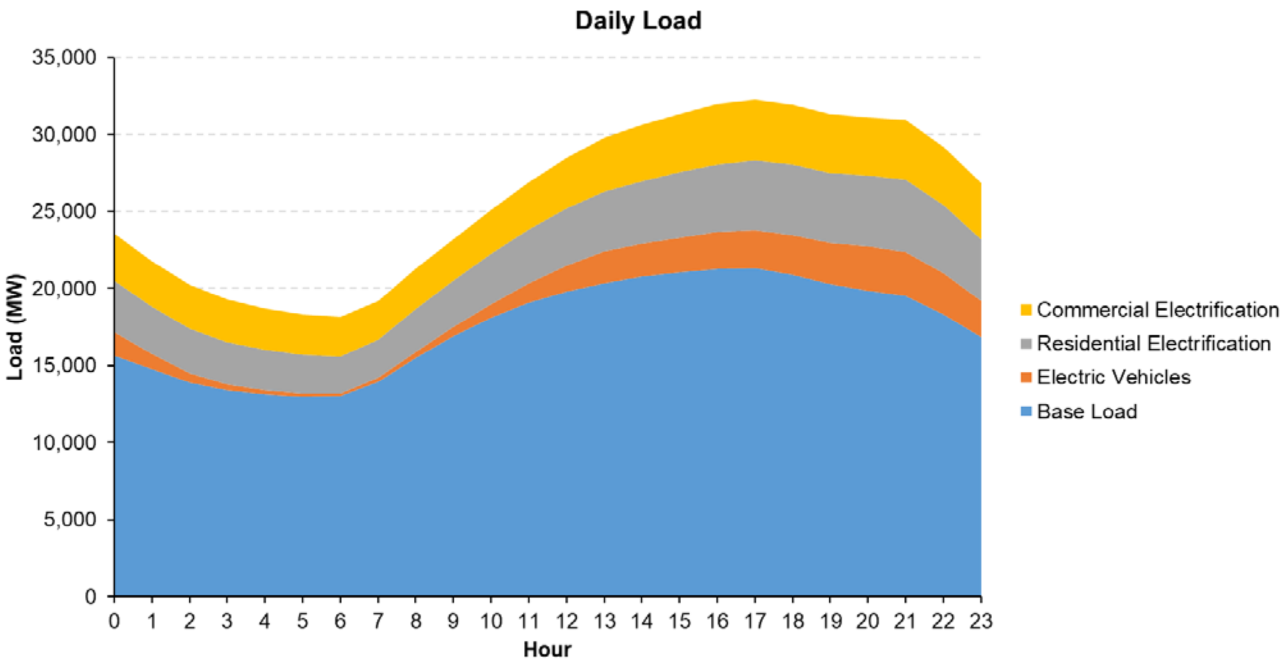
Summer Modeling Period (July 2040) Load Summary

Total Demand (GWh)	Reference	Accelerated Climate Change	State Policy	CLCPA
Base Load	18,473	19,334	15,323	15,323
Electric Vehicles	1,111	1,111	1,380	1,380
Residential Electrification	0	0	841	3,230
Commercial Electrification	0	0	439	3,180
Total Adjusted Load	**19,584**	**20,445**	**17,984**	**23,114**

Example Daily Load Shape

CLCPA Scenario

July 1, 2040



Review of Generation Inputs

- Reference Case resource starting assumptions similar to 2019 CARIS Phase 1 "70x30" case, adjusted for potential 2040 conditions. Resources assumed:
  - 8,761 MW land-based wind
  - 9,000 MW of offshore wind injected into zones J and K
  - 19,361 MW grid-connected solar PV
  - 3,629 MW behind-the-meter solar PV
  - 3,900 MW of battery storage, grid-connected and behind-the-meter
- State Policy and CLCPA cases assume additional ~5,500 MW BTM PV installations
- Land-based and offshore wind profiles based on synchronous NREL data (2009 measurements)
- Grid-connected and BTM solar profiles based on synchronous NREL data (2006 measurements)
- Assumes imports of 1,310 MW from Hydro Quebec; not assuming imports or exports to or from other neighboring zones
- Additional resource mixes will be provided from the Grid in Transition study

Summary of Load and Generation Inputs

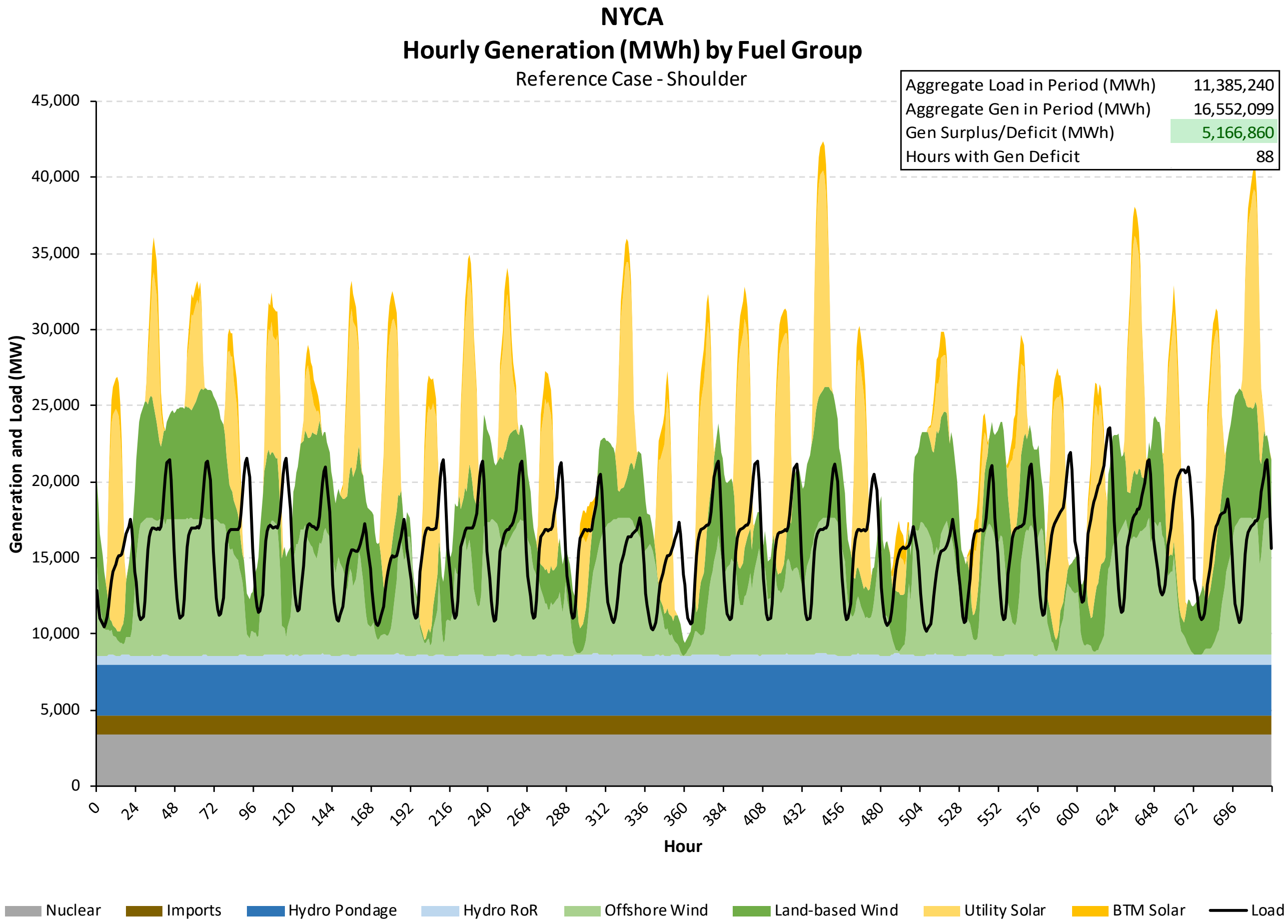
Case	Load	Resources
Reference Case Itron Climate Impact Phase 1 CARIS 2019 Phase 1 70 by 30 Case CLCPA Targets	**Itron Phase 1 - Reference Case** 0.7 F increase per decade 2,200 GWh per year in energy efficiency EV penetration from 2019 Gold Book (13,200 GWh) **Peak Load:** 38,666 MW (July 18, 2040) **Annual Energy:** 168,752 GWh	**No Fossil Fuel Units** 3,629 MW of BTM Solar 19,631 MW of Grid-Connected Solar 8,761 MW of Land-Based Wind 3,364 MW of Nuclear 4,246 MW of Hydro 9,000 MW of Offshore Wind (2035) 3,900 MW of Battery Storage (3,000 MW by 2030)
Accelerated Climate Change Case	**Itron Phase 1 - Accelerated Climate Change Case** Built off reference case 1.4 F increase per decade **Peak Load:** 40,208 MW (July 18, 2040) **Annual Energy:** 171,348 GWh	**Same as Reference Case**
State Policy Case	**Itron Phase 1 - State Policy Case** Built off reference case 0.7 F increase per decade Additional > 2,200 GWh per year in energy efficiency EV penetration from 2019 Gold Book (13,200 GWh) Conversion of 25% of existing residential natural gas heating to electric heat pumps **Peak Load:** 36,902 MW (July 18, 2040) **Annual Energy:** 155,218 GWh	**Built off Reference Case** **Plus Additional Resources** BTM Solar PV increased to 9,068 MW
2040 - CLCPA Itron Climate Impact Phase 1	**Itron Phase 1 - CLCPA Case** Built off reference case Additional > 2,200 GWh per year in energy efficiency 85% reduction in GHGs from residential, commercial, and transportation electrification; assumes replacement of fossil-based technologies 85% reduction in transportation GHG emissions via transition to EVs **Peak Load:** 57,144 MW (January 12, 2040) **Annual Energy:** 221,133 GWh	**Same as State Policy Case**

Initial Aggregate Load/Generation Balance

Overview of Load/Generation Balance

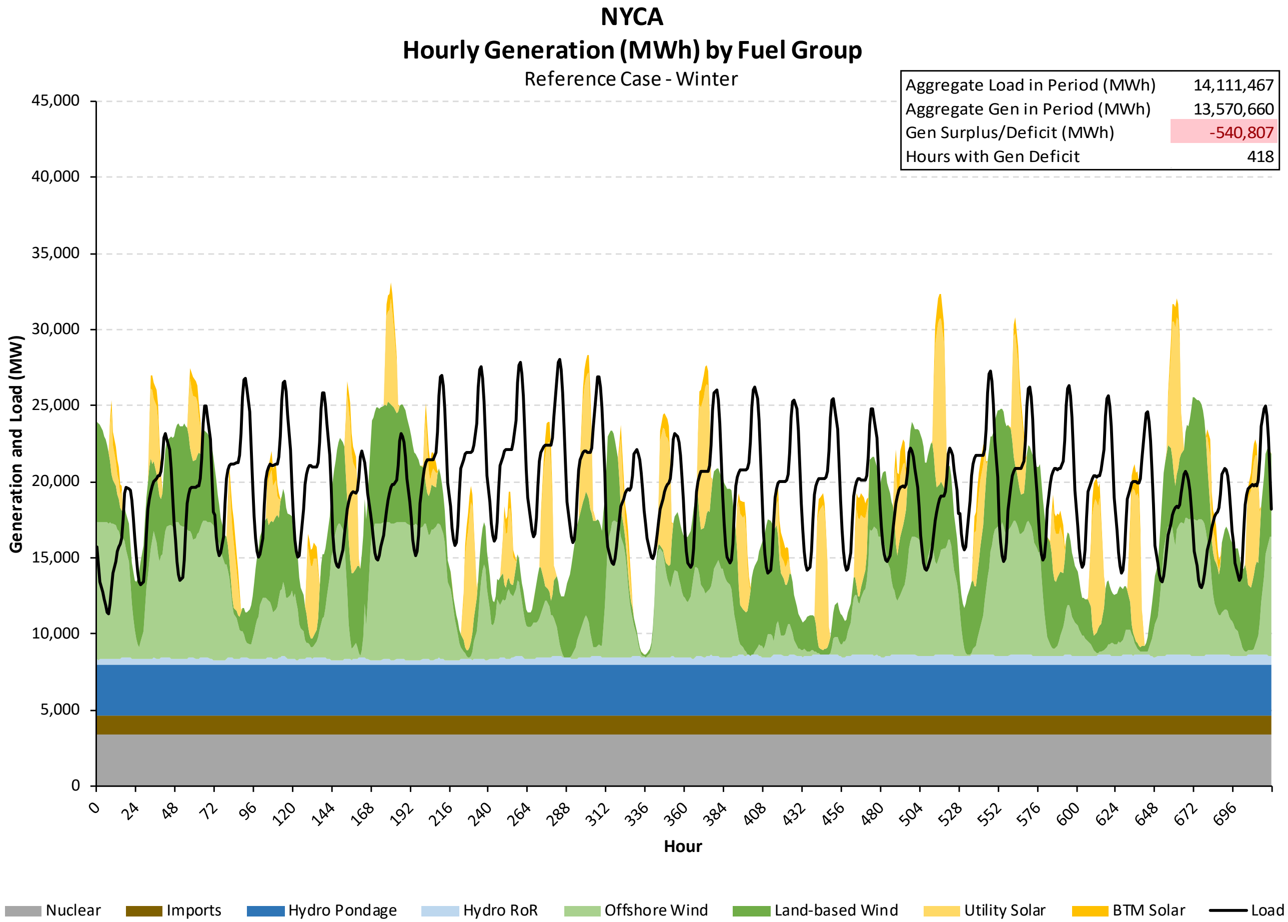
- Given the starting point of an emissions free resource mix and applying 2040 CLCPA loads, imbalances between load and generation are expected and will need to be met with additional resources
- The following slides quantify the “initial” balance between load and generation without accounting for use of storage, which shifts generation intertemporally
- Two dimensions to load/generation balance:
  - Balance of power – Are there enough MWs of generation and storage to meet instantaneous load in each hour?
  - Balance of energy – Are there enough MWhs generated over the modeling period to meet aggregate load over the same period (assuming unlimited intertemporal shift in generation using storage)?
- Power imbalances and energy imbalances require different technological solutions
  - Deficits in power require technologies with high power output
  - Deficits in energy require technologies with flexible long-term storage

Shoulder Season Load and Generation Balance



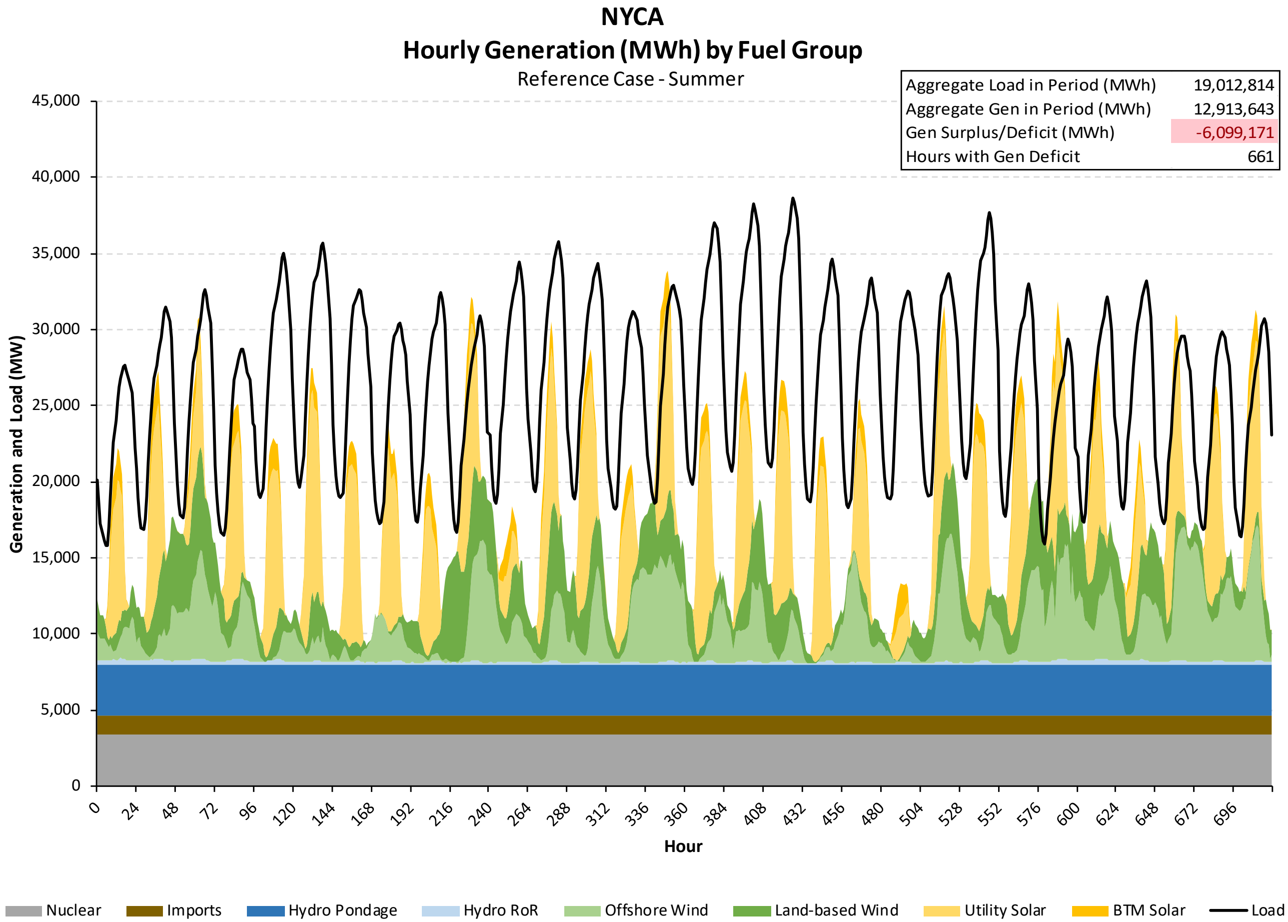
- In the shoulder season modeling period (April 2040) for the reference case, there is a substantial surplus of generation over load in terms of aggregate energy
- However, individual hours exist with >5,000 MW difference between load and generation, before accounting for storage usage
- Largest gaps occur when Land-based and offshore wind generation simultaneously drop

