ANALYSIS GROUP

NYISO Climate Change Phase II Study

Analysis Updates and Discussion of Climate Cases

June 4, 2020

Today:

- Review of 2040 Resource Set Development
- Comparison of Analysis Group Resource Set with Grid in Transition Study Resource Set
- Overview of Climate Disruption Cases
- Example Outputs for Climate Disruption Cases
- Appendix: Additional Comparison of Analysis Group Resource Set with Grid in Transition Study Resource Set (Reference Case)

Review of 2040 Resource Set Development

Review of 2040 Resource Set Development

- Climate Change Phase II study requires assumption of specific "resource set" as reliable starting point from which to review more stressed system conditions due to disruptions from climate change
- There are many potential ways to meet 2040 state policy requirements, no single presumed resource set is "correct"
  - Feasible resource sets could be different in many ways (e.g., renewables/transmission focused versus dispatchable generation focused)
- In the previous presentation, we identified one feasible resource set for the purpose of the Climate Change Phase II Study
  - Our resource set focuses on maximum renewable contributions and transmission as needed to match renewable output to load
- We recognize that there are other studies underway that have a different focus – e.g., the Grid in Transition effort represents a resource outcome with a different focus, and leads to a different resource set

Review of Load Inputs

- Three 30-day modeling periods: Winter (January 2040), Summer (July 2040), and Off-peak (April 2040)
- Phase I scenarios referenced in this presentation:
  - *Reference Case* – Load growth based on Gold Book 2019 Estimates with 0.7° F per decade average temperature increase
  - *CLCPA Case* – 85% reduction in overall GHG by 2050, large scale electrification in residential and commercial sectors; 85% reduction in transportation GHG

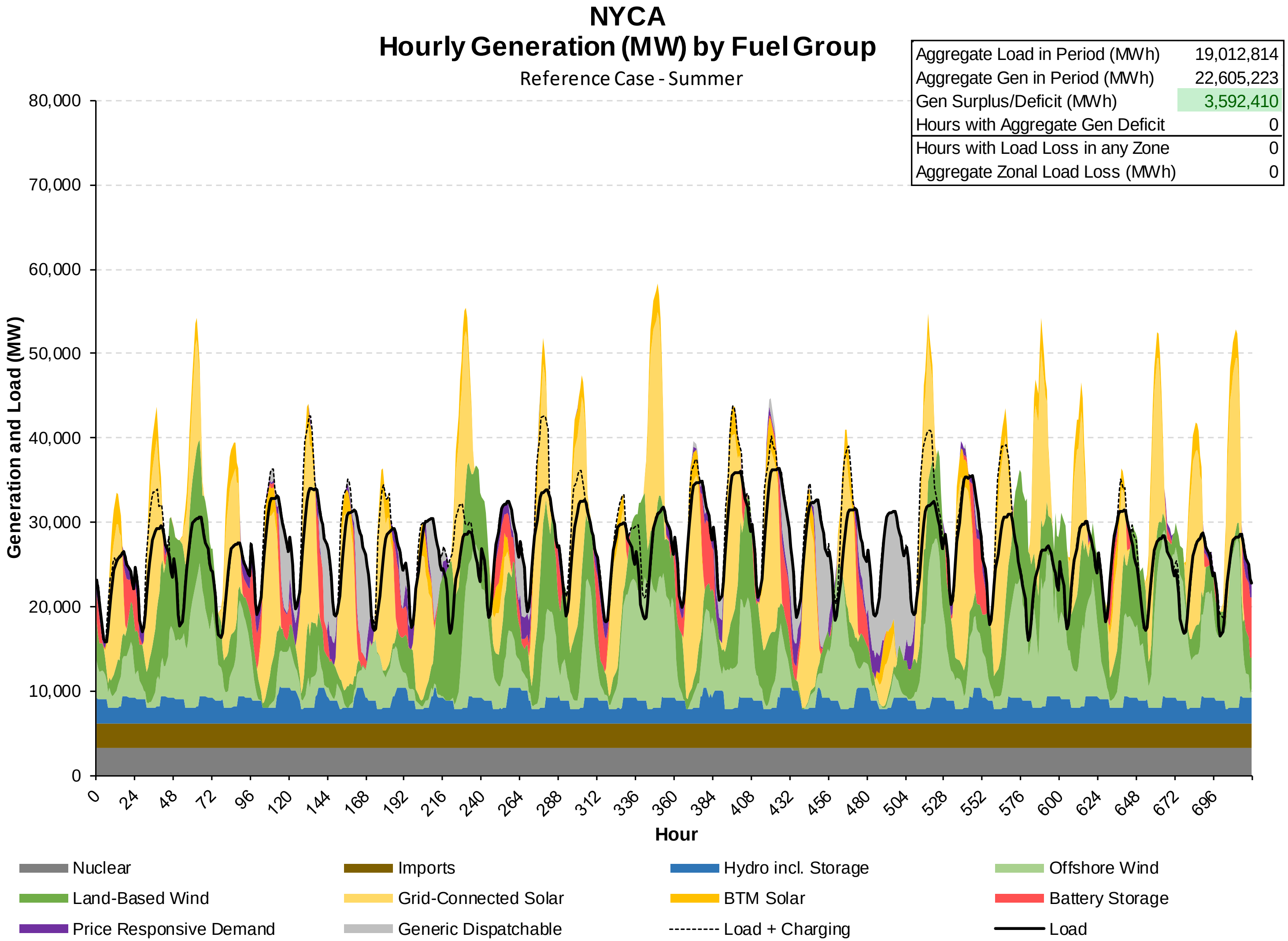
2040 Analysis Group Resource Set Development

- Development process for Climate Change Phase II resource sets for reference and CLCPA load scenarios:
  1. Start with CARIS 2019 Phase I 70/30 resources
  2. Increase nameplate capacity of renewable generation such that the aggregate MWh of generation from renewable resources is larger than aggregate load.
     a. Solar or wind resources increased incrementally based on “marginal benefit” of each resource type, which differs based on peak season within load scenario
  3. Reshape daily load based on price responsive demand for EV load
  4. Relax transmission constraints to bind in less than 10% of modeling period hours
  5. Increase energy storage in locations designed to optimize use of renewable generation
  6. Assume dispatchable generation as backstop, up to minimum required quantity to meet loads in most constrained season (summer for reference case, winter for CLCPA case)
     a. Generic dispatchable generation used only if and when renewables-based resource set insufficient to meet demand

Additional Modeling Changes

- Other changes to load/generation modeling:
  - Revisions to hydroelectric generation profile to account for daily cycle at Niagara; reduces hydro capacity factor overall
  - Battery now assumes 8 hour storage throughout state
  - Explicit modeling of Gilboa pumped storage using same logic as other battery storage
  - Increase of Zone D imports to 1,500 MW to account for all Hydro Quebec lines

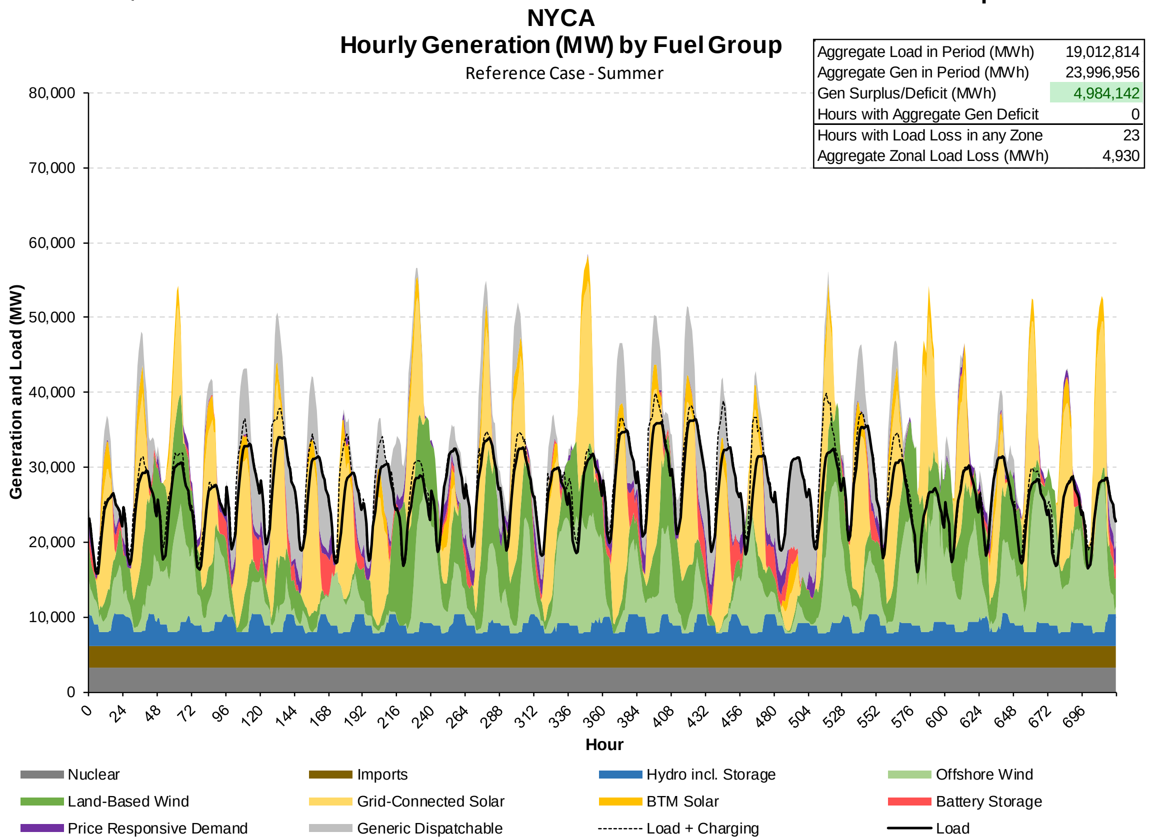
Updated Reference Case Results (Summer 2040)



Aggregate Load in Period (MWh)	19,012,814
Aggregate Gen in Period (MWh)	22,605,223
Gen Surplus/Deficit (MWh)	3,592,410
Hours with Aggregate Gen Deficit	0
Hours with Load Loss in any Zone	0
Aggregate Zonal Load Loss (MWh)	0

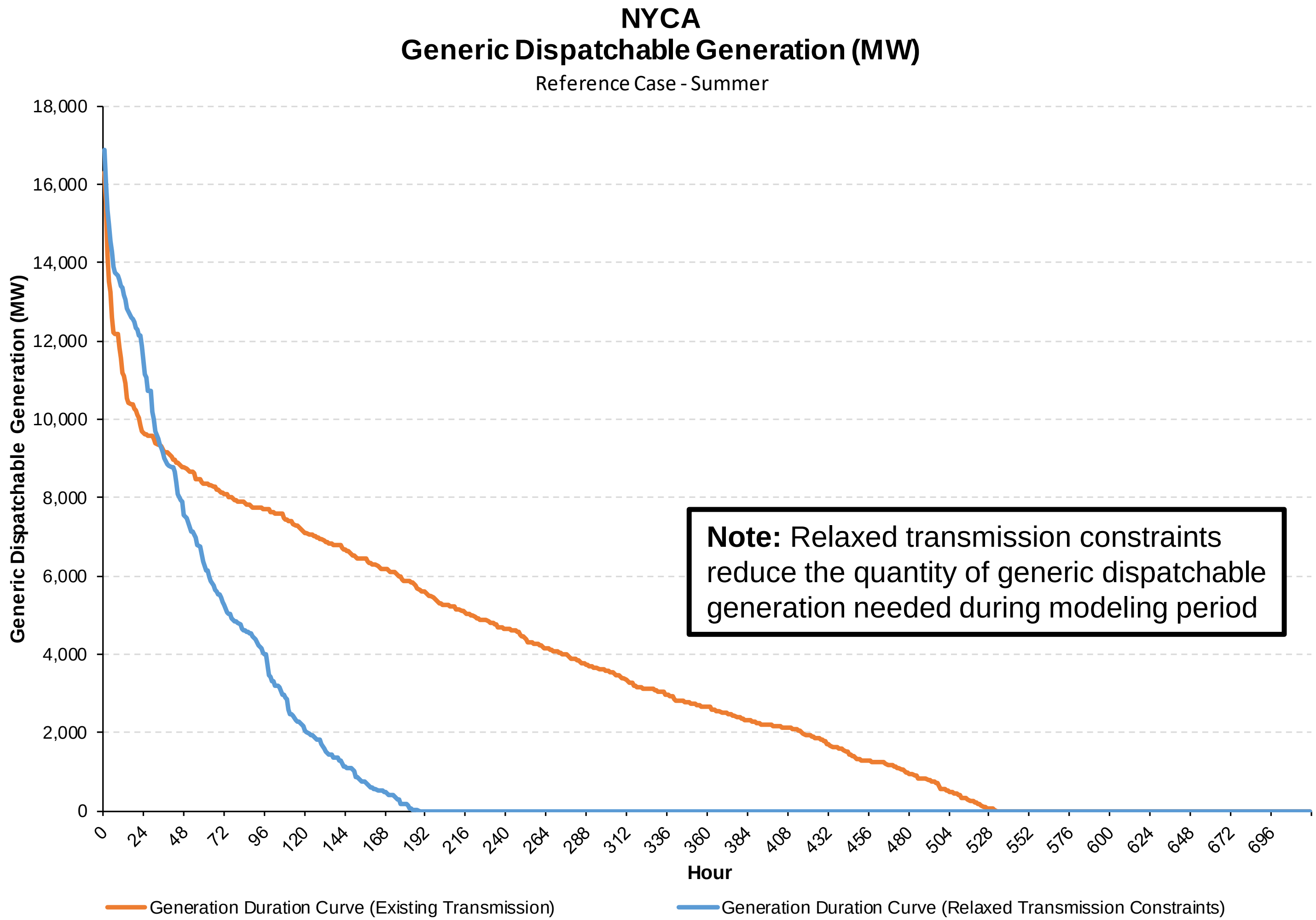
Effect of Transmission on Load Losses

- Development focuses on renewables and transmission, with goal to meet as much load as possible with renewable generation
- Additional quantities of renewables *without* relaxation of existing transmission constraints would lead to renewable curtailments and hours with local losses of load
- Without transmission, reliable solution must increase use of assumed dispatchable generation