Winter Season Load and Generation Balance



- In the winter season modeling period (January 2040) for the reference case, there is an overall deficit of generation over load in terms of aggregate energy
- Individual hours exist with >10,000 MW difference between load and generation, before accounting for storage usage

Summer Season Load and Generation Balance



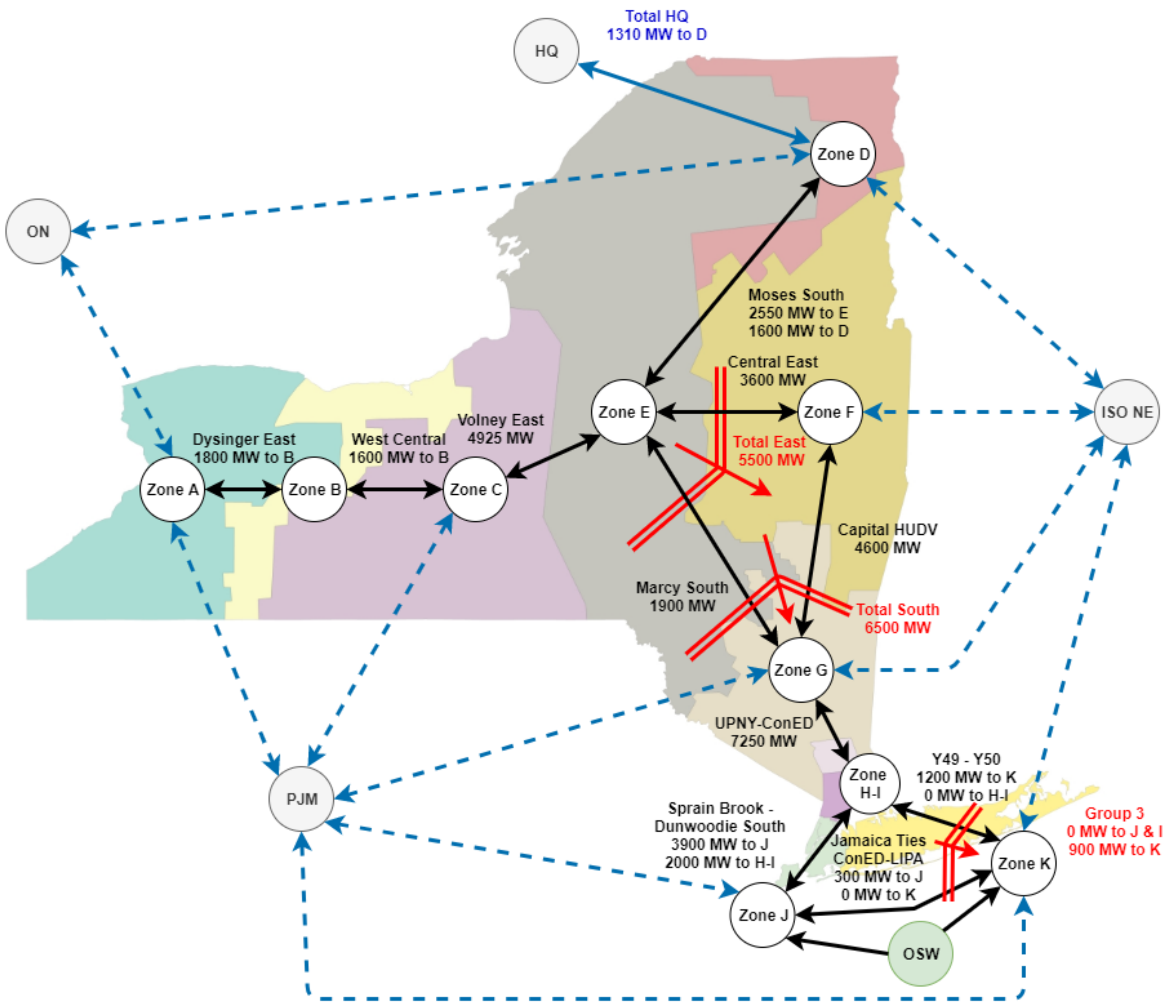
- In the summer season modeling period (July 2040) for the reference case, there is a substantial overall deficit of generation over load in terms of aggregate energy
- Individual hours exist with >15,000 MW difference between load and generation, before accounting for storage usage
- Lower wind capacity factors in summer exacerbate issues during peak hours

Summary of NYCA Load and Generation Balance, Reference Case

Modeling Period	Load (MWh)	Generation (MWh)	Net Load/Generation Balance (MWh)	Max Hourly Generation Deficit (MW)	Total Hours with Generation Deficit	Length Longest Consecutive Deficit (Hours)
Shoulder	11,385,240	16,552,099	5,166,860	> 8,000	88	11
Winter	14,111,467	13,570,660	-540,807	> 15,000	418	67
Summer	19,012,814	12,913,643	-6,099,171	> 25,000	661	225

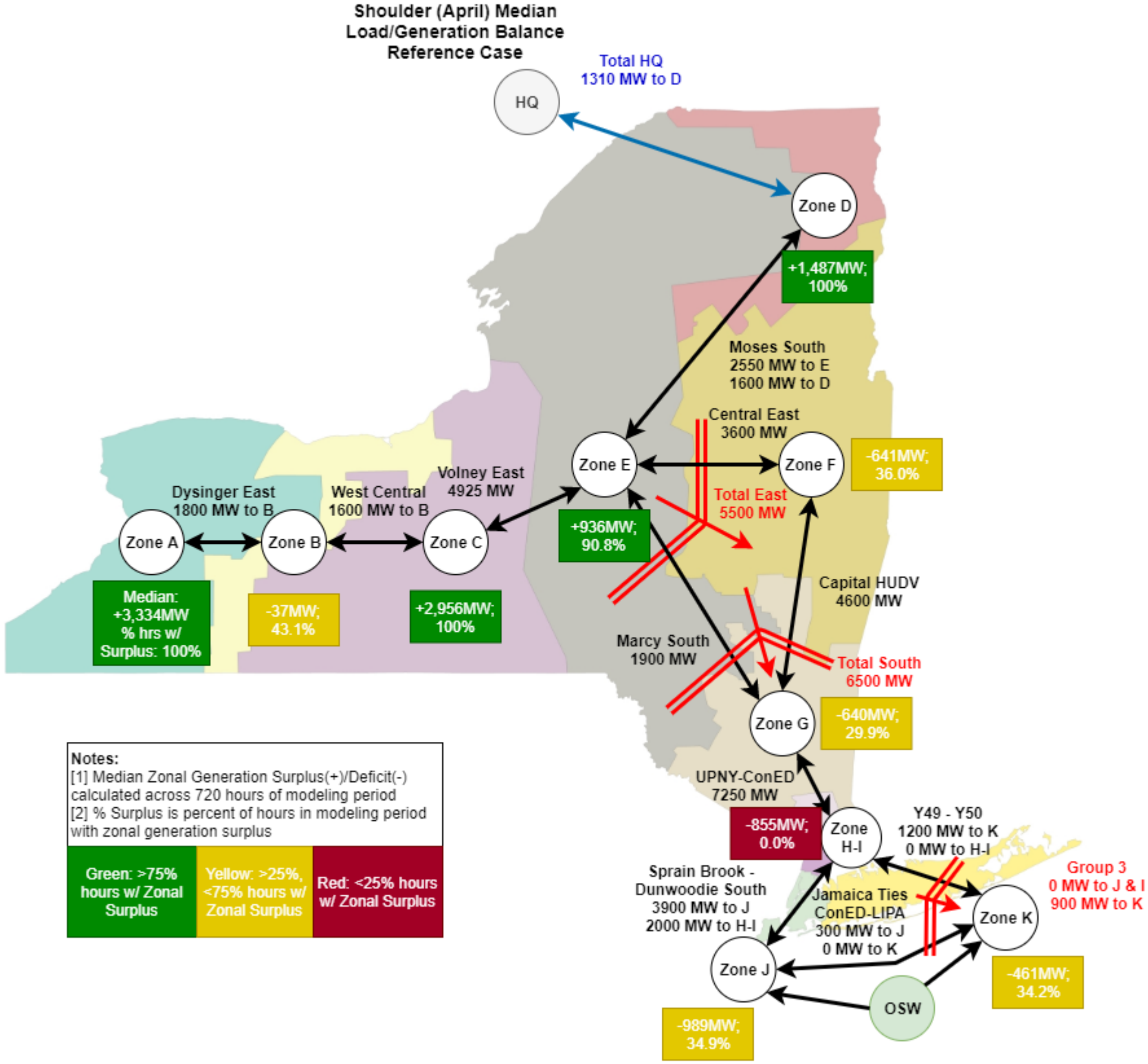
Initial Transmission Limitations

Overview of Current Transmission Model



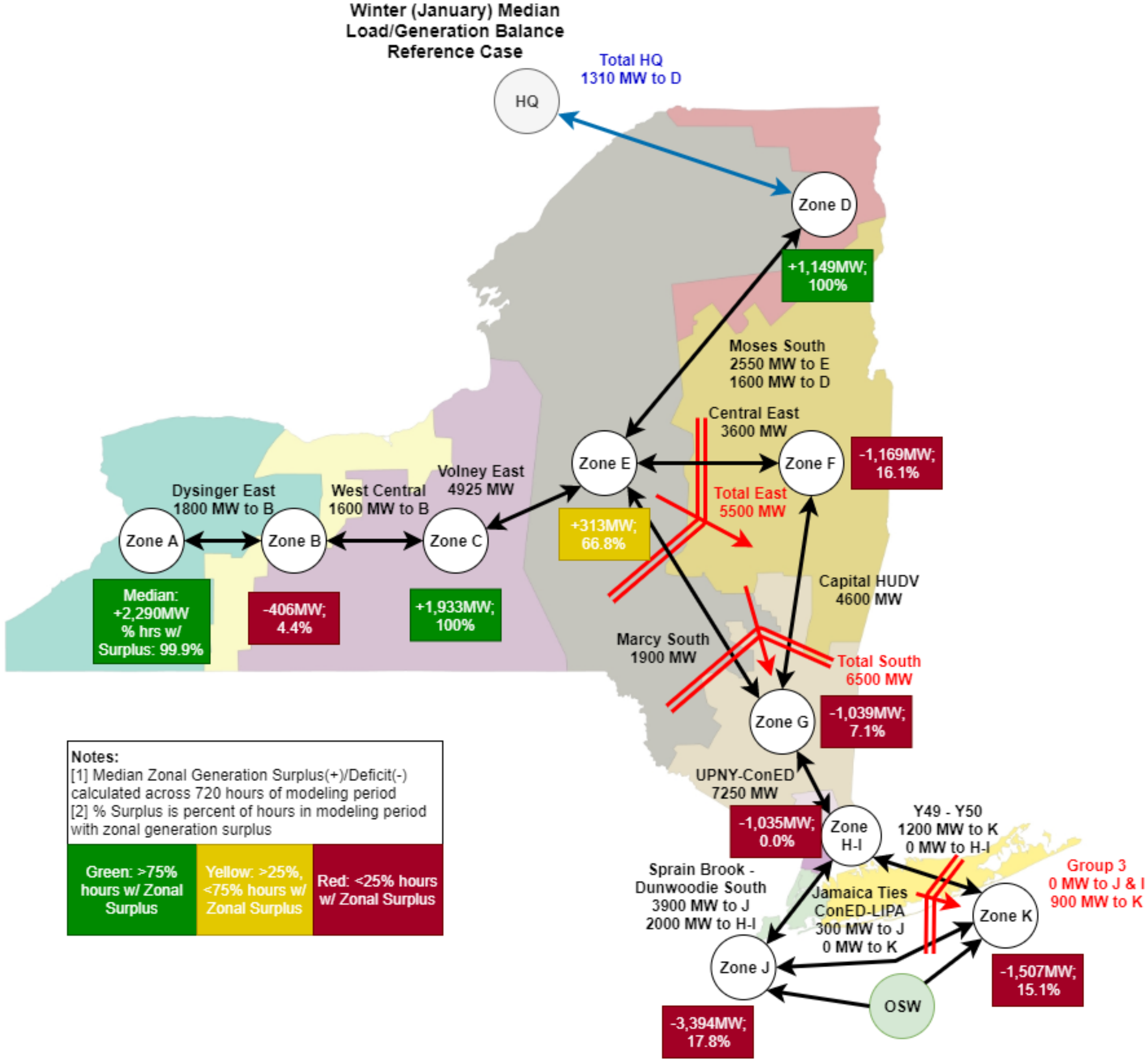
- Transmission modeling includes all 11 Zones with expected line limits in 2040
  - Includes Western NY and AC Public Policy Transmission
- Assumes N-1 Normal Transfer Criteria limits between all Zones