Aggregate Load in Period (MWh)	19,012,814
Aggregate Gen in Period (MWh)	23,996,956
Gen Surplus/Deficit (MWh)	4,984,142
Hours with Aggregate Gen Deficit	0
Hours with Load Loss in any Zone	23
Aggregate Zonal Load Loss (MWh)	4,930

Effect of Transmission on Generic Dispatchable Generation



Revised Reference Case and CLCPA Resource Set

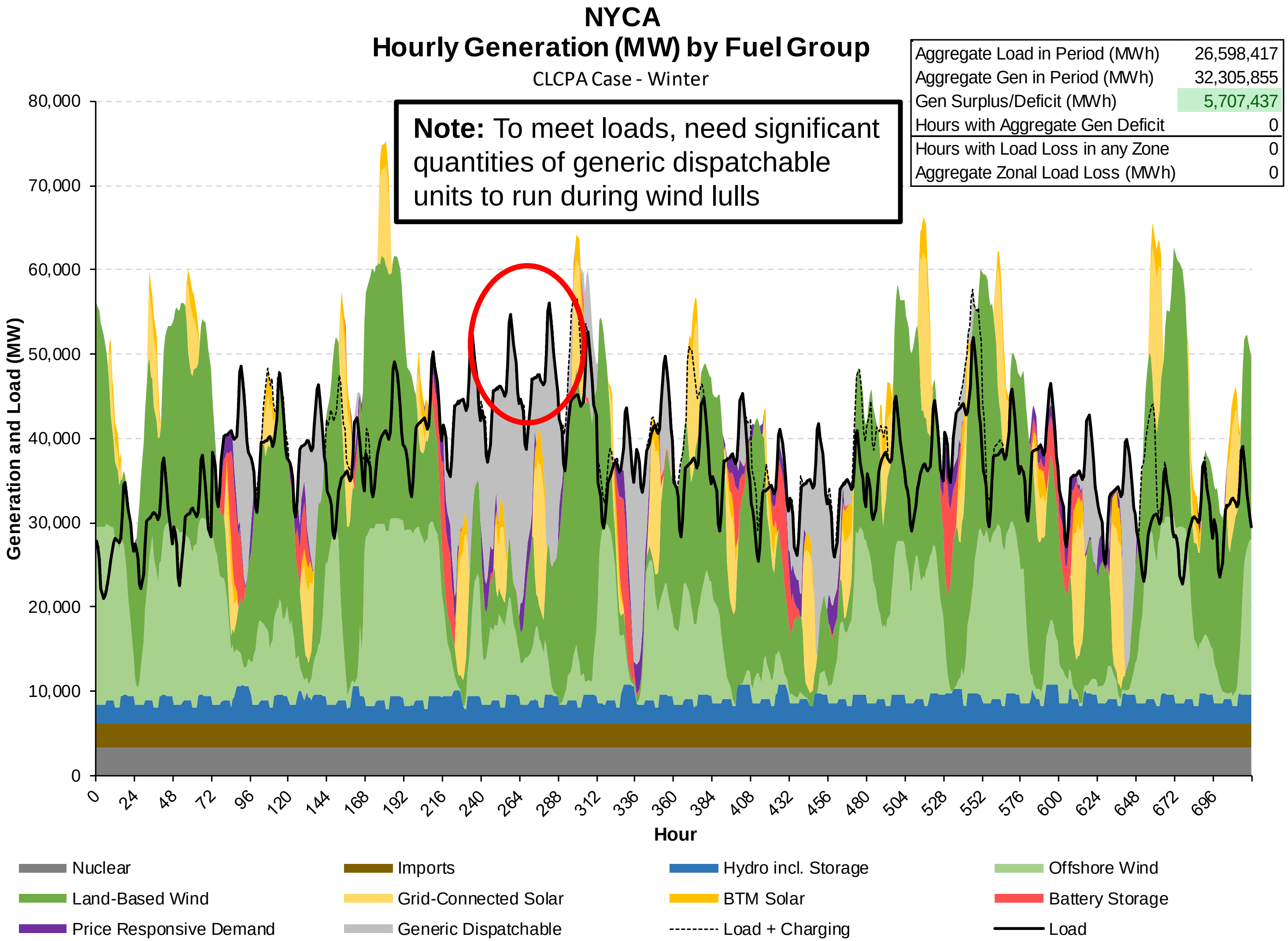
		Reference Case		CLCPA Case		
Resource Type	NYISO Base	After Resource Additions	Percent of Base	After Resource Additions	Percent of Base	Technical Potential
Land-Based Wind	8,761 MW	19,712 MW	225%	35,200 MW	402%	35,200 MW [1]
Offshore Wind	9,000 MW	20,250 MW	225%	21,063 MW	234%	21,063 MW [2]
Grid-Connected Solar	19,631 MW	34,354 MW	175%	34,354 MW	175%	1,350,000 MW [1,3]
Behind-the-Meter Solar	Case Specific	6,351 MW	175%	9,518 MW	175%	50,000 MW [1]
Battery Energy Storage	3,900 MW	7,800 MW	200%	12,675 MW	325%	
Generic Dispatchable	N/A	16,875 MW	N/A	29,260 MW	N/A	

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.

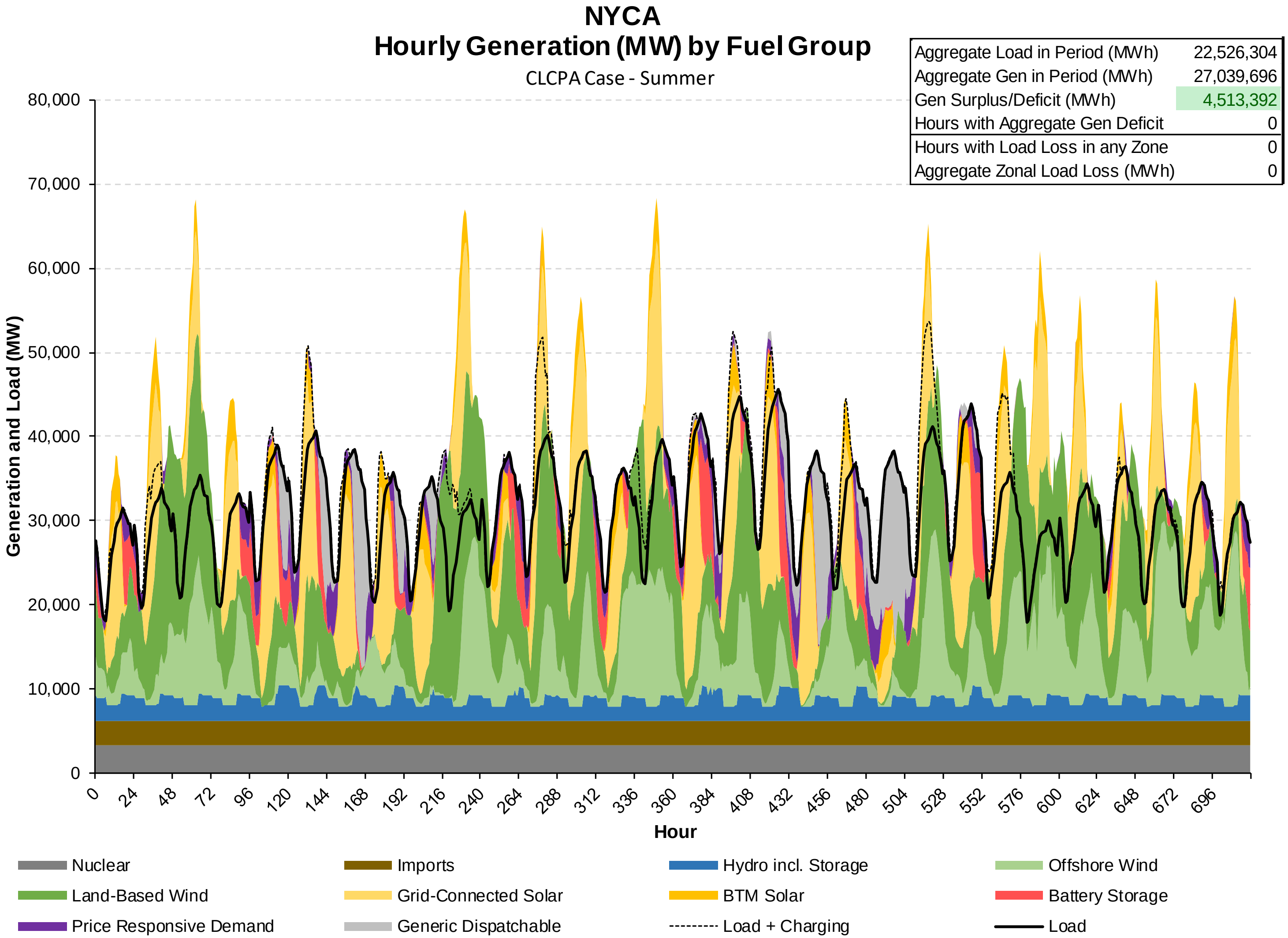
Sources:
[1] NREL, Estimating Renewable Energy Economic Potential in the United States: Methodology and Initial Results, August 2016, Appendices A and F.
[2] NREL, Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment, January 2016.
[3] Bureau of Ocean Energy Management, 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.