Shoulder Season Transmission Bottlenecks



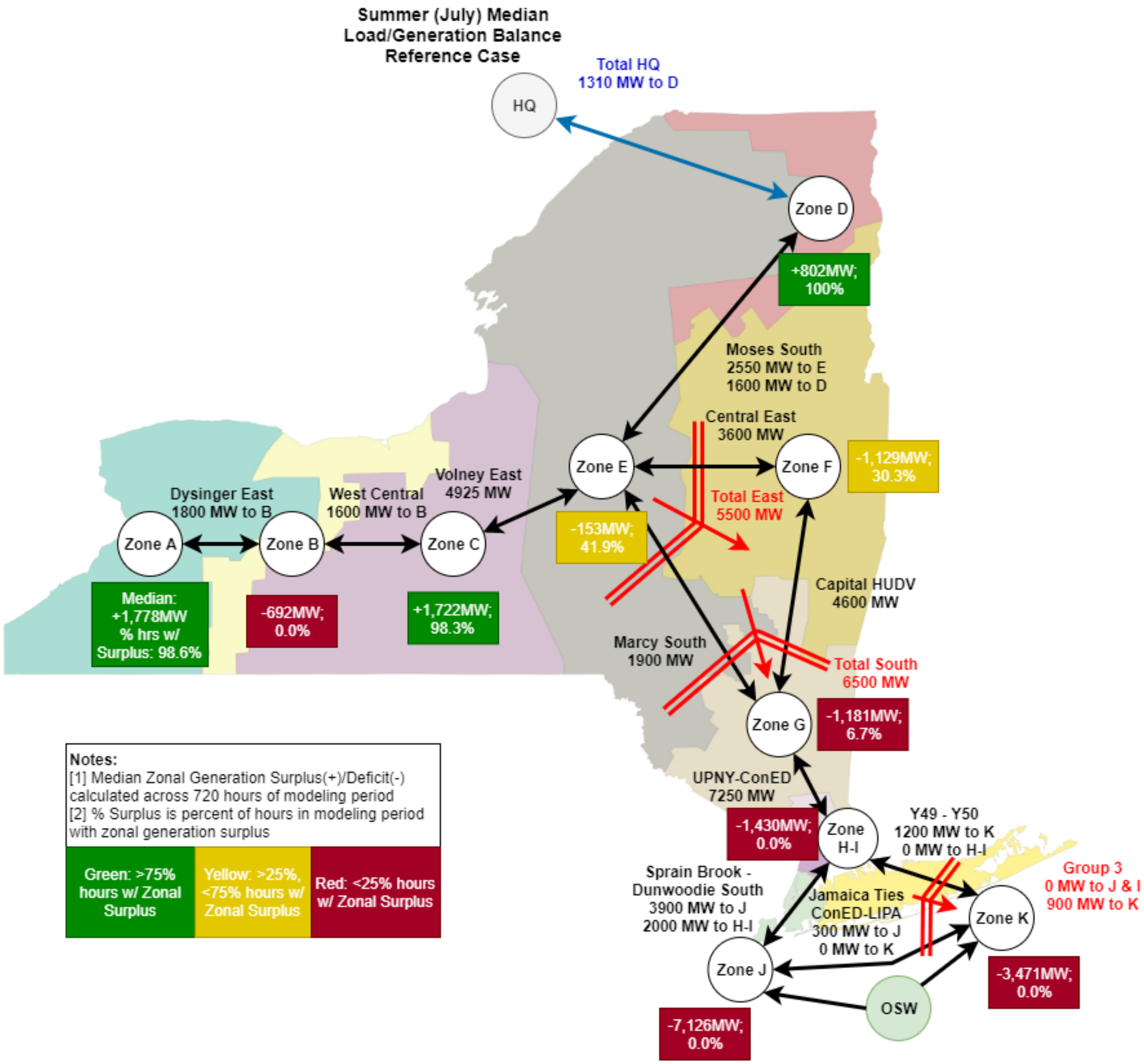
- Given current transmission limits, transmission is not able to transfer all "surplus" generation (above local load) from Zones A-E to downstate in many hours
- Bottlenecks are particularly pronounced in shoulder season, when load is lowest and renewable generation "surplus" is maximized
- Due to low loads, not all transmission constraints would lead to unmet load

Winter Season Transmission Bottlenecks



- Similar bottleneck patterns arise in winter
- Downstate Zones have more frequent hourly load deficits (before transfers) in winter due to increased loads

Summer Season Transmission Bottlenecks



- Transmission bottlenecks are not as pronounced during summer due to high loads in each zone
- Downstate zones have local load deficits (before transfers) in all hours of summer due to increased loads and decreased wind production

Options for Balancing Load and Generation

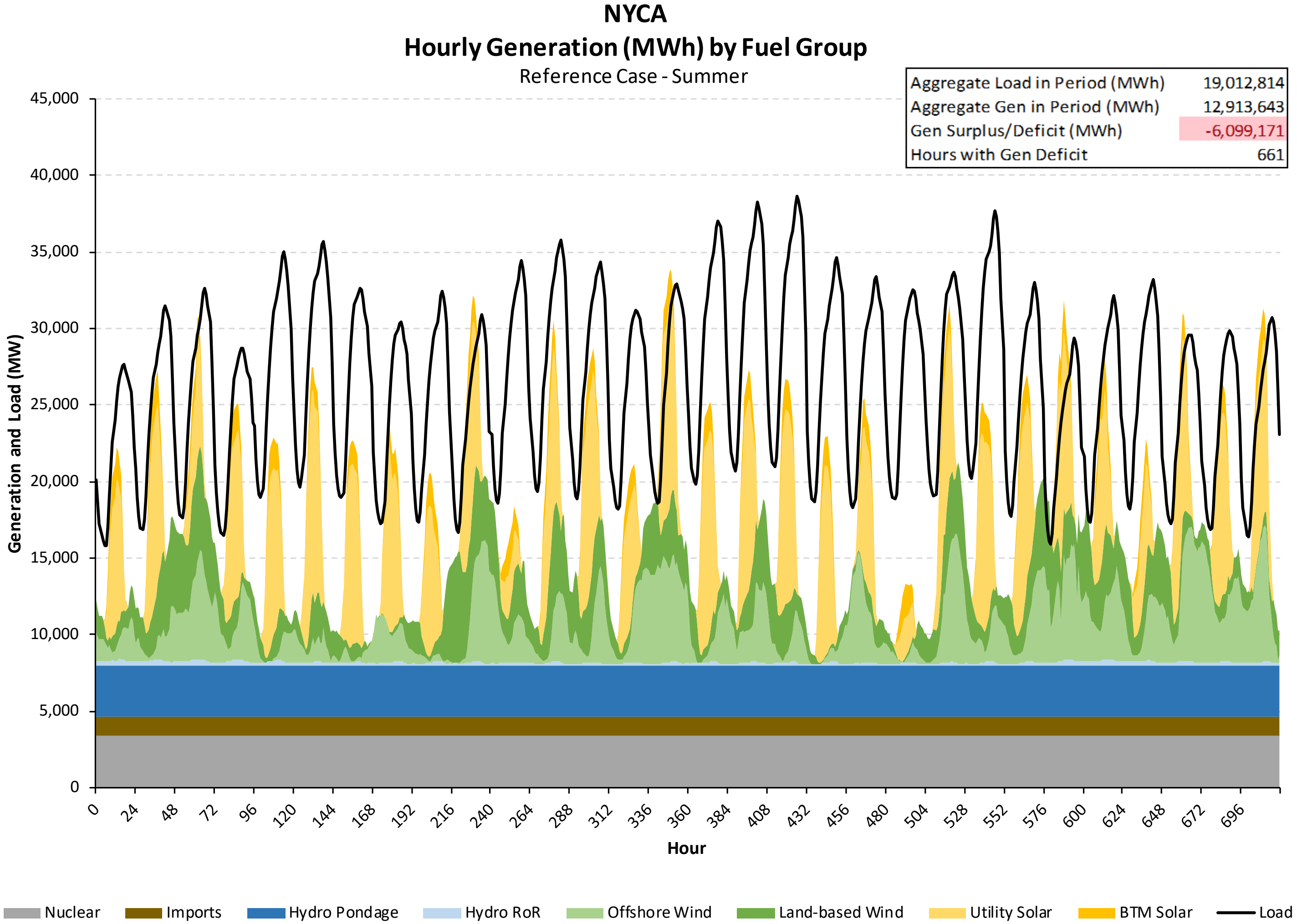
Development of Incremental Resource Options

- As expected, removal of dispatchable resources leads to major resource deficiencies in 2040, even with addition of significant MWs of variable renewable resources on top of 2020 system levels
  - Thus, the first step is to identify incremental “resource sets” for each load scenario constructed of combinations of generation, storage, transmission, and demand reshaping that achieve basic reliability in all seasons
  - Further analysis of climate scenarios and physical disruptions will be based on these “Reliable Starting Point” cases with incremental resource sets added

Resource Options Under Consideration

- Resource options each have different features; we identify combinations that mostly or fully address load loss outcomes, drawing from the following resources:
  - **Additional intermittent renewable generation**
    - Can reduce aggregate energy deficits, but will be vulnerable to low instantaneous output during low-wind, low-solar hours
  - **Additional transmission**
    - Reduces zonal bottlenecks but does not address aggregate energy deficits
  - **Additional low-carbon resources outside of NYCA requiring transmission (*e.g.*, resources in neighboring regions)**
    - Could in theory help with both energy and power, but availability and emissions characteristics uncertain
  - **Demand modulation through (1) additional demand response and (2) "shaping" of electrification loads**
    - Potential assistance with power deficits, but limited support for addressing aggregate energy deficits
  - **Additional energy storage**
    - Can meet instantaneous power needs but does not address aggregate energy deficits
  - **Generic dispatchable resources**
    - Can help with energy and power, but availability of zero-emission fuel source is speculative; location of assumed resources will matter given transmission constraints
- Development of incremental resource sets is path-dependent; adding additional generation may reduce need for transmission and vice versa
- The following slides show one approach to developing incremental resource sets starting with additional intermittent renewable generation and transmission. Other approaches could result in a different final resource mix

Summer Season Load and Generation Balance



Step 1: Increase Intermittent Resources

- Increasing intermittent resources alone will not meet load during all hours except at extreme quantities, due to lulls in wind production and limited hours of solar production in the Winter
- Additional intermittent resource additions will be modeled within upper bounds on NREL-calculated renewable technical potential in NY
- Preliminary resource additions double nameplate capacity of intermittent resources

Resource Type	NYISO Base	After Resource Additions	Technical Potential[1]
Land-Based Wind	8,761 MW	17,522 MW	35,200 MW
Offshore Wind	9,000 MW	18,000 MW	21,063 MW[2]
Grid-Connected Solar	19,631 MW	39,262 MW	1,350,000 MW[3]
BTM Solar	3,629 MW	7,258 MW	50,000 MW

Note:
[1] Technical Potential calculated by NREL for land-based wind and solar based on real-world geographic constraints and system performance, but not economics.
[2] Technical Potential calculated from BOEM and DOE data assumes maximum 3 MW/km^2 wind capacity installed in 7,021 km^2 New York Bight Lease Areas.
[3] Technical Potential calculated by NREL for grid-connected solar is an extreme upper bound given land use assumptions, and is likely infeasible in practice.

Sources:
[1] NREL, Estimating Renewable Energy Economic Potential in the United States: Methodology and Initial Results, August 2016, Appendices A and F.
[2] NREL, Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment, January 2016.
[3] Bureau of Ocean Energy Management, New York Bight, available at https://www.boem.gov/renewable-energy/state-activities/new-york-bight.
[4] Department of Energy, Computing America's Offshore Wind Energy Potential, September 9, 2016.

Step 1: Increase Intermittent Resources

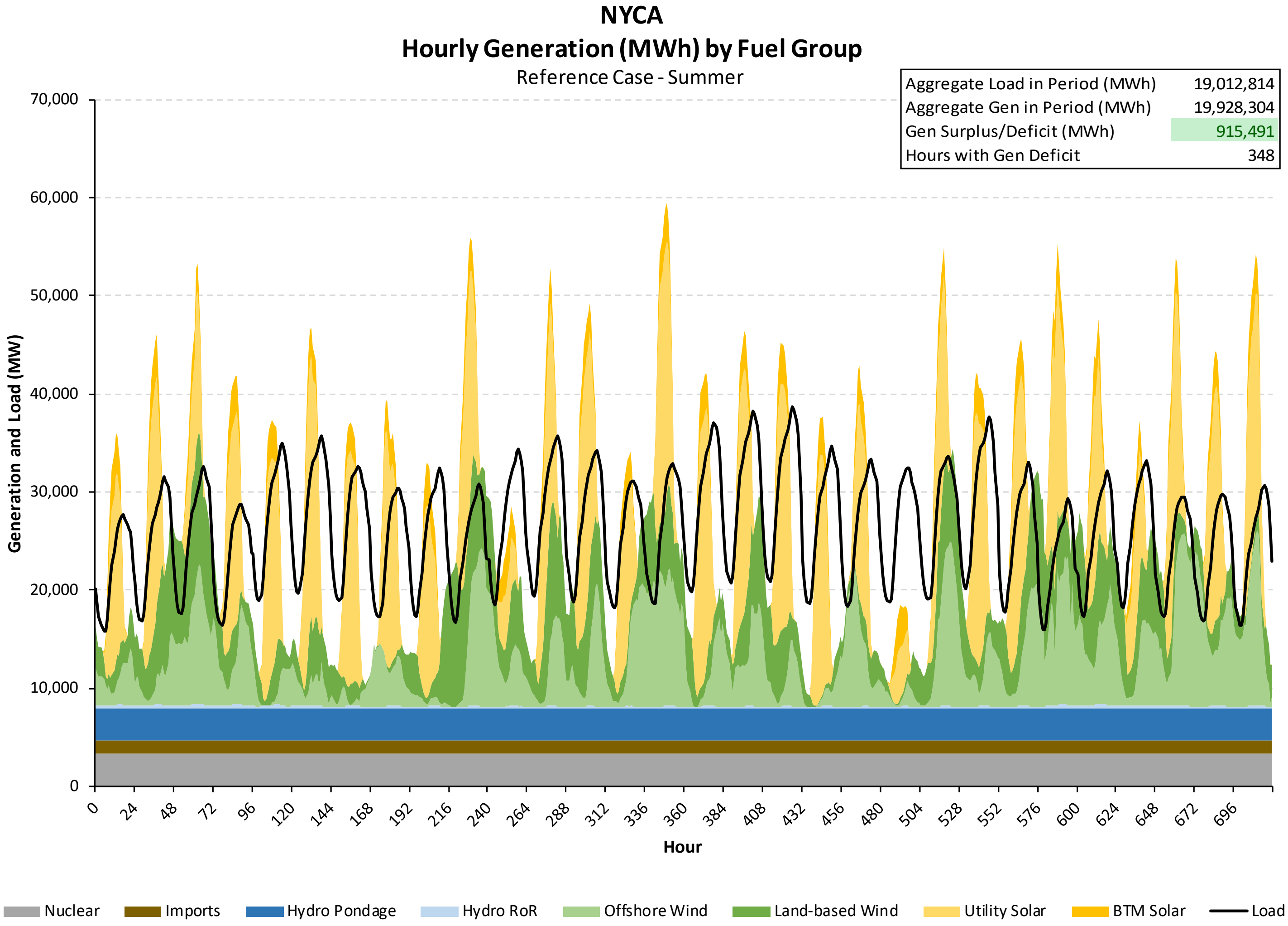
- Preliminary resource additions assume same location and generation profiles for intermittent resources by zone, but double nameplate capacity

Nameplate Capacity by Zone, MW

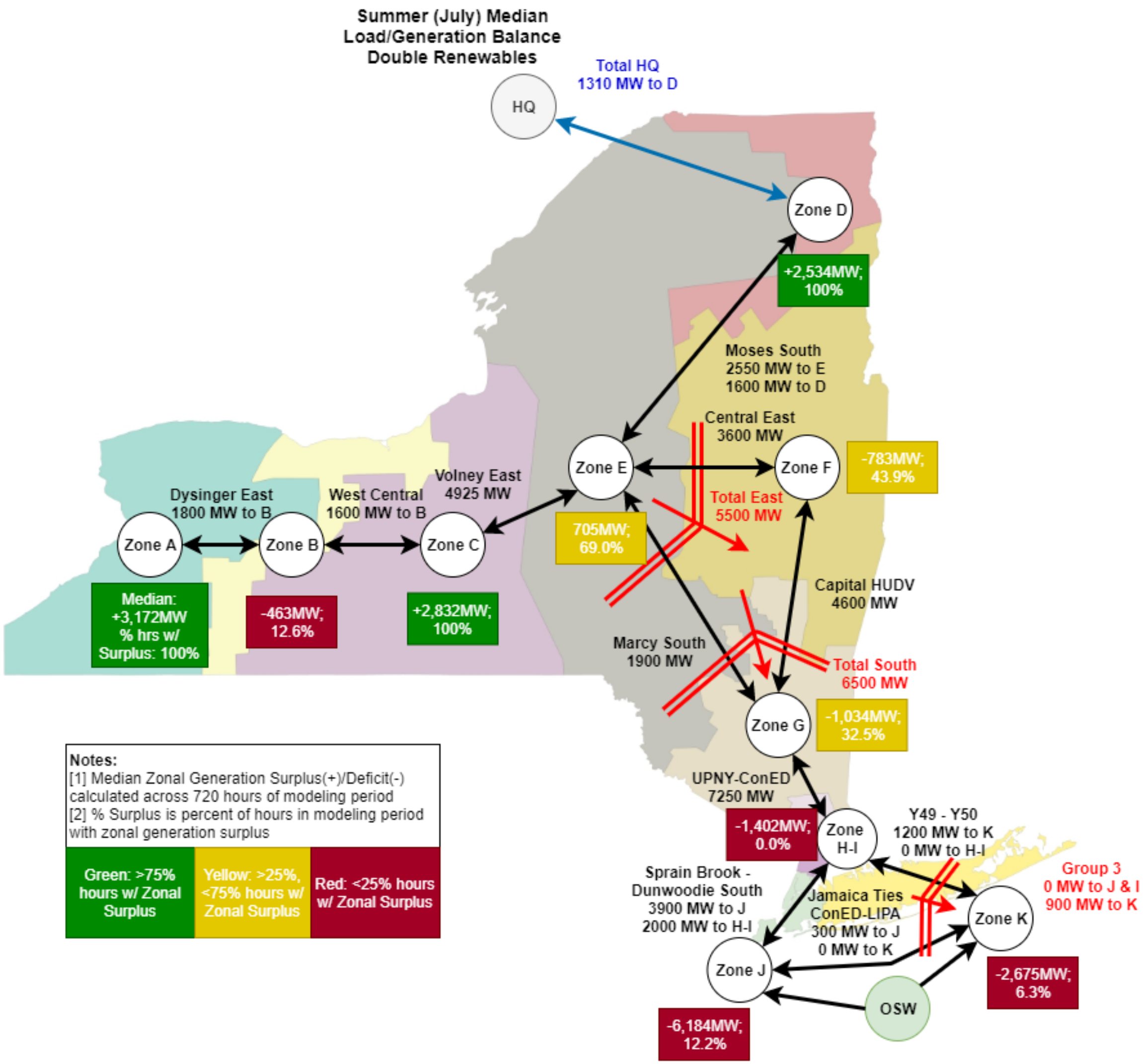
Initial Reference Case Resources	A	B	C	D	E	F	G	H	I	J	K	NYCA Total
Land-based Wind	2,692	390	1,923	1,935	1,821	-	-	-	-	-	-	8,761
Offshore Wind	-	-	-	-	-	-	-	-	-	6,391	2,609	9,000
Grid-Connected Solar	5,748	656	3,585	-	2,268	4,661	2,636	-	-	-	77	19,631
BTM Solar	470	146	398	46	449	552	456	40	60	448	565	3,629

Proposed Resources after Additions	A	B	C	D	E	F	G	H	I	J	K	NYCA Total
Land-based Wind	5,384	780	3,846	3,870	3,642	-	-	-	-	-	-	17,522
Offshore Wind	-	-	-	-	-	-	-	-	-	12,783	5,217	18,000
Grid-Connected Solar	11,496	1,312	7,170	-	4,536	9,322	5,272	-	-	-	154	39,262
BTM Solar	940	291	796	92	898	1,103	912	81	120	896	1,129	7,258

Summer 2040 Load and Generation Balance with Additional Intermittent Resources



Initial Summer Season Transmission Bottlenecks



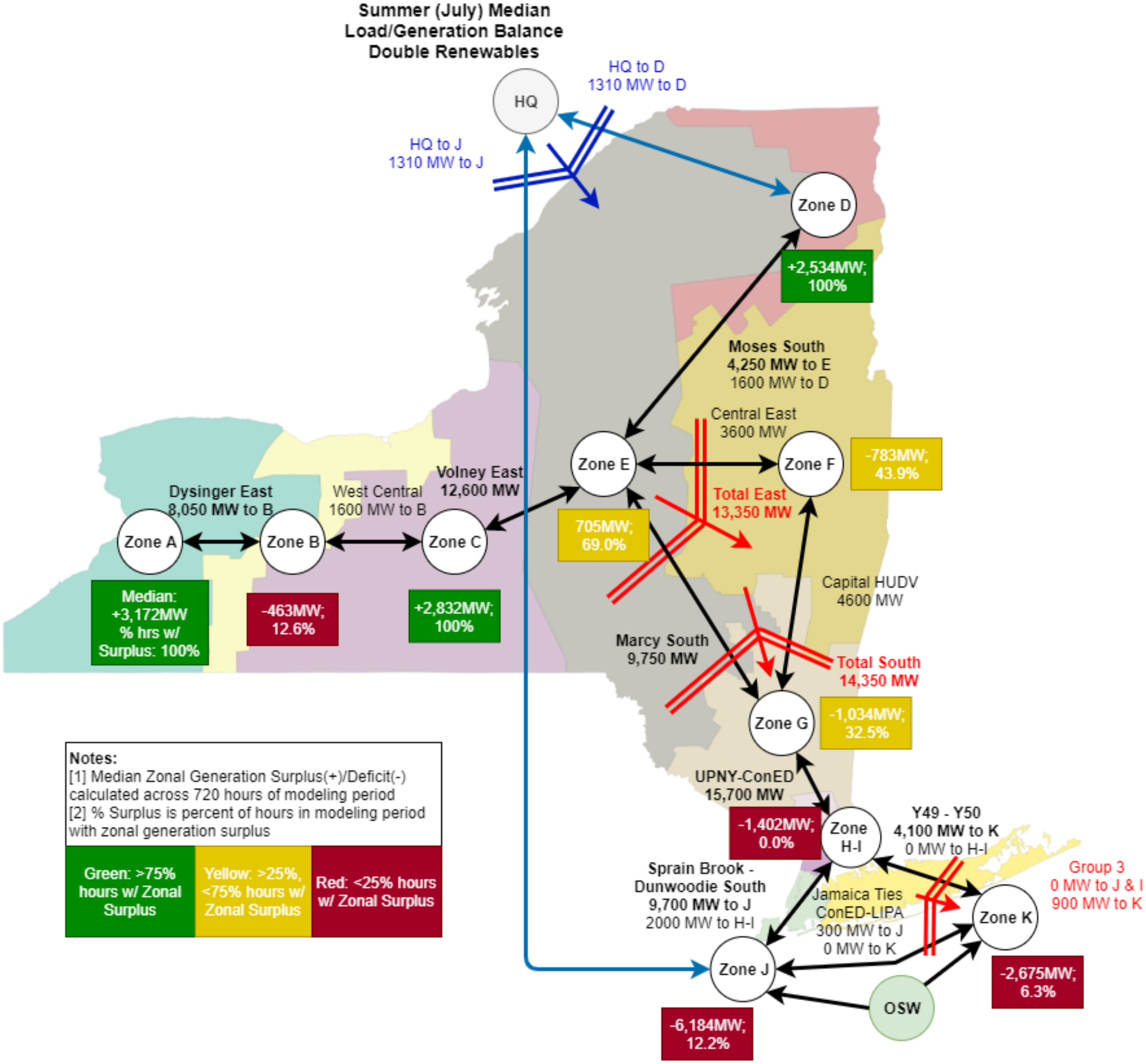
- Transmission constraints are somewhat alleviated by double intermittent generation, but would still bind in many hours and lead to losses of load

Step 2: Reduce Transmission Constraints

- Inter-zonal transmission limits will limit intermittent resources' ability to meet zonal deficits due to line congestion
- During summer period, current transmission limits would result in an average of 2,529 MW of load unable to be met per hour (~10% of total NYCA load) due to binding transmission limits.
- Significant transmission increases would be needed to alleviate the majority of constrained hours

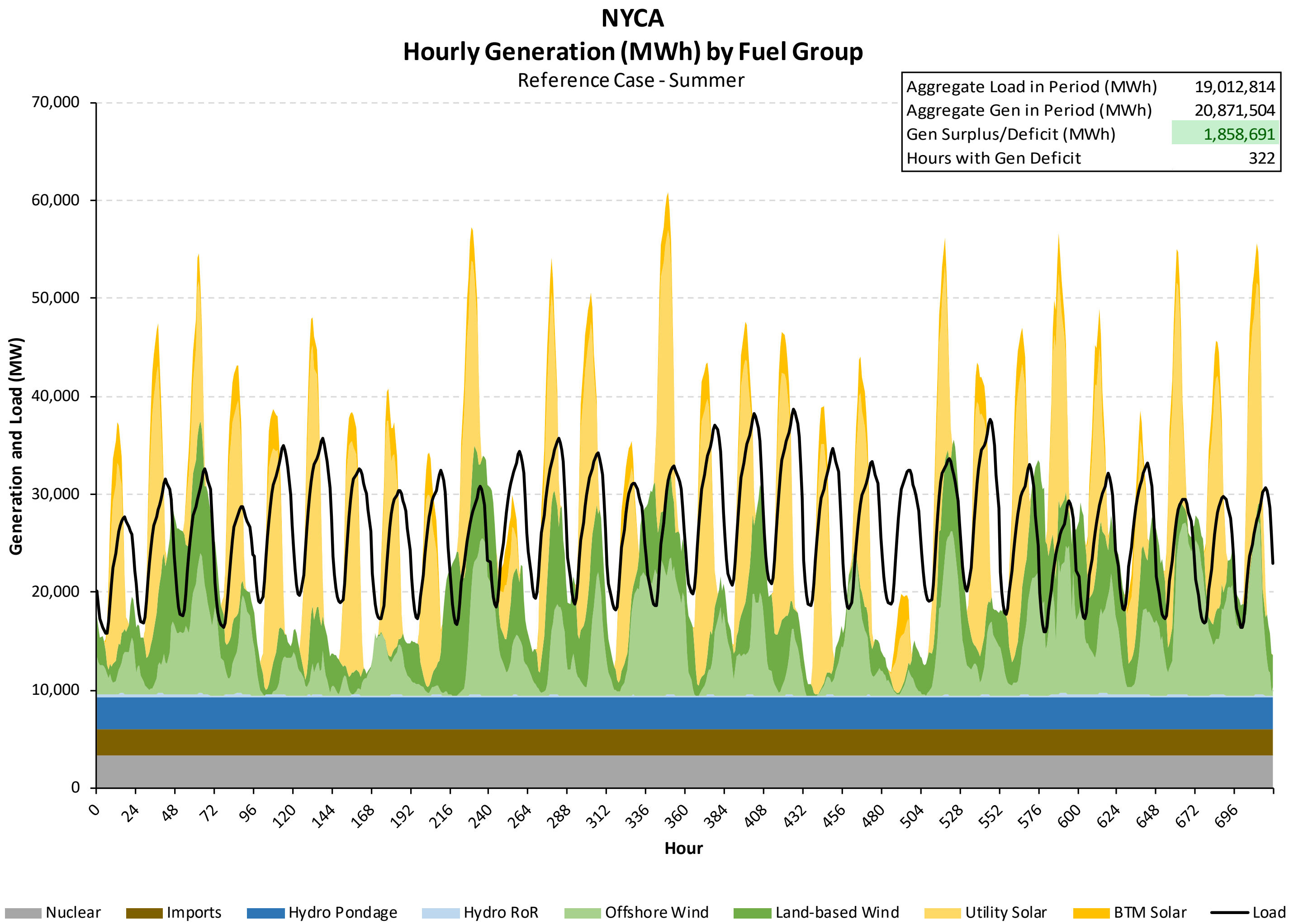
		MW limit required to meet % of constrained hours w/ load losses		
Line	**Current limit**	**70%**	**90%**	**100%**
I to J	3,900 MW	8,500 MW	9,700 MW	11,100 MW
I to K	1,200 MW	3,250 MW	4,100 MW	5,850 MW
E (to F) to G	5,500 MW	10,450 MW	13,350 MW	15,750 MW
G to H	7,250 MW	13,350 MW	15,700 MW	17,500 MW
C to E	4,925 MW	9,950 MW	12,600 MW	14,100 MW
D to E	2,550 MW	3,750 MW	4,250 MW	5,000 MW
A to B	1,800 MW	5,400 MW	8,050 MW	10,400 MW

Summer Load and Generation Balance w/ Additional Transmission



- Transmission lines are updated to meet 90% of transmission constraints that would lead to load losses
- Additionally assumes a doubling of transmission to zero-carbon resources in Canada, here represented as a direct connection between Canada and Zone J

Summer 2040 Load and Generation Balance with Additional HQ Imports

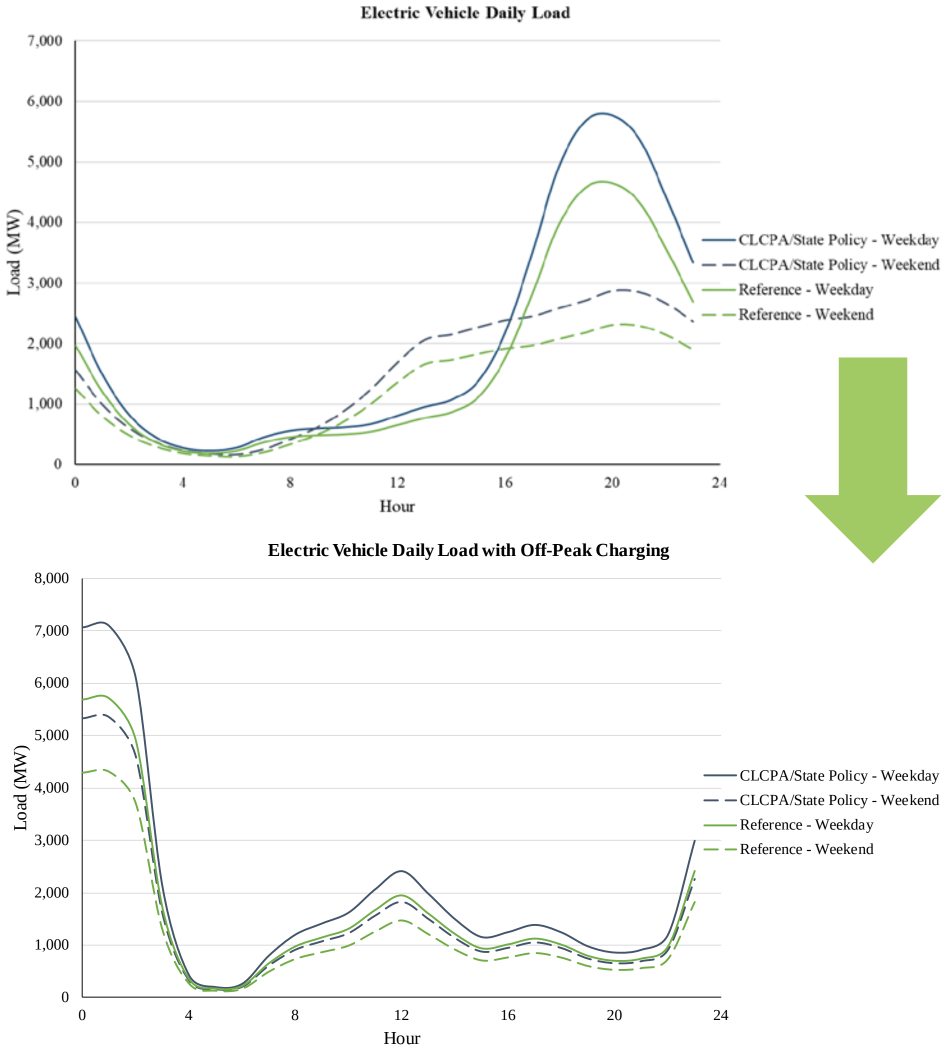


Step 3: Managed Load

- Active load management (time-shifting of load) has potential to reduce peaks and synchronize demand with solar output
- For example, time-of-use rates and smart metering can move electric vehicle charging load from evening to night-time and solar peak hours
- Load management has follow-on effect reducing need for battery storage capacity
- Potential to reshape assumed building electrification load as well