- Note that wind generation is limited by technical potential in NY in CLCPA case

CLCPA Case Results (Winter 2040)



CLCPA Case Results (Summer 2040)



Comparison of Analysis Group Resource Set with Grid in Transition Study Resource Set

Overview of *Grid in Transition* Study

- *Grid in Transition* Study started in Q1 2020 to analyze challenges with current NYISO market structures related to the transition to a zero-emissions grid with high levels of intermittent renewable resources and distributed generation
- End goal is to explore possible future resource mixes. This will then lead to a review of possible market design improvements so that market signals are consistent with the requirement to maintain system reliability
- *Grid in Transition* is meant to be an economic study
- The Brattle Group is running a model of economic investment and retirements of power plants to identify the potential path leading to a resource mix through 2040
- **Question: What are the impacts of the *Grid in Transition* resource mix in 2040 during winter, summer, and shoulder seasons when used in the Analysis Group reliability model?**

Comparison of Resources – CLCPA Demand Case

Comparison of CLCPA Case 2040 Nameplate Capacity (MW)

Grid in Transition Resource Set		Climate Change Phase II Resource Set		Difference
Resource Type	**NYS Total (MW) [A]**	**Resource Type**	**NYS Total (MW) [B]**	**NYS Total (MW) [B] - [A]**
Hydro	5,018	Hydro	4,486	-532
Renewable Gas Total	33,702	Dispatchable Total	29,270	-4,433
Nuclear	2,156	Nuclear	3,364	+1,208
Pumped Storage	1,171	Pumped Storage	1,170	-1
Grid-Connected Solar	31,669	Grid-Connected Solar	34,354	+2,685
BTM Solar	6,435	BTM Solar	9,518	+3,083
Storage 2-Hour	8,194			
Storage 4-Hour	5,912	Battery Storage	12,675	-1,432
Offshore Wind	25,102	Offshore Wind	21,063	-4,039
Land-based Wind	23,255	Land-based Wind	35,200	+11,945
Imports	1,100	Imports	2,810	+1,710
Demand Response + Flexible Load	4,500	Price Responsive Demand - Summer	5,236	+736
Total	**148,216**		**159,146**	**+10,930**

Notes:

[1] Climate Change Phase II price responsive demand in the winter is 3,412 MW, 1,088 MW less than in *Grid in Transition*.

[2] Climate Change Phase II model assumes 8-hour storage

Comparison of Transmission – CLCPA Demand Case

Comparison of CLCPA Case 2040 Transmission Limits (MW)

Grid in Transition Resource Set			Climate Change Phase II Resource Set			
Transmission Interface		Line Limit (MW) [A]	Transmission Interface		Line Limit (MW) [B]	Difference (MW) [B] - [A]
Total East	E to F + E to G	5,500	Total East	E to F + E to G	16,547	+11,047
Total South	E to G + F to G	6,500	Total South	E to G + F to G	17,547	+11,047
Sprain Brook -	I to J	3,900	Sprain Brook -	I to J	9,307	+5,407
Dunwoodie	J to I	2,000	Dunwoodie South	J to I	2,000	+0

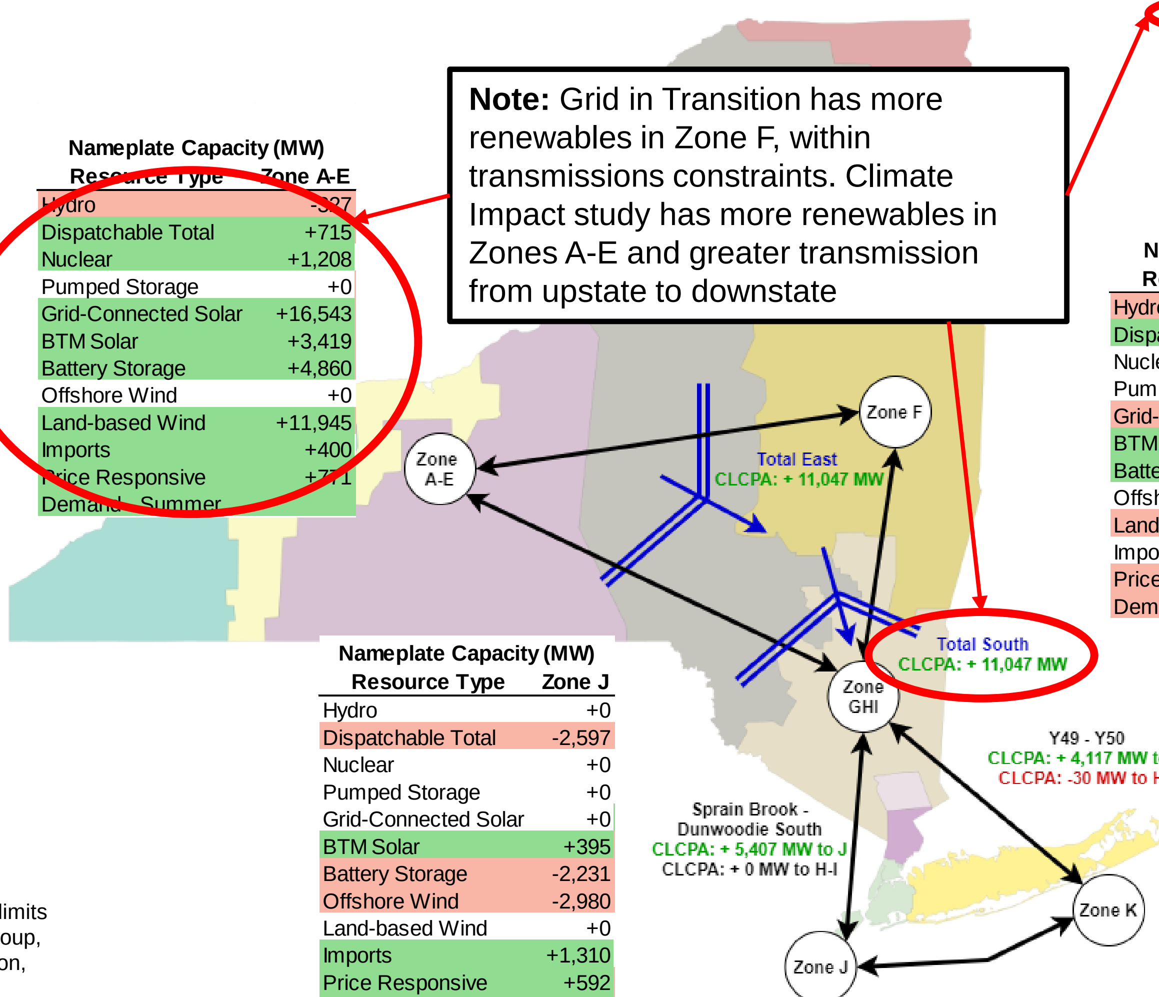
Notes:

[1] Climate Change Phase II resource set reflects limits when transmission constraints are relaxed to bind in less than 10% of the hours which would otherwise experience loss of load due to constrained transmission.

[2] Grid in Transition transmission limits are from The Brattle Group, Introduction to GridSim Presentation, March 6, 2020, Slide 21.

Comparison of Resources – CLCPA Case Difference (Climate Impact minus *Grid in Transition*)

Note: Grid in Transition has more renewables in Zone F, within transmissions constraints. Climate Impact study has more renewables in Zones A-E and greater transmission from upstate to downstate



Nameplate Capacity (MW)

Resource Type	Zone A-E
Hydro	-327
Dispatchable Total	+715
Nuclear	+1,208
Pumped Storage	+0
Grid-Connected Solar	+16,543
BTM Solar	+3,419
Battery Storage	+4,860
Offshore Wind	+0
Land-based Wind	+11,945
Imports	+400
Price Responsive Demand - Summer	+771

Nameplate Capacity (MW)

Resource Type	Zone F
Hydro	-203
Dispatchable Total	-5,658
Nuclear	+0
Pumped Storage	-1
Grid-Connected Solar	-13,222
BTM Solar	-1,396
Battery Storage	-1,877
Offshore Wind	+0
Land-based Wind	-0
Imports	+0
Price Responsive Demand - Summer	+128

Nameplate Capacity (MW)

Resource Type	Zone GHI
Hydro	-2
Dispatchable Total	+4,330
Nuclear	+0
Pumped Storage	+0
Grid-Connected Solar	-714
BTM Solar	+1,194
Battery Storage	+94
Offshore Wind	+0
Land-based Wind	-0
Imports	+0
Price Responsive Demand - Summer	-33

Nameplate Capacity (MW)

Resource Type	Zone J
Hydro	+0
Dispatchable Total	-2,597
Nuclear	+0
Pumped Storage	+0
Grid-Connected Solar	+0
BTM Solar	+395
Battery Storage	-2,231
Offshore Wind	-2,980
Land-based Wind	+0
Imports	+1,310
Price Responsive Demand - Summer	+592

Nameplate Capacity (MW)

Resource Type	Zone K
Hydro	+0
Dispatchable Total	-1,222
Nuclear	+0
Pumped Storage	+0
Grid-Connected Solar	+78
BTM Solar	-529
Battery Storage	-2,278
Offshore Wind	-1,059
Land-based Wind	+0
Imports	+0
Price Responsive Demand - Summer	-721

Note: Differences in transmission limits calculated based on the Brattle Group, Introduction to GridSim Presentation, March 6, 2020, Slide 21.

Differences in Climate Phase II vs *GIT* Resource Sets

- Tradeoff between transmission and dispatchable generation
  - Higher assumed transmission limits in Climate Phase II resource set
  - Higher assumed gas dispatchable resources in *Grid in Transition* resource set
- Location of solar units in *Grid in Transition* concentrated in Zone F, likely due to transmission constraints

Climate Disruption Case Discussion

Climate Disruption Case Modeling

- Reminder: Climate impacts will be analyzed using a set of climate cases that affect model input parameters during modeling periods
    - Exact magnitude of climate impacts will be based on Phase I modeling and/or literature review
- Model currently built with selectable short term physical disruptions on system. Disruptions include:
    - Load or renewable generation increase/decrease
    - Transmission limit increase/decrease or failure
    - Nuclear generation reduction
    - Reduced initial battery stored energy
- All toggles built with selectable durations, initial hours
    - Impacts can be limited to specific zones or technologies
    - Climate disruption cases will be built from combinations of modeled disruptions