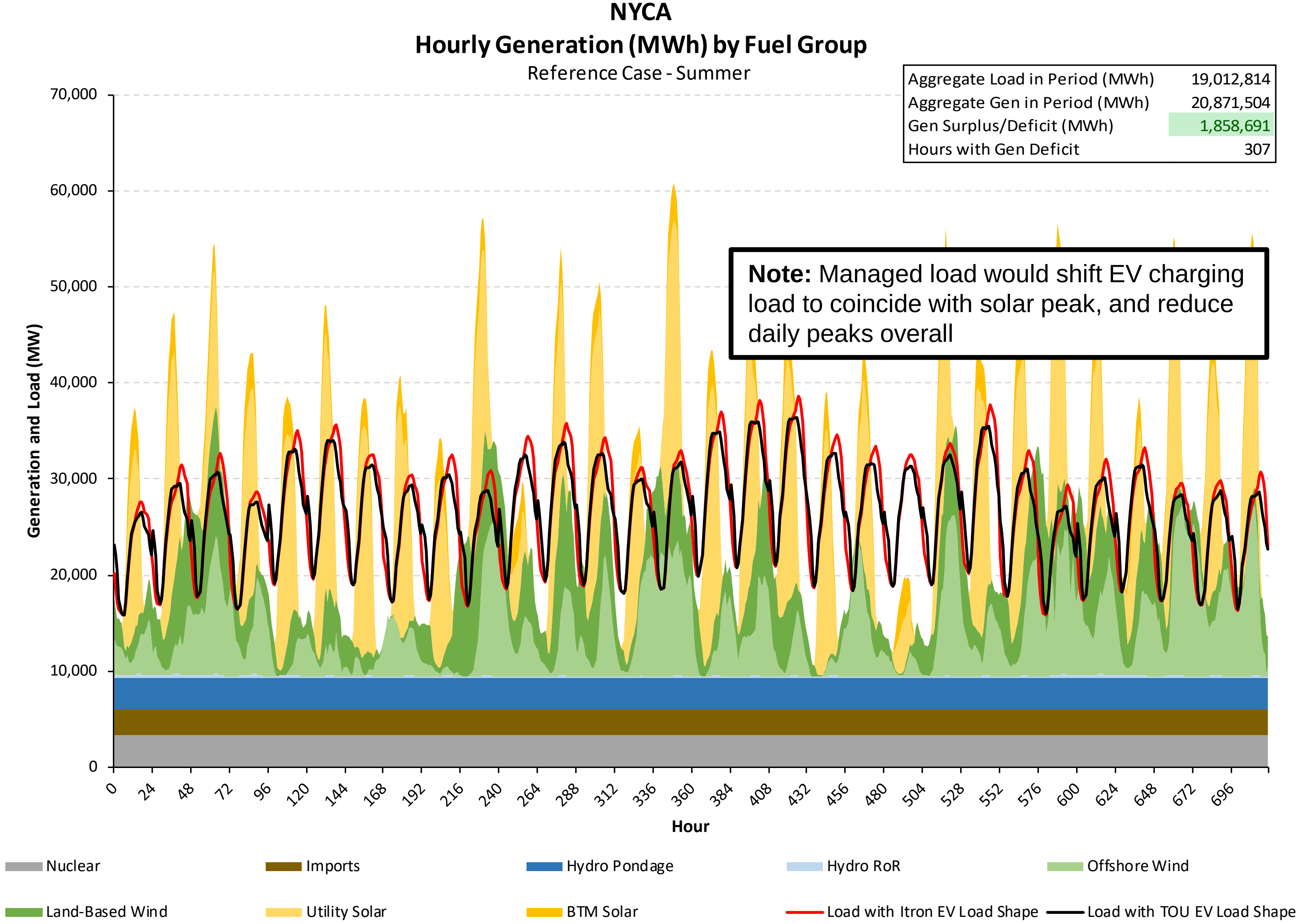
Step 3: Managed Load

- Proposed reshaping of EV load based on NYSERDA study of plug-in electric vehicle charging
- Total energy for EV charging is unchanged, but timing is altered to peak during night time instead of evening

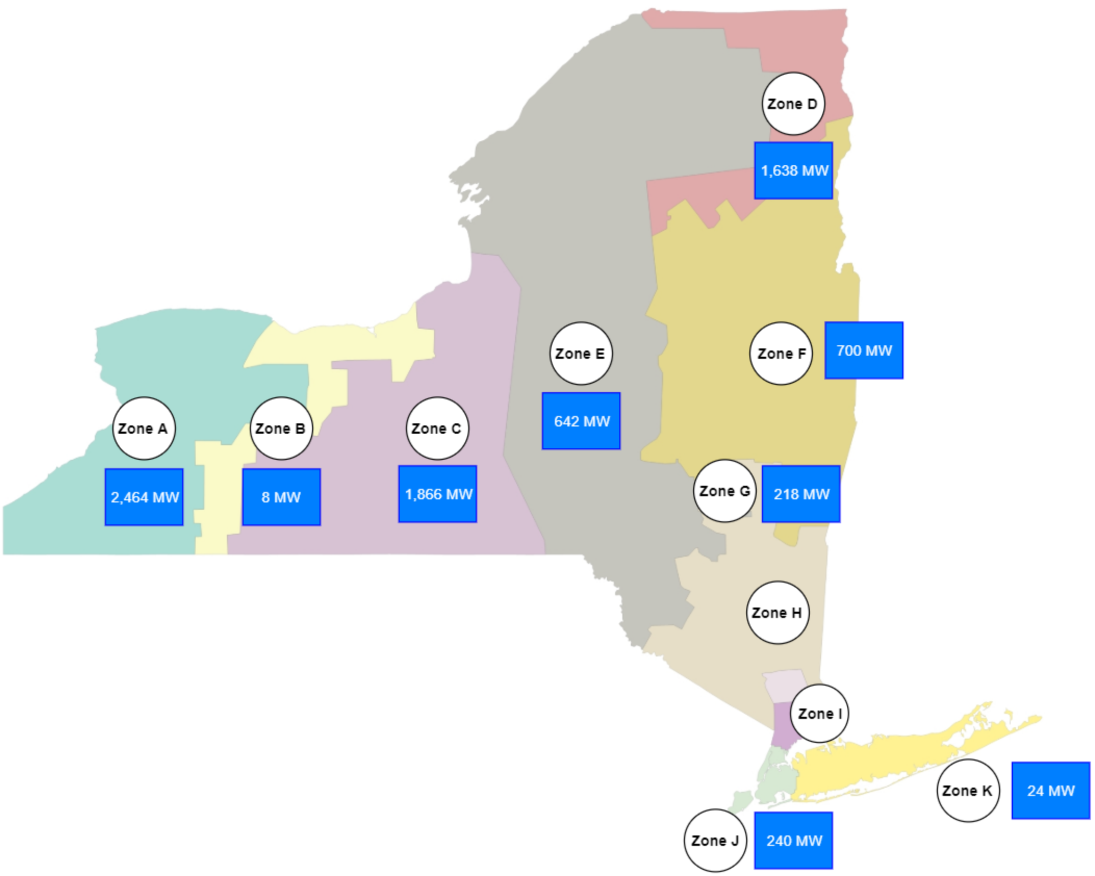


Source:
[1] NYSERDA, Electricity Pricing Strategies to Reduce Grid Impacts from Plug-in Electric Vehicle Charging in New York State, June 2015

Summer 2040 Load and Generation Balance with Managed Electric Vehicle Load



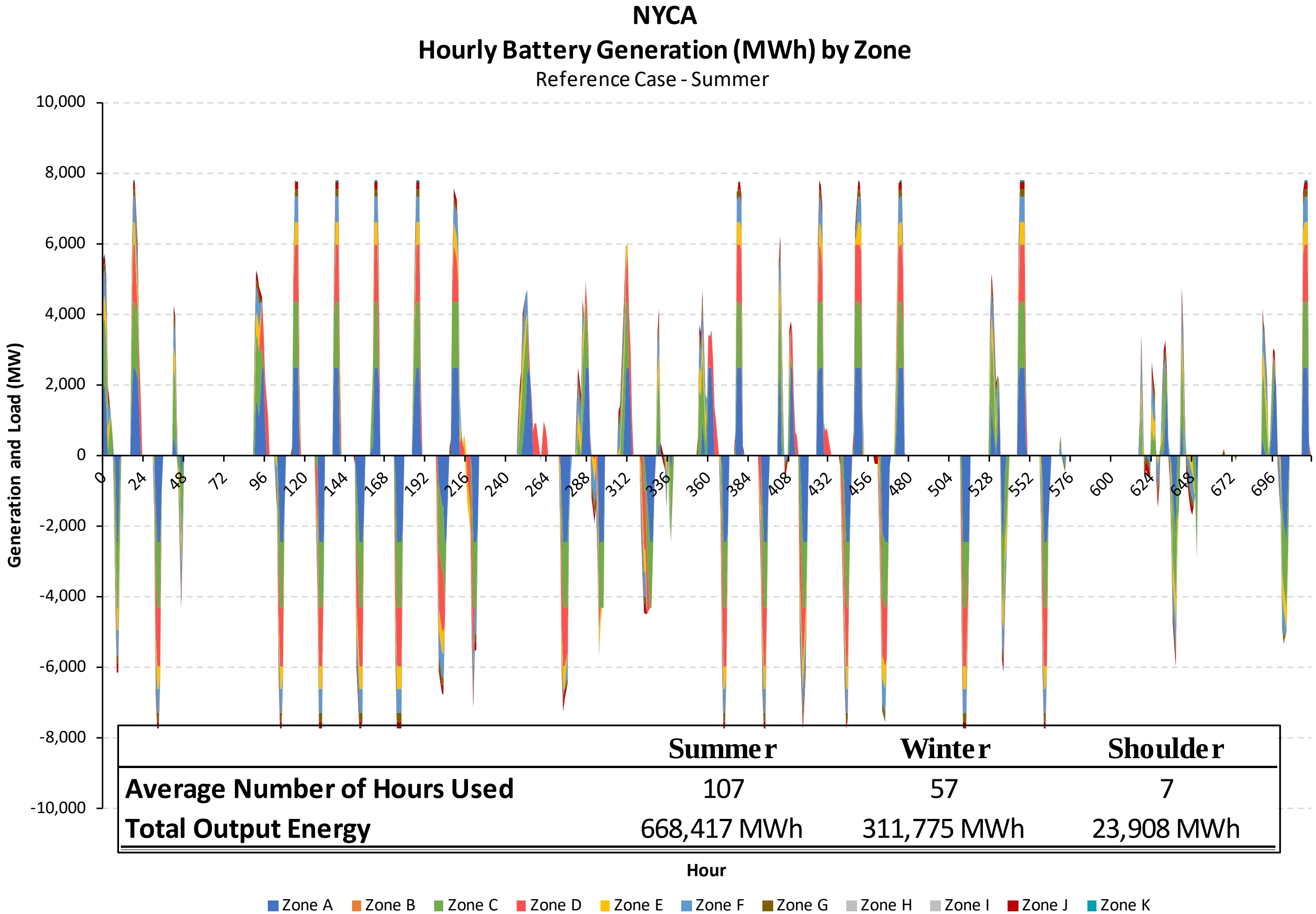
Step 4: Additional Batteries with Modified Location



- Batteries are zonally distributed proportional to excess renewable generation; assumed increases in transmission capability
- Located near generation to optimize transmission usage; transmission is used to move solar power during daytime and battery power during evening and night
- Battery storage nameplate capacity is doubled from 3,900 MW to 7,800 MW across NY
- Future analyses will examine the impact of different battery storage locations

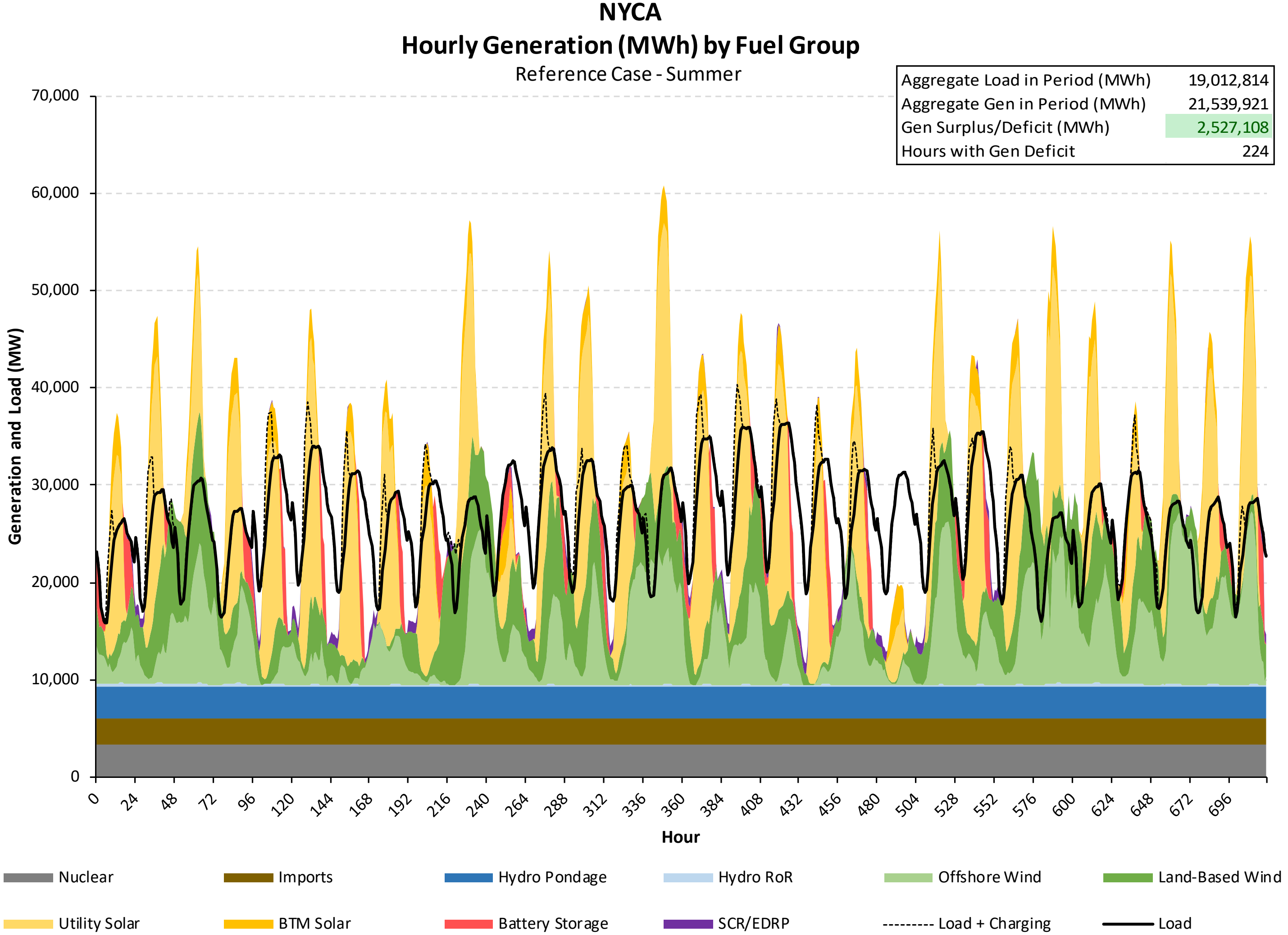
Battery Energy Storage Results

- On average, each battery is used 27 days of the summer modeling period



	Summer	Winter	Shoulder
Average Number of Hours Used	107	57	7
Total Output Energy	668,417 MWh	311,775 MWh	23,908 MWh