Climate Disruption Initial Case List

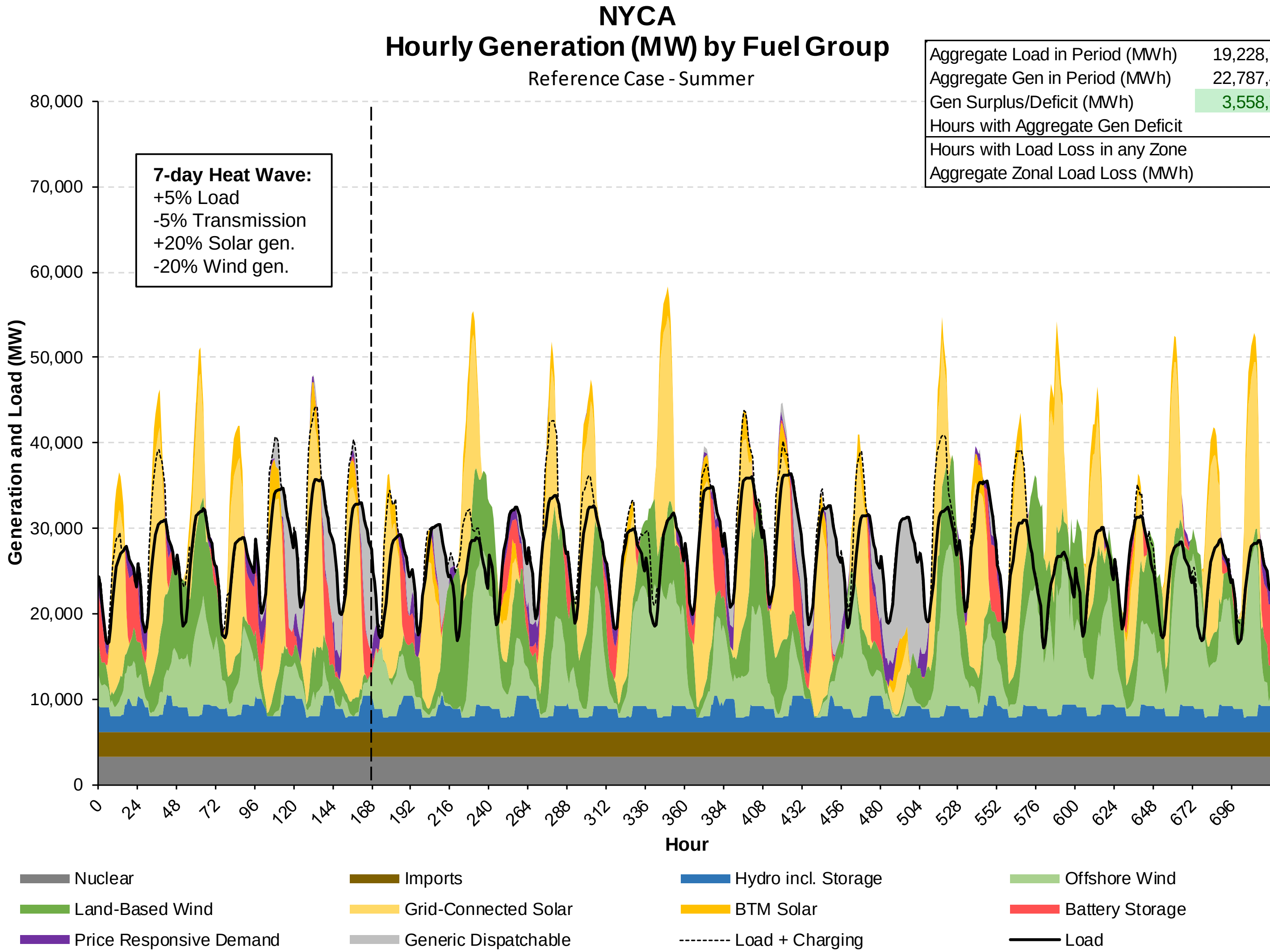
Event Case	Description	Case Adjustments
Extreme heat wave	Multi-day heat wave in summer season	Load Increase Wind Generation Decrease Solar Generation Increase Transmission Limit Decrease
Extreme cold wave/icing event	Multi-day cold wave in winter season	Load Increase Wind Generation Decrease Solar Generation Decrease Transmission Limit Decrease
Wind output reduction/outage	Wind impact (can be different between land-based and offshore)	Wind Generation Decrease
Solar output reduction/outage		Solar Generation Decrease
Hurricane/wind storm	Hurricane impact on NY grid	Generation and transmission outages; recovery over multiple days
Drought/intensive rainfall		Hydro Generation Decrease/Increase
Reduced initial stored energy	Batteries only charged to reduced percentage	Reduced starting battery quantities

Example of Output Metrics to be Used in Climate Disruption Cases

Climate Disruption Example Case #1

- This section illustrates the impact hypothetical climate disruption scenarios and provides examples of output metrics
- Starting point: Reference Case load scenario, with reliable starting point resource set
- Example disruption: Heat wave on days 1-7:
  - +5% Increase in load across all zones
  - -5% Decrease in transmission line limits across all zones
  - +20% Increase in solar generation across all zones
  - -20% Decrease in wind generation across all zones and offshore wind

Climate Disruption Example Case #1 Results (Summer 2040)



Aggregate Load in Period (MWh)	19,228,722
Aggregate Gen in Period (MWh)	22,787,462
Gen Surplus/Deficit (MWh)	3,558,740
Hours with Aggregate Gen Deficit	0
Hours with Load Loss in any Zone	0
Aggregate Zonal Load Loss (MWh)	0

Climate Disruption Example Case #1 Results (Summer 2040)

- Differences between Reference Case – Summer Base and Example Case #1 results over days 1-7, duration of heat wave event:
  - Heat wave results in increased usage of generic dispatchable, battery storage, and price-responsive demand (PRD) to compensate for net loss in renewable generation and loss in transmission capacity

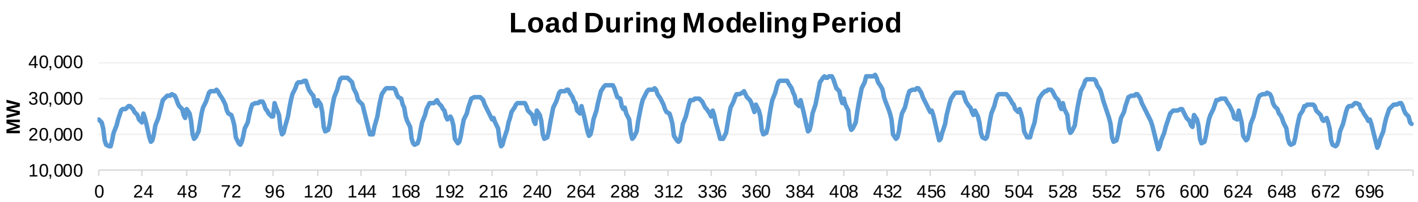
	Reference Summer, Days 1-7			
	Reference Case [A]	Heat Wave Example Case [B]	Difference [B]-[A]	% Difference [B]/[A] - 1
NY State Load (Base)	4,318,165 MWh	4,534,073 MWh	+215,908 MWh	+5.0%
NY State Load (Including Charging)	4,503,783 MWh	4,845,983 MWh	+342,200 MWh	+7.6%
Output by Resource Type				
Wind	1,565,221 MWh	1,252,177 MWh	-313,044 MWh	-20.0%
Solar	1,387,089 MWh	1,664,307 MWh	+277,218 MWh	+20.0%
Generic Dispatchable	228,649 MWh	314,280 MWh	+85,631 MWh	+37.5%
Battery Storage	205,597 MWh	290,393 MWh	+84,796 MWh	+41.2%
Price-Responsive Demand	110,292 MWh	139,249 MWh	+28,957 MWh	+26.3%

Note: Wind includes land-based and offshore wind. Solar includes behind-the-meter and grid-connected solar.

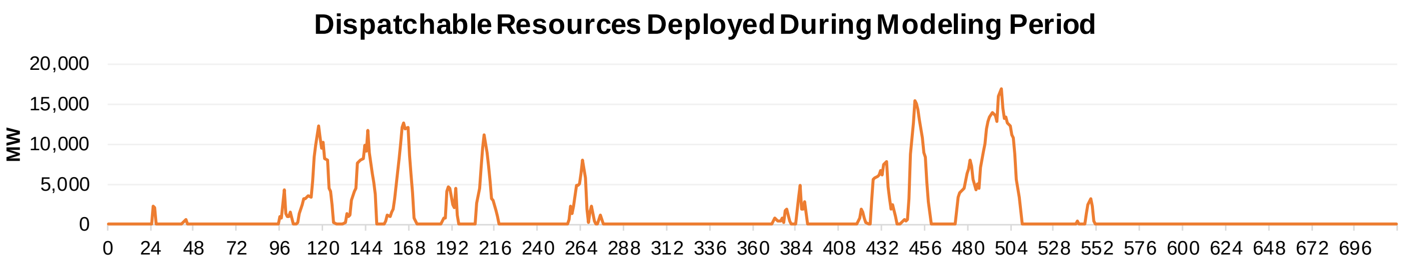
Climate Disruption Example Case #1 Sample Output

Hourly Results Summary

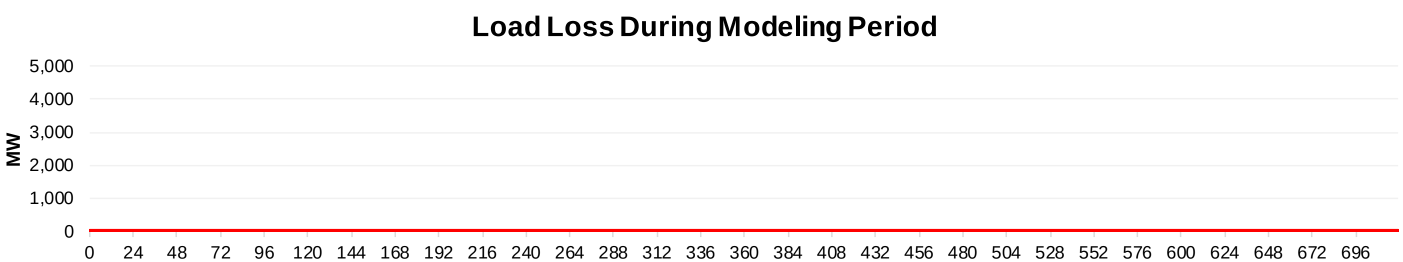
Case Name: Reference Case - Summer



Load	
Total Hrs.	720
Total MWh	19,228,722
Avg. MW	26,706.6

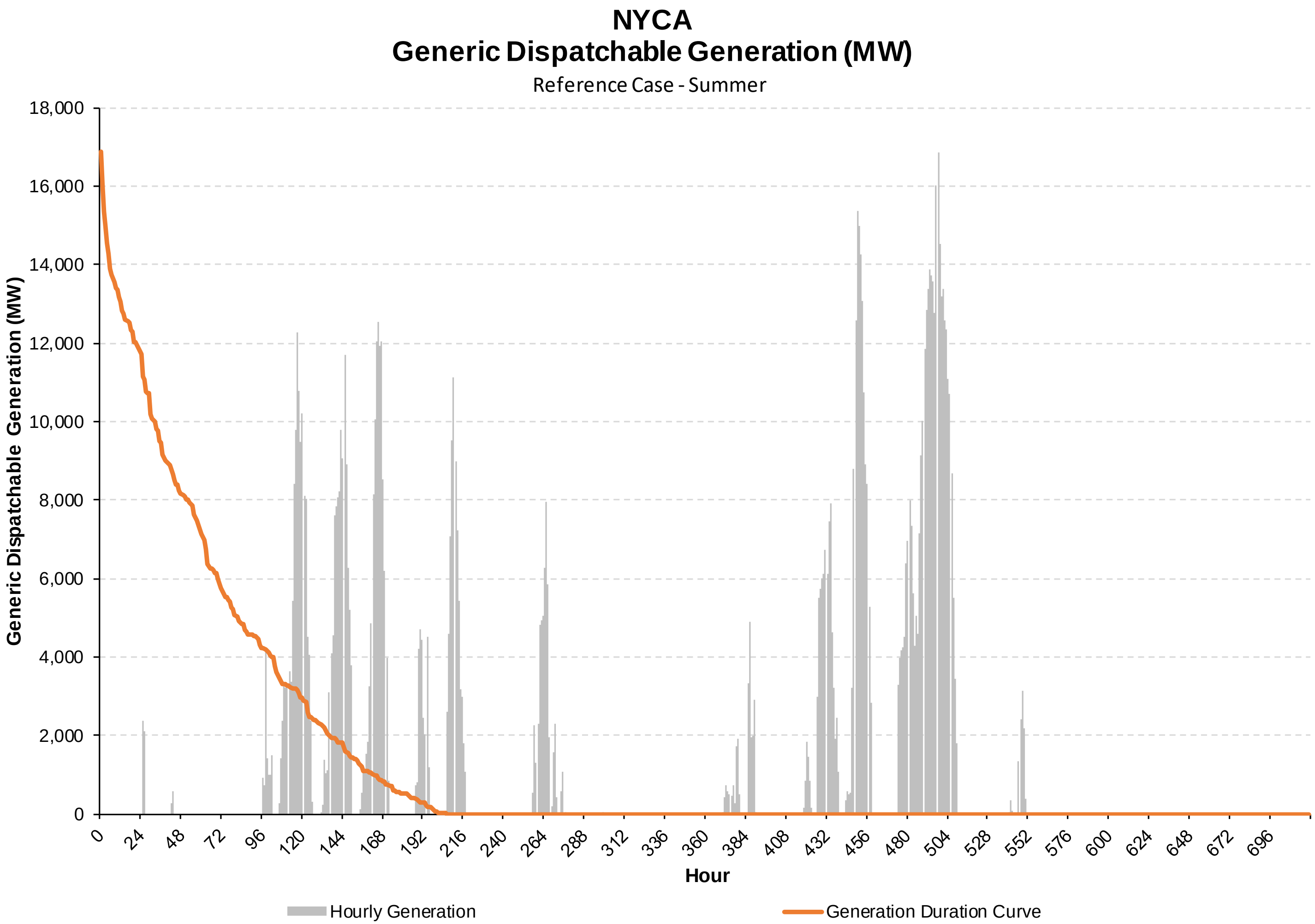


Dispatchable Generation	
Total Hrs.	207
Total MWh	1,028,418
Avg. MW	4,968.2



Load Loss	
Total Hrs.	0
Total MWh	0
Avg. MW	0.0

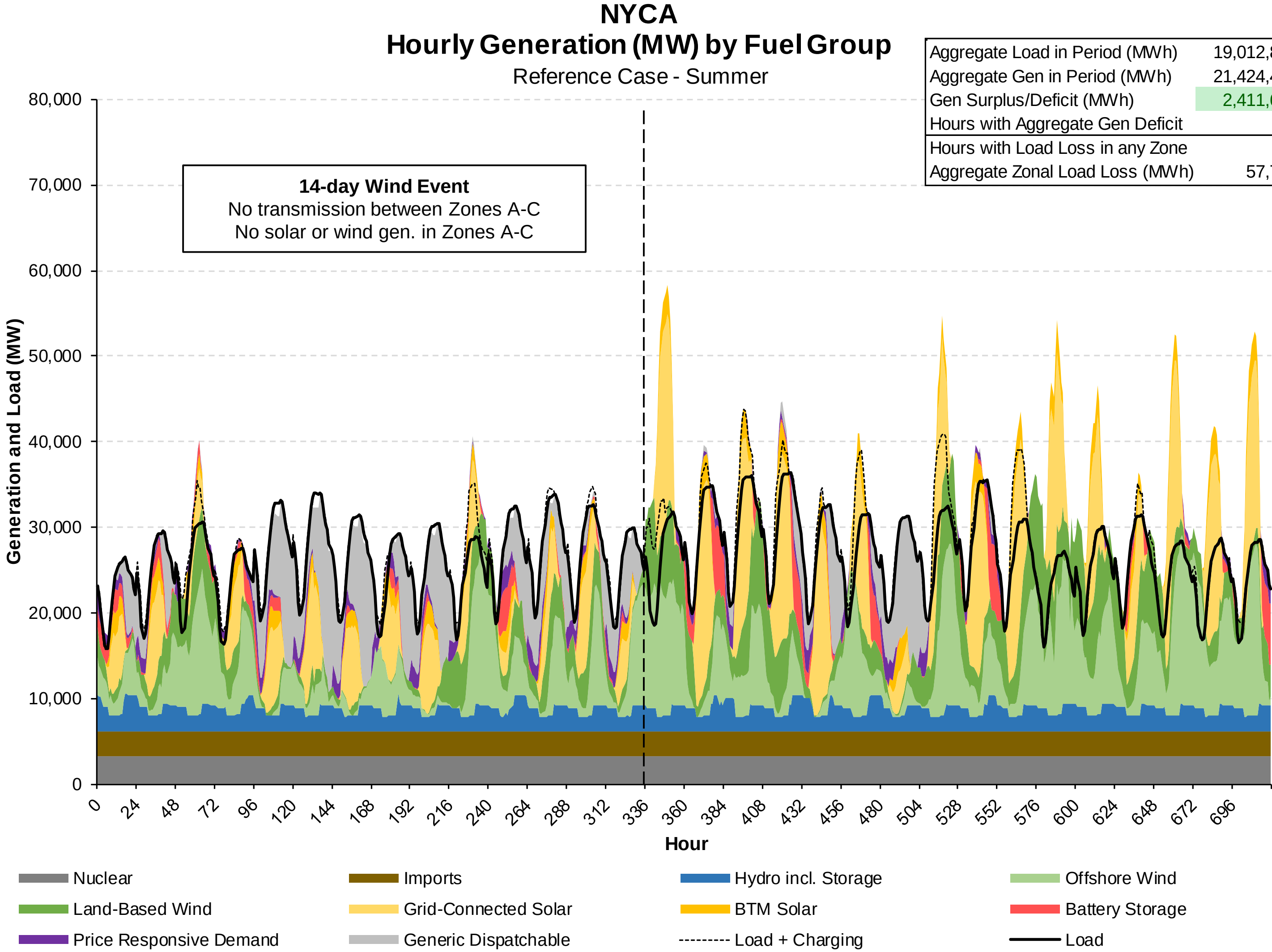
Climate Disruption Example Case #1 Sample Output