Summer 2040 Load and Generation Balance with Battery Storage Usage



Step 5: Add Generic Dispatchable Resources as Needed

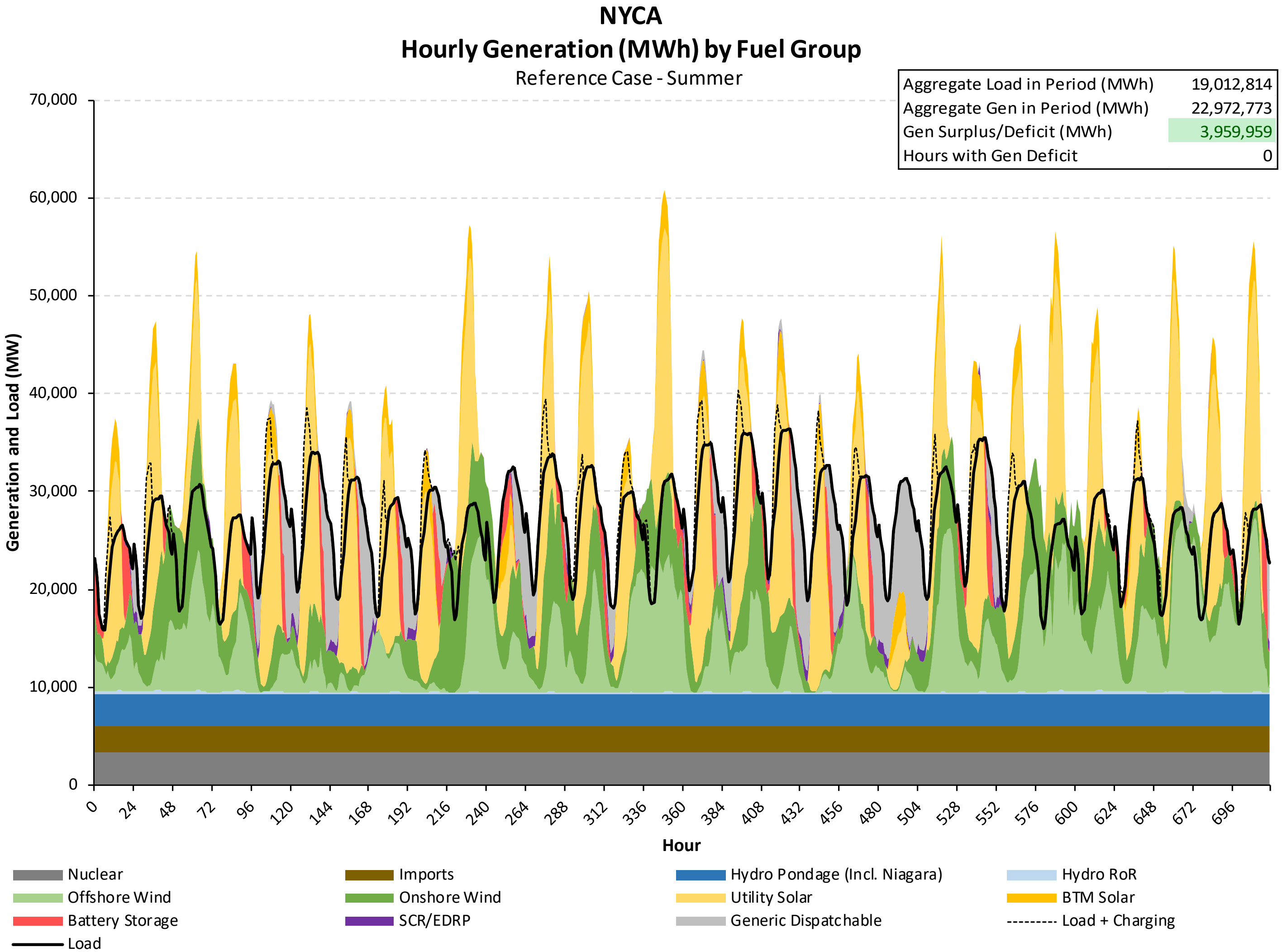
- Generic dispatchable generation will be the final resource added to meet deficits
  - Assume there is ~19,000 MW of natural gas and 3,400 MW of #2 fuel oil resources convertible to operate on a net-zero GHG basis (based on existing thermal resource capacities and locations)
- During peak days in the summer with low wind production, almost all of the capacity is operating; some dispatchable generation needed for 39% of summer hours
- For illustration, we compare fuel needs with rough estimates of low-GHG fuel potential

	From Model	MW Existing Convertible Plants	
Max Capacity (Summer)	16,513 MW	22,471 MW	73.5%

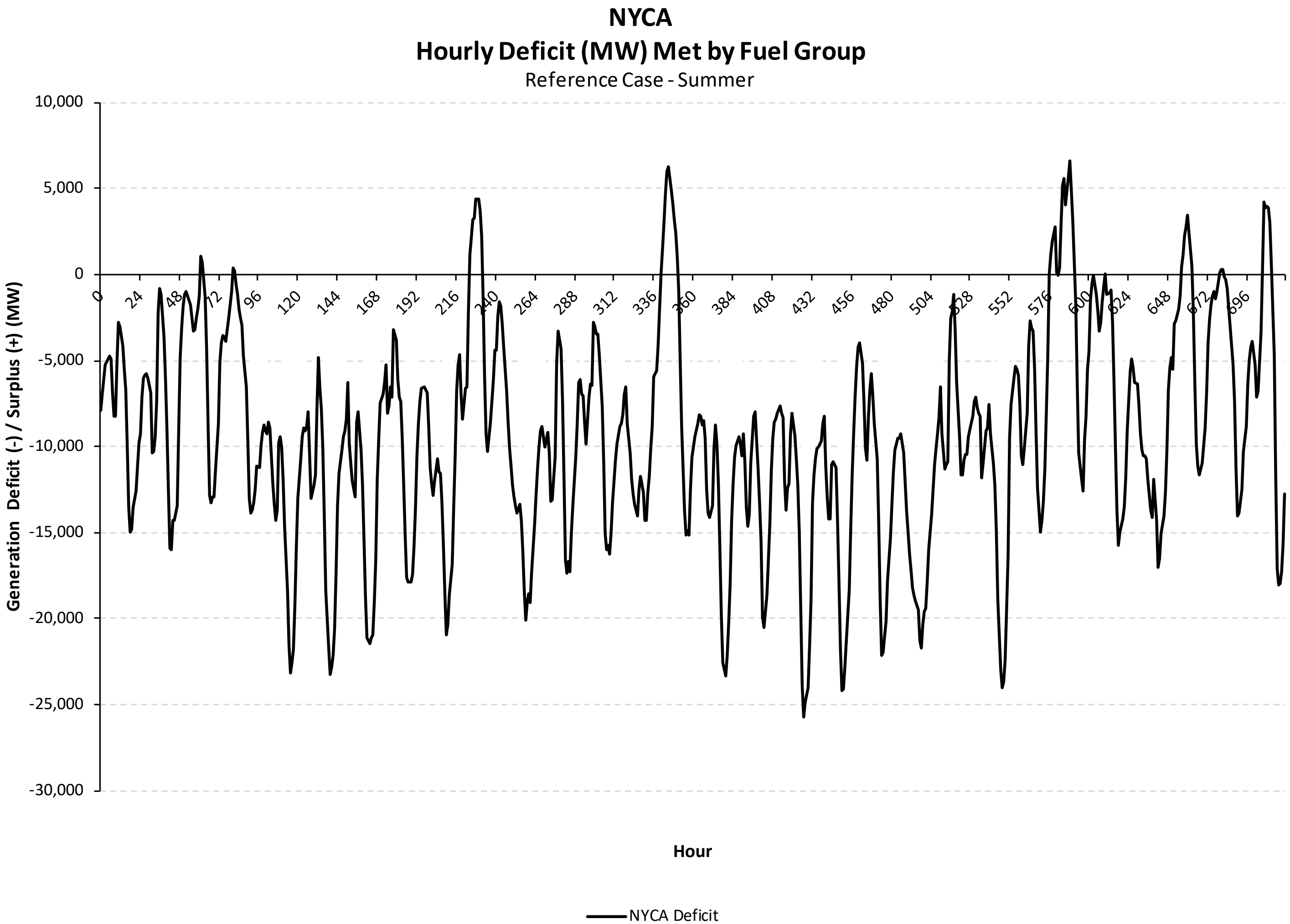
	Summer	Winter	Shoulder
Number of Hours Needed	281	64	0
Maximum Consecutive Hours of Generation Needed	41	12	0
Total Generic Dispatchable Energy [A]	1,432,852 MWh	136,521 MWh	0 MWh
RNG Potential [B]	242,521 MWh	242,521 MWh	242,521 MWh
Hydrogen Potential [C] (from excess renewables)	724,836 MWh	1,672,714 MWh	3,427,762 MWh
Net Energy [D = C + B - A]	-465,494 MWh	1,778,714 MWh	3,670,283 MWh

Sources:
[1] American Gas Foundation, The Potential for Renewable Gas: Biogas Derived from Biomass Feedstocks and Upgraded to Pipeline Quality, September 2011.
[2] National Grid, Renewable Gas — Vision for a Sustainable Gas Network, 2010.

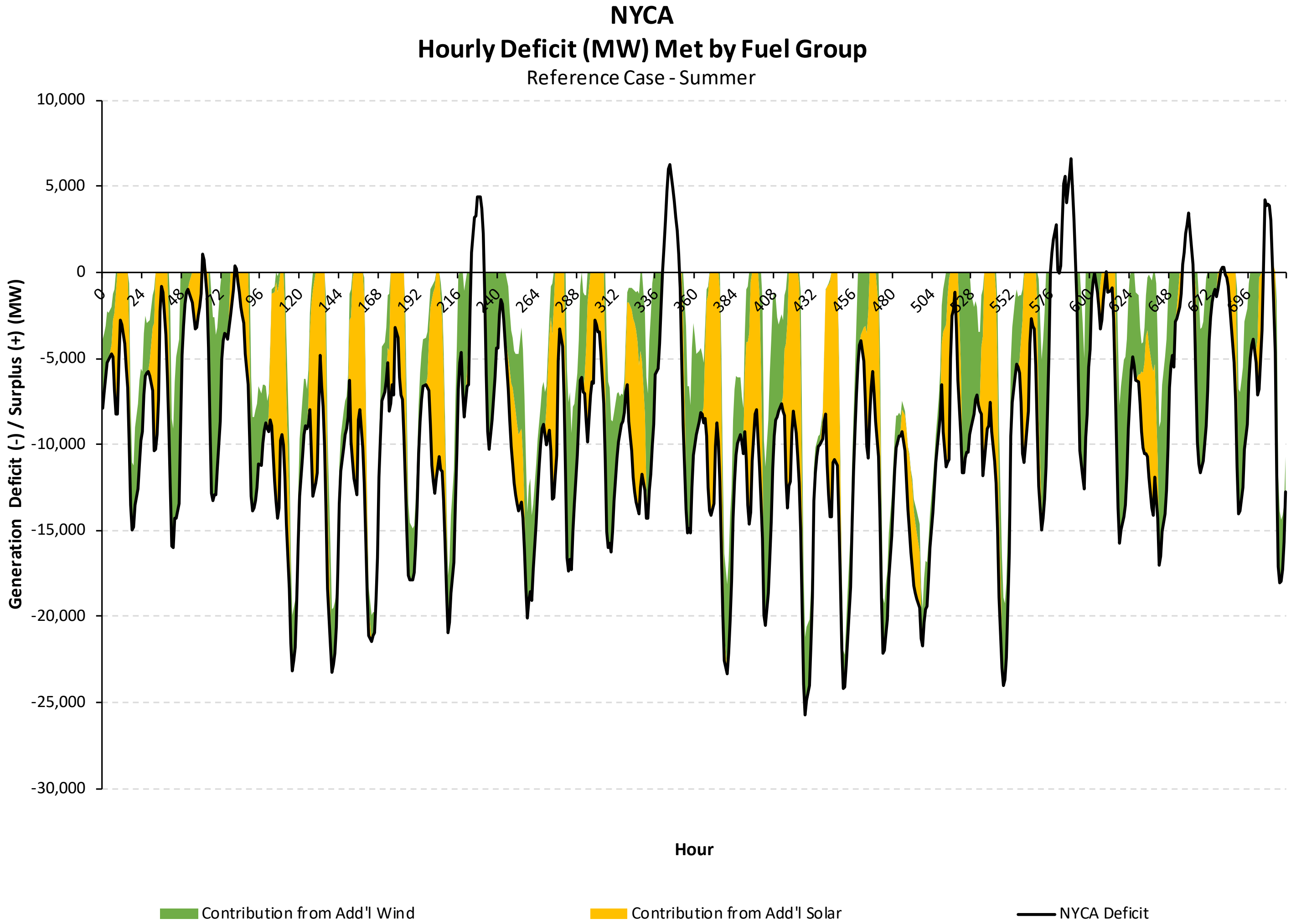
Summer 2040 Load and Generation Balance with Generic Dispatchable Resources



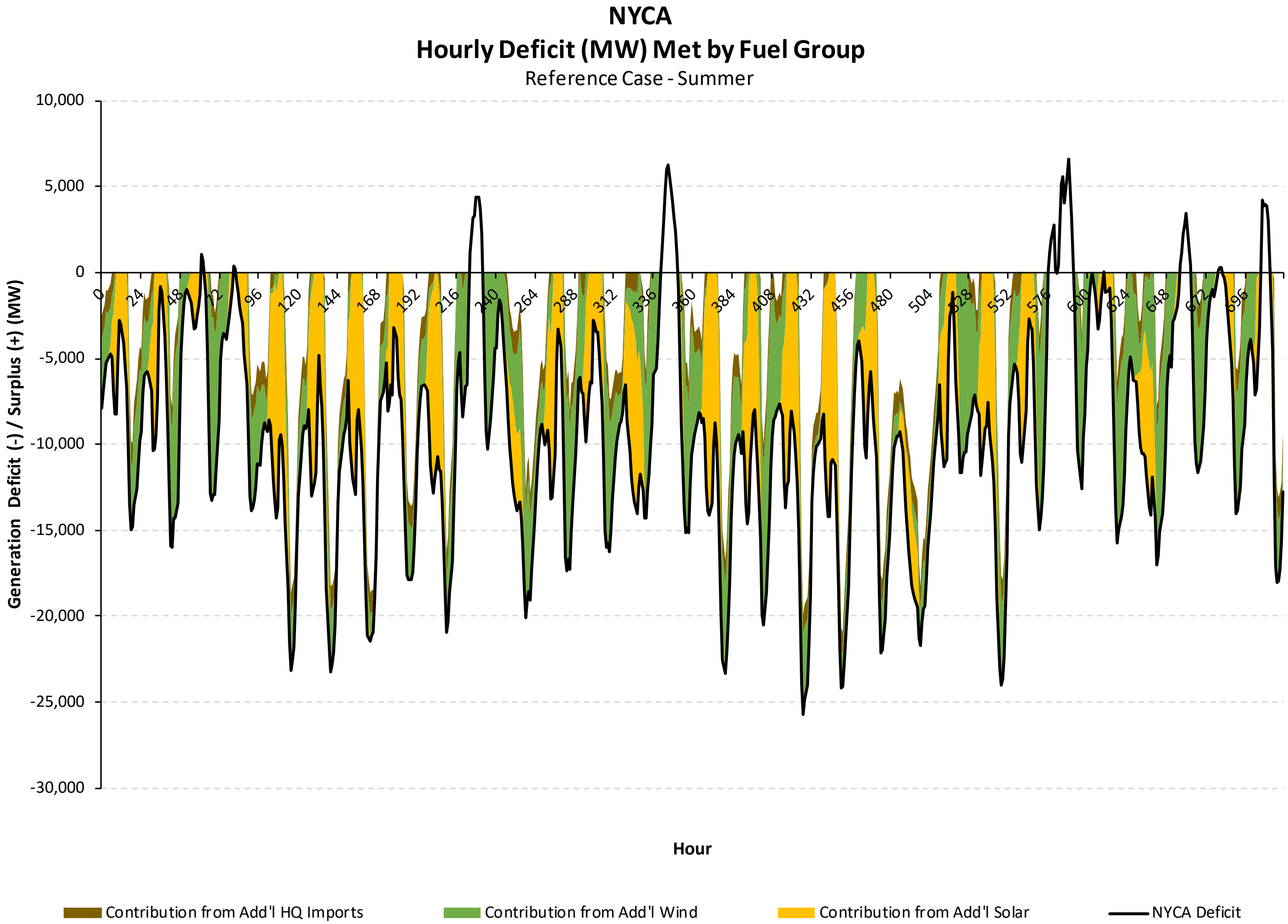
Summer Season Hourly Deficit



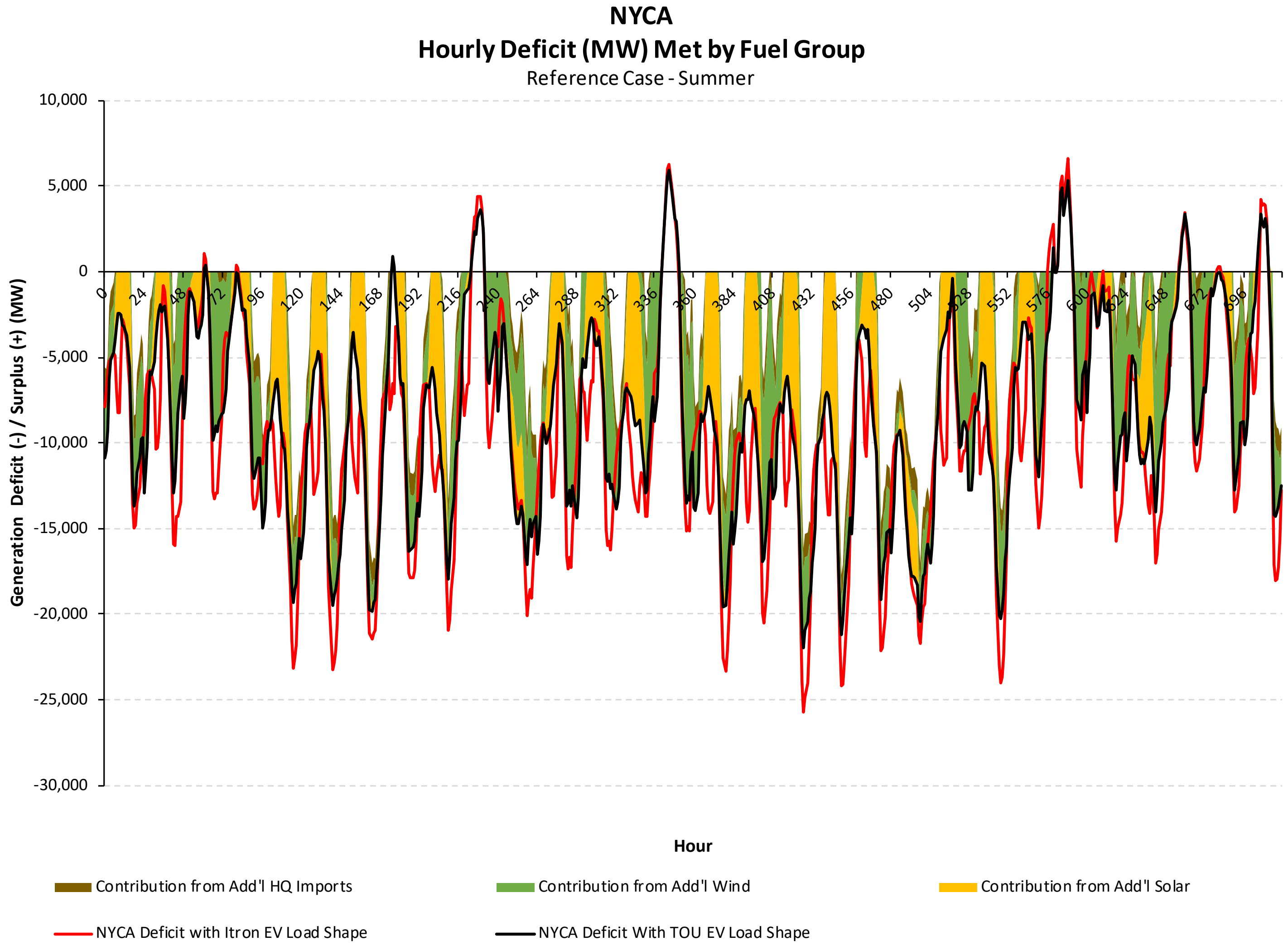
Summer 2040 Hourly Deficit Met with Additional Intermittent Resources



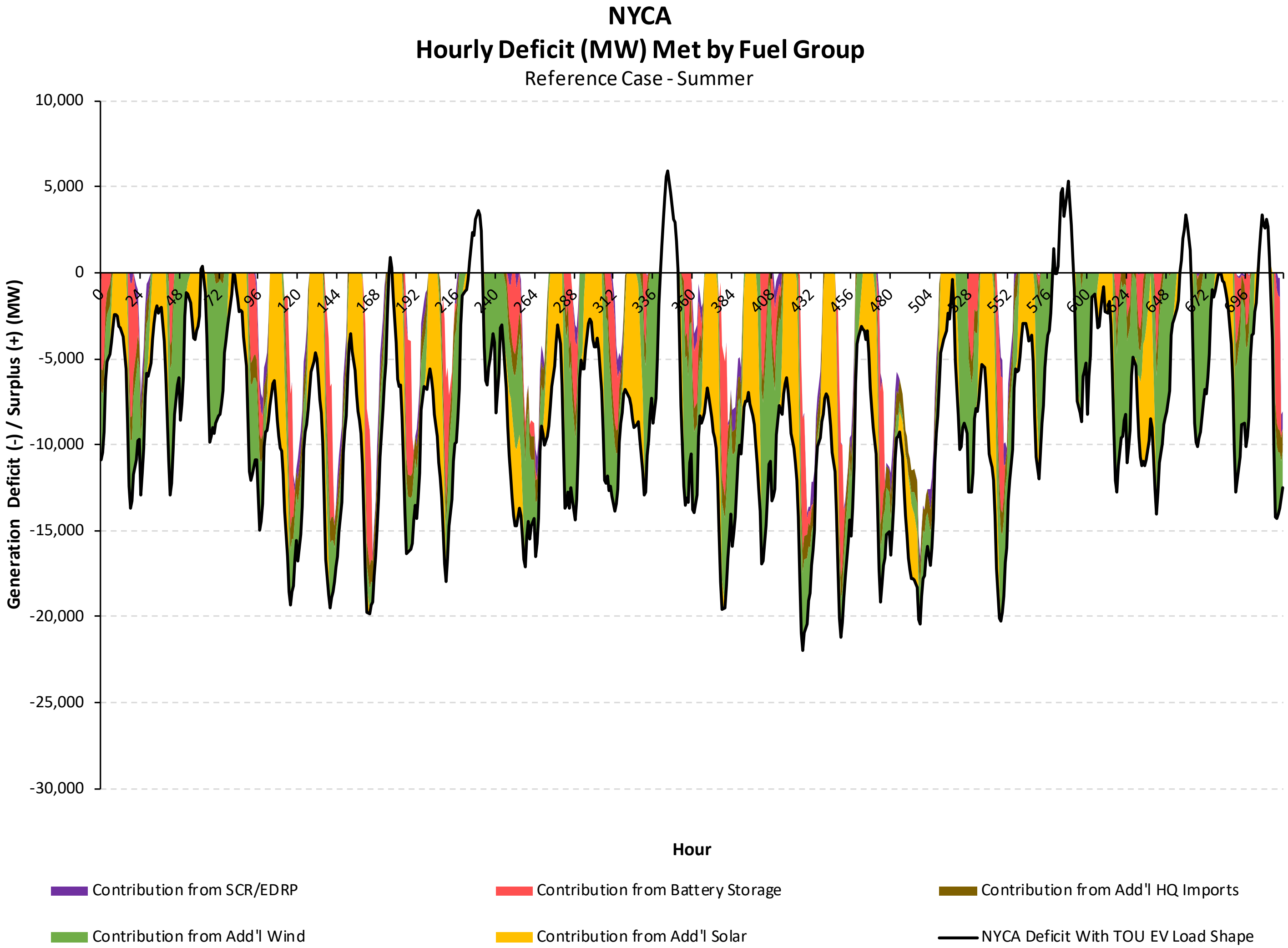
Summer 2040 Hourly Deficit Met with Additional HQ Imports



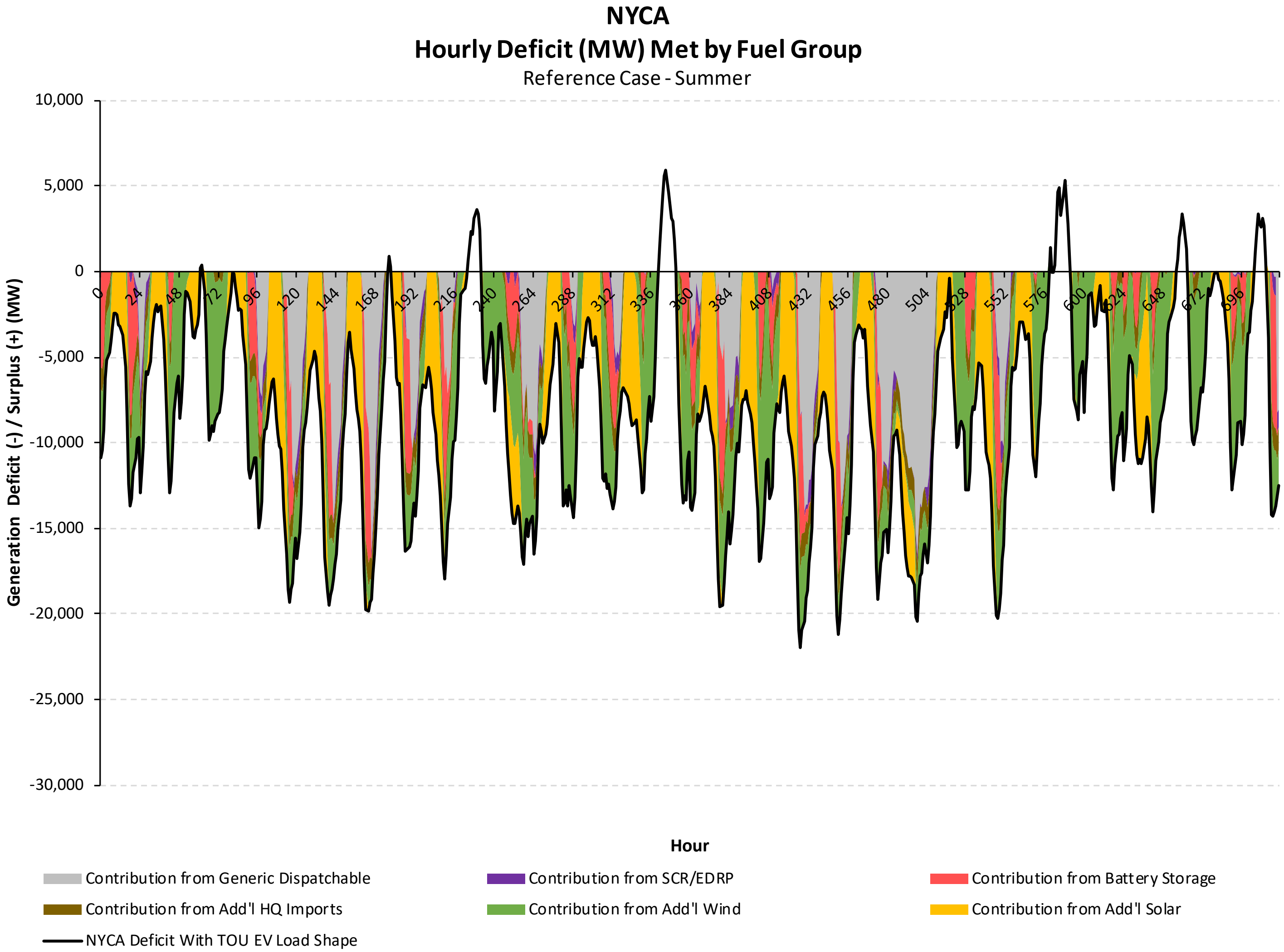
Summer 2040 Hourly Deficit Met with Managed Electric Vehicle Load



Summer 2040 Hourly Deficit Met with Battery Storage Usage



Summer 2040 Hourly Deficit
Met with Generic Dispatchable Resources



Reference Case Reliable Starting Point Results

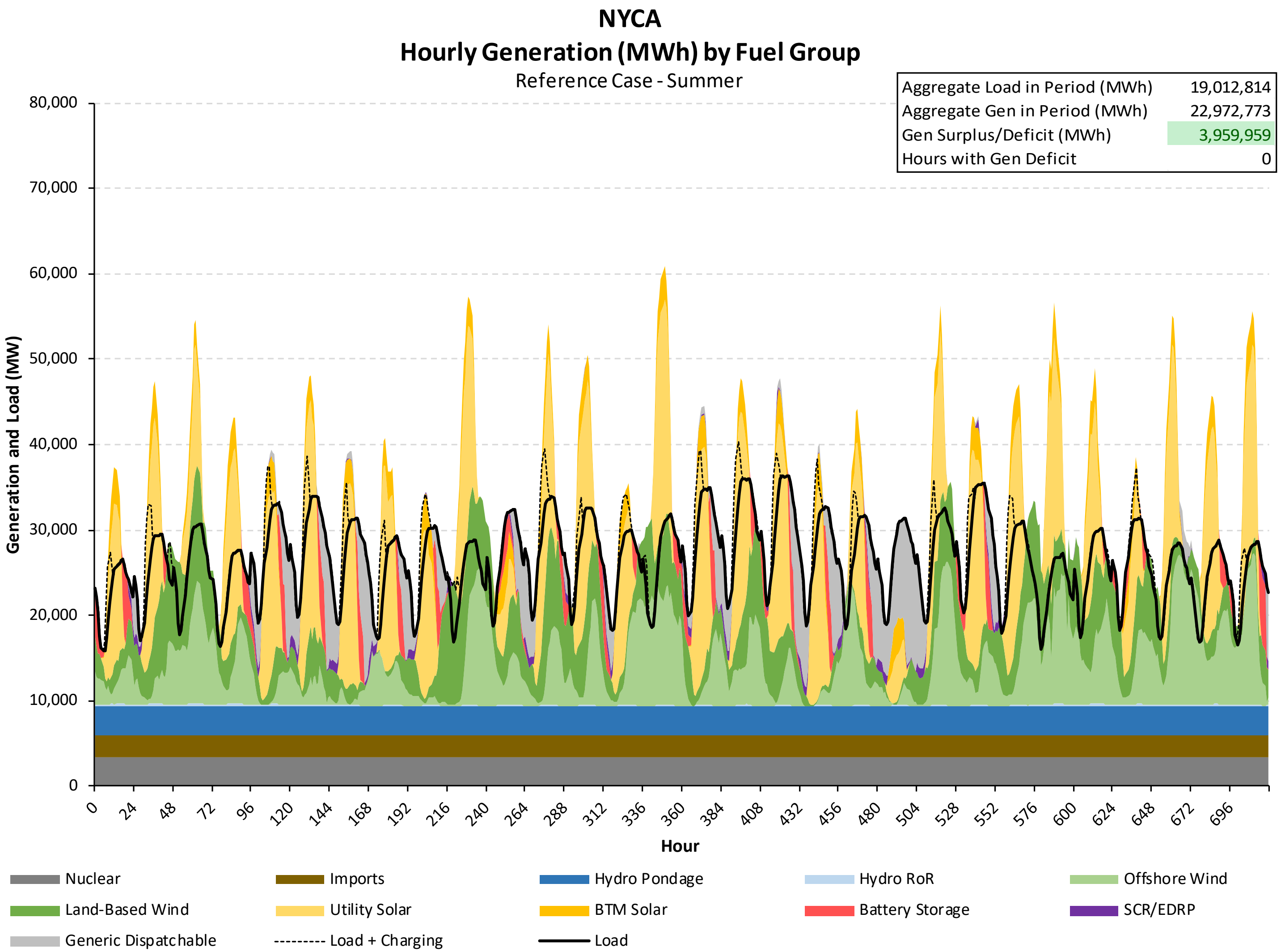
Overview of Reference Case Reliable Starting Point

- Reminder: Reference Case assumes 2040 load from Phase 1 study and resource mix similar to CARIS 2019 Phase 1 “70x30” case, adjusted for potential 2040 conditions
- We added generation, transmission, and load response resources well above current expectations to develop a Reliable Starting Point
  - Reliable Starting Point requires balance of additional resource options
  - Developed resource set represents *one* way to address imbalances in both instantaneous power (i.e. peak summer load) and aggregate energy
  - In particular, assumptions about transmission have large impact on how well other types of resources can meet load/generation imbalances
- Resource set results in excess intermittent generating capacity in winter and shoulder modeling periods (in much the same way that fossil resources operate at less than full capacity across the year)
- This construct is a starting point from which to review more stressed system conditions tied to expanded electrification and the impact of climate change on load and resource operations
- All results are preliminary and subject to final audits; construct is a work-in-progress

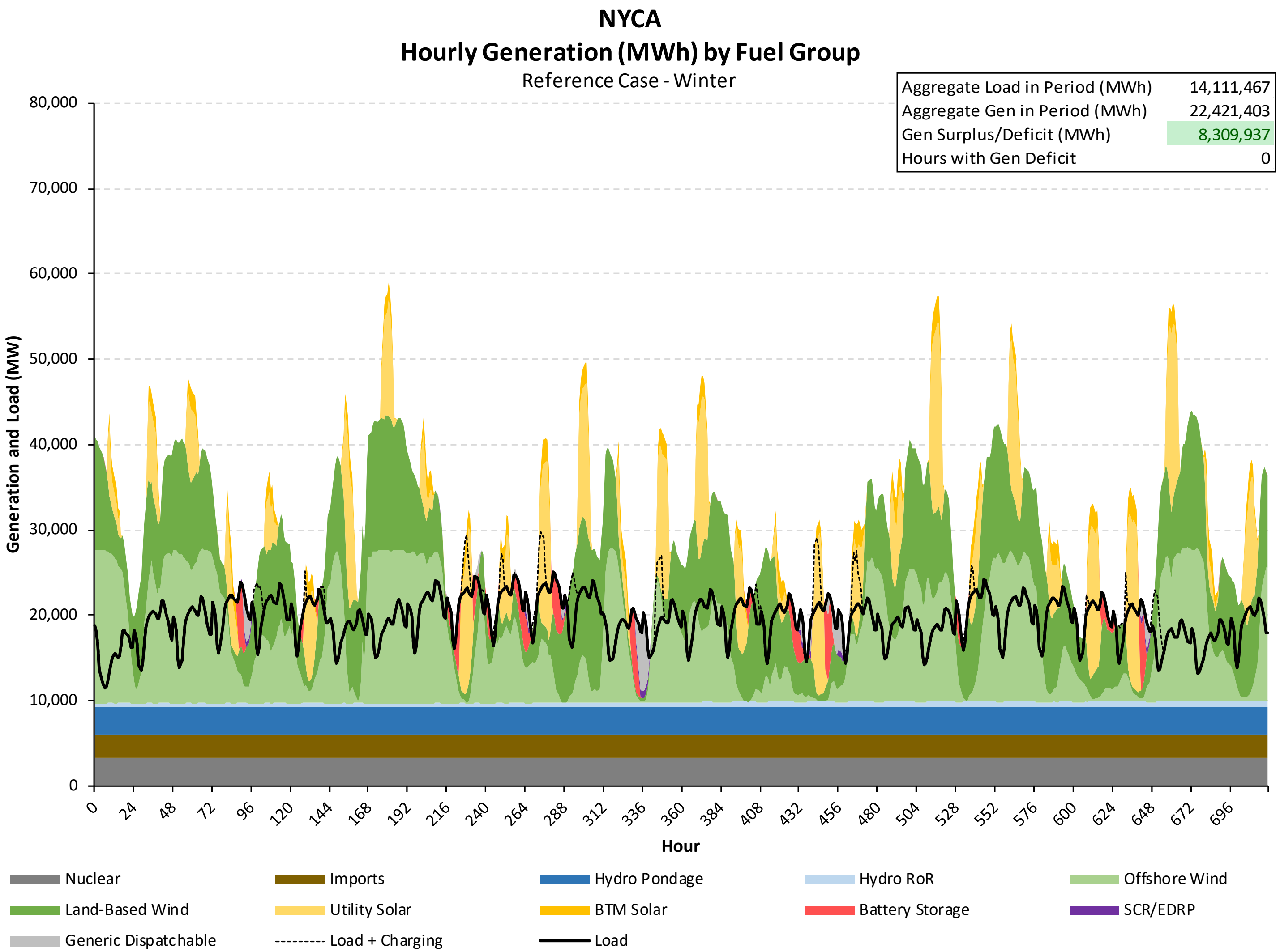
Overview of Reference Case Reliable Starting Point

Case/Stage	Load	Resources
Reference Case Itron Climate Impact Phase 1 CARIS 2019 Phase 1 70 by 30 Case CLCPA Targets	**Itron Phase 1 - Reference Case** 0.7 F increase per decade 2,200 GWh per year in energy efficiency EV penetration from 2019 Gold Book (13,200 GWh)	**No Fossil Fuel Units** 3,629 MW of BTM Solar 19,631 MW of Grid-Connected Solar 8,761 MW of Land-Based Wind 3,364 MW of Nuclear 4,246 MW of Hydro 9,000 MW of Offshore Wind (2035) 3,900 MW of Battery Storage (3,000 MW by 2030)
Reference Case **(Reliable Starting Point)**	**Reference Case Load** Including Load Reshaping due to EV Time of Use Rates	**Plus Additional Resources** 3,629 MW of BTM Solar (Total 7,258 MW) 19,631 MW of Grid-Connected Solar (Total 39,262 MW) 8,761 MW of Land-Based Wind (Total 17,522 MW) 9,000 MW of Offshore Wind (Total 18,000 MW) 3,900 MW of Battery Storage (Total 7,800 MW) >16,513 MW of Generic Dispatchable Resources **Plus Additional Transmission** 1,700MW - 8,450 MW Increases in Transmission Limits

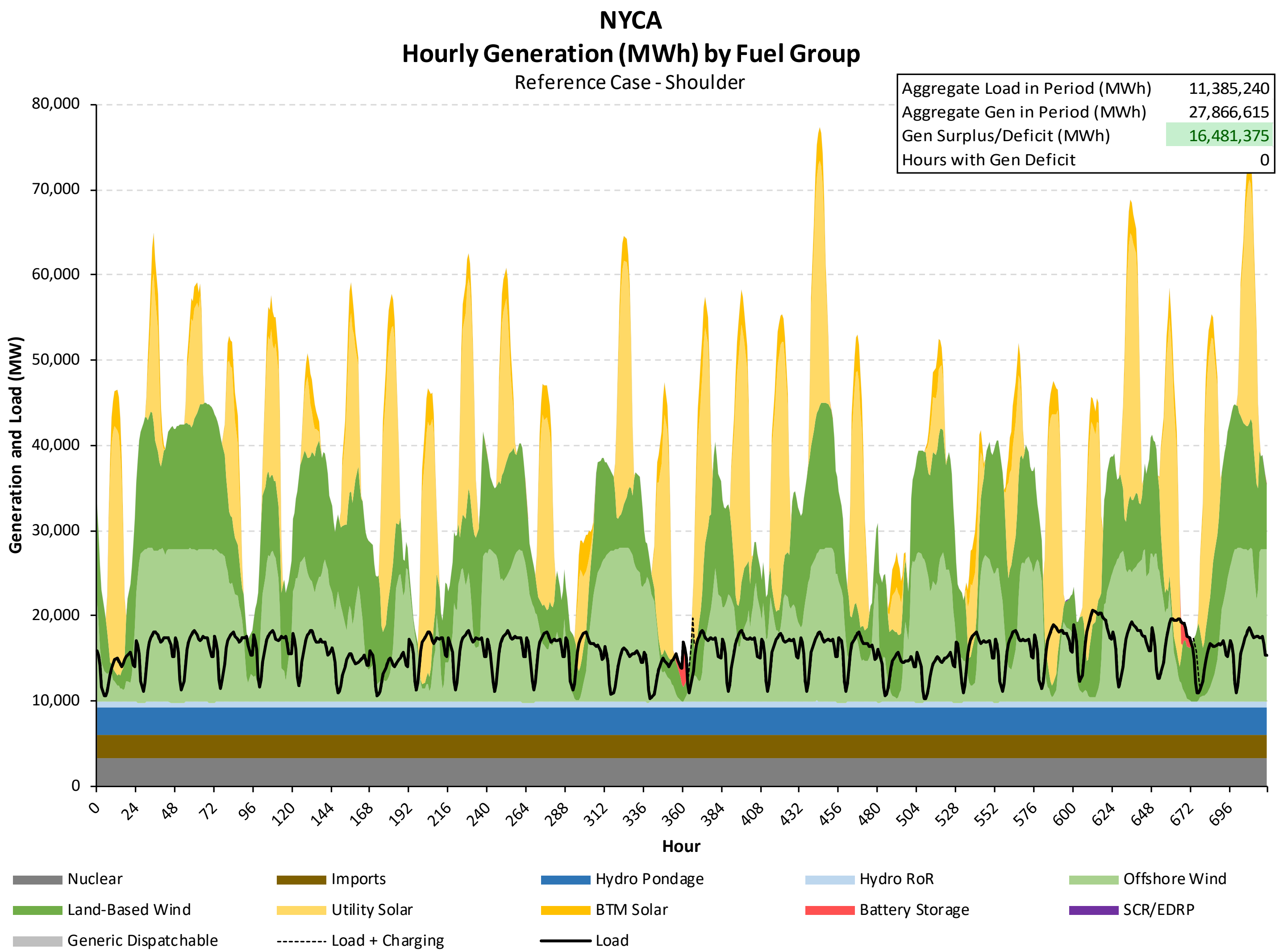
Reference Case Results (Summer 2040)



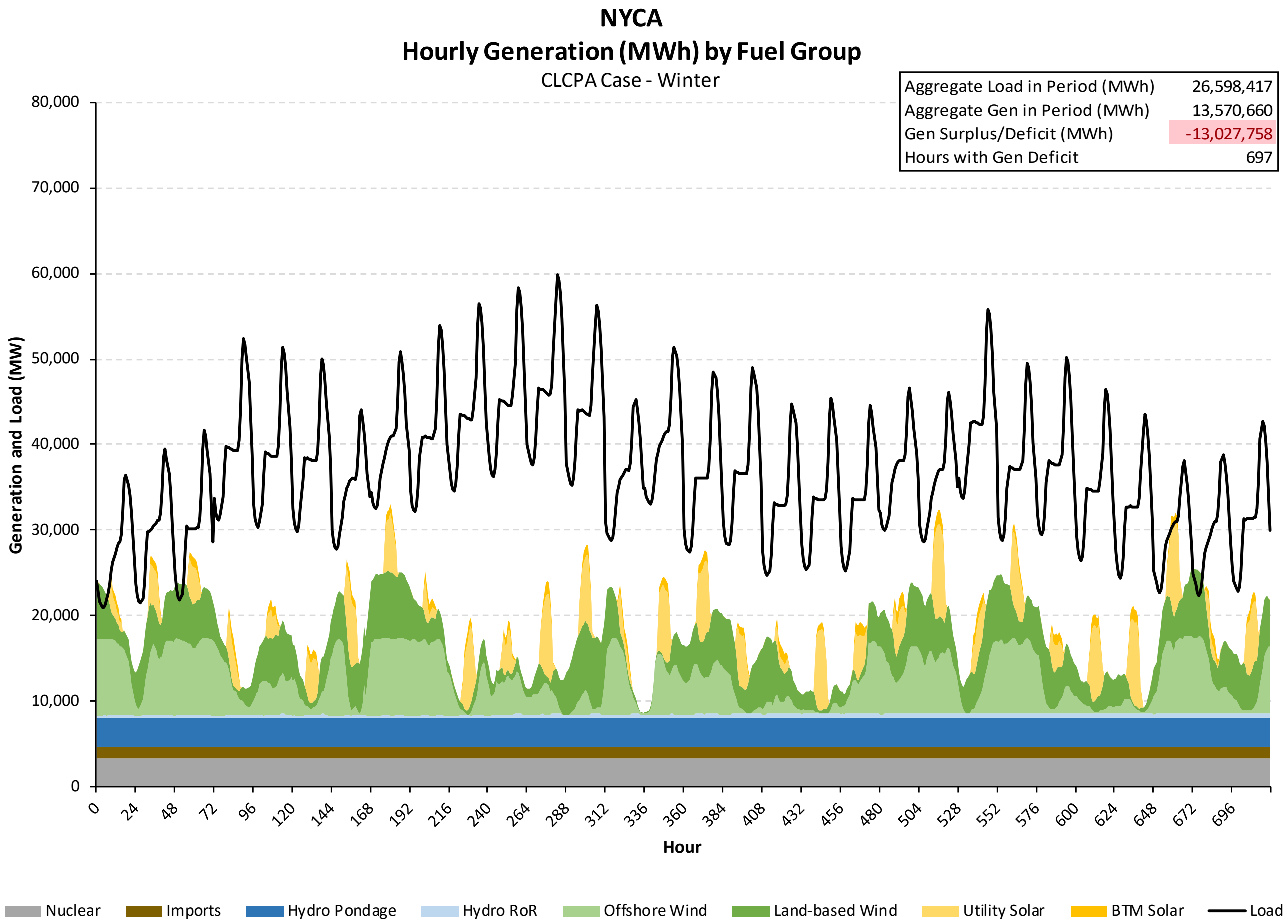
Reference Case Results (Winter 2040)



Reference Case Results (Shoulder Period 2040)

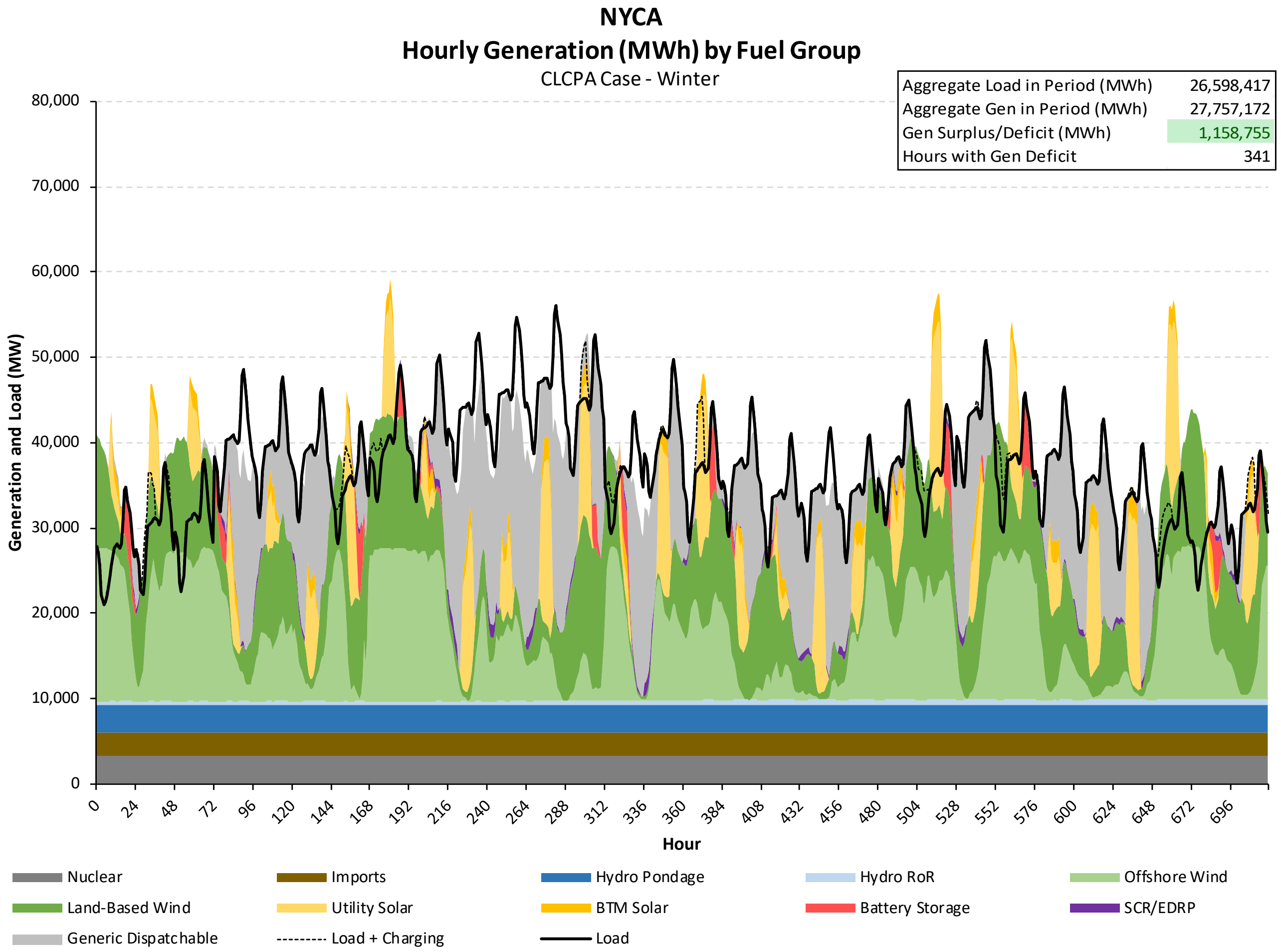


Winter 2040 Season Load and Generation Balance (CLCPA)



- Higher differences occur in the CLCPA case, with higher predicted loads in all seasons
- In the winter season (January 2040) for the CLCPA case, there is an overall deficit of generation over load in almost every hour
- Higher residential and commercial electrification estimates increase load across all winter hours

Winter 2040 CLCPA Load and Generation Balance with Reference Case Resource Set



- Reference Case Reliable Starting Point resources are insufficient to meet ensure reliability under CLCPA load scenario in all hours
- CLCPA scenario will require separate (in-progress) resource set development

Next Steps

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Key issues for discussion in the coming months

- Finalize model structure
- Finalize reference and CLCPA cases
- Consider Grid in Transition Resource Mix (Brattle)
- Develop climate change scenarios, run through model
- Evaluate impacts
- Draft Report

Contact

Paul Hibbard, Principal
Paul.Hibbard@analyisgroup.com

Charles Wu, Manager
Charles.Wu@analyisgroup.com