Climate Disruption Example Case #2

- Example #2 is constructed to be more extreme, and shows effects of load losses
- Starting point: Reference Case load scenario, with reliable starting point resource set
- Example disruption: High wind storm (west) with transmission and generation disruption/damage on days 1-14:
  - Transmission off in Zones A-C
  - Solar and wind generation off in Zones A-C

Climate Disruption Example Case #2 Results (Summer 2040)



Aggregate Load in Period (MWh)	19,012,814
Aggregate Gen in Period (MWh)	21,424,465
Gen Surplus/Deficit (MWh)	2,411,652
Hours with Aggregate Gen Deficit	74
Hours with Load Loss in any Zone	78
Aggregate Zonal Load Loss (MWh)	57,717

Climate Disruption Example Case #2 Results (Summer 2040)

- Differences between Reference Case – Summer Base and Example Case #2 results over days 1-14, duration of high wind storm event:
  - High wind storm results in increased usage of generic dispatchable and price-responsive demand to compensate for loss in wind and solar generation, loss of battery storage, and loss in transmission capacity

	Reference Case [A]	Reference Summer, Days 1-14 High Wind Storm (West) Example Case [B]	Difference [B]-[A]	% Difference [B]/[A] - 1
NY State Load (Base)	8,723,889 MWh	8,723,889 MWh	+0 MWh	+0.0%
NY State Load (Including Charging)	9,219,186 MWh	8,931,322 MWh	-287,864 MWh	-3.1%
Output by Resource Type				
Wind	3,496,685 MWh	2,439,185 MWh	-1,057,500 MWh	-30.2%
Solar	2,663,343 MWh	1,348,898 MWh	-1,314,445 MWh	-49.4%
Generic Dispatchable	390,546 MWh	1,694,008 MWh	+1,303,462 MWh	+333.8%
Battery Storage	383,596 MWh	214,729 MWh	-168,867 MWh	-44.0%
Price-Responsive Demand	234,642 MWh	309,555 MWh	+74,913 MWh	+31.9%

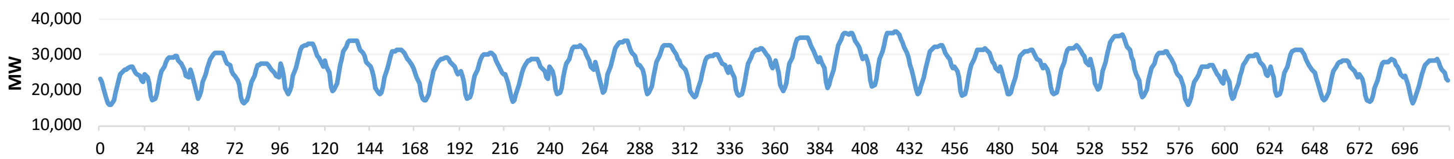
Note: Wind includes land-based and offshore wind. Solar includes behind-the-meter and grid-connected solar.

Climate Disruption Example Case #2 Sample Output

Hourly Results Summary

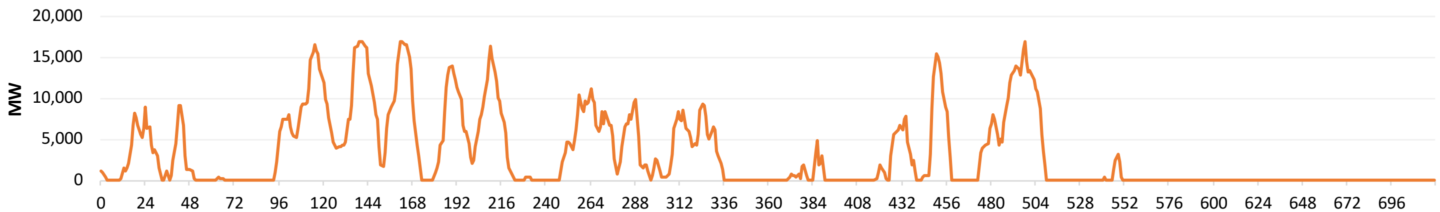
Case Name: Reference Case - Summer

Load During Modeling Period



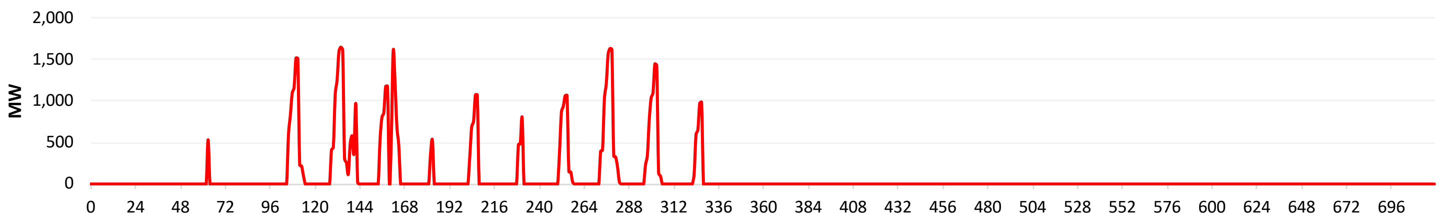
Load	
Total Hrs.	720
Total MWh	19,012,814
Avg. MW	26,406.7

Dispatchable Resources Deployed During Modeling Period



Generation	
Total Hrs.	356
Total MWh	2,248,054
Avg. MW	6,314.8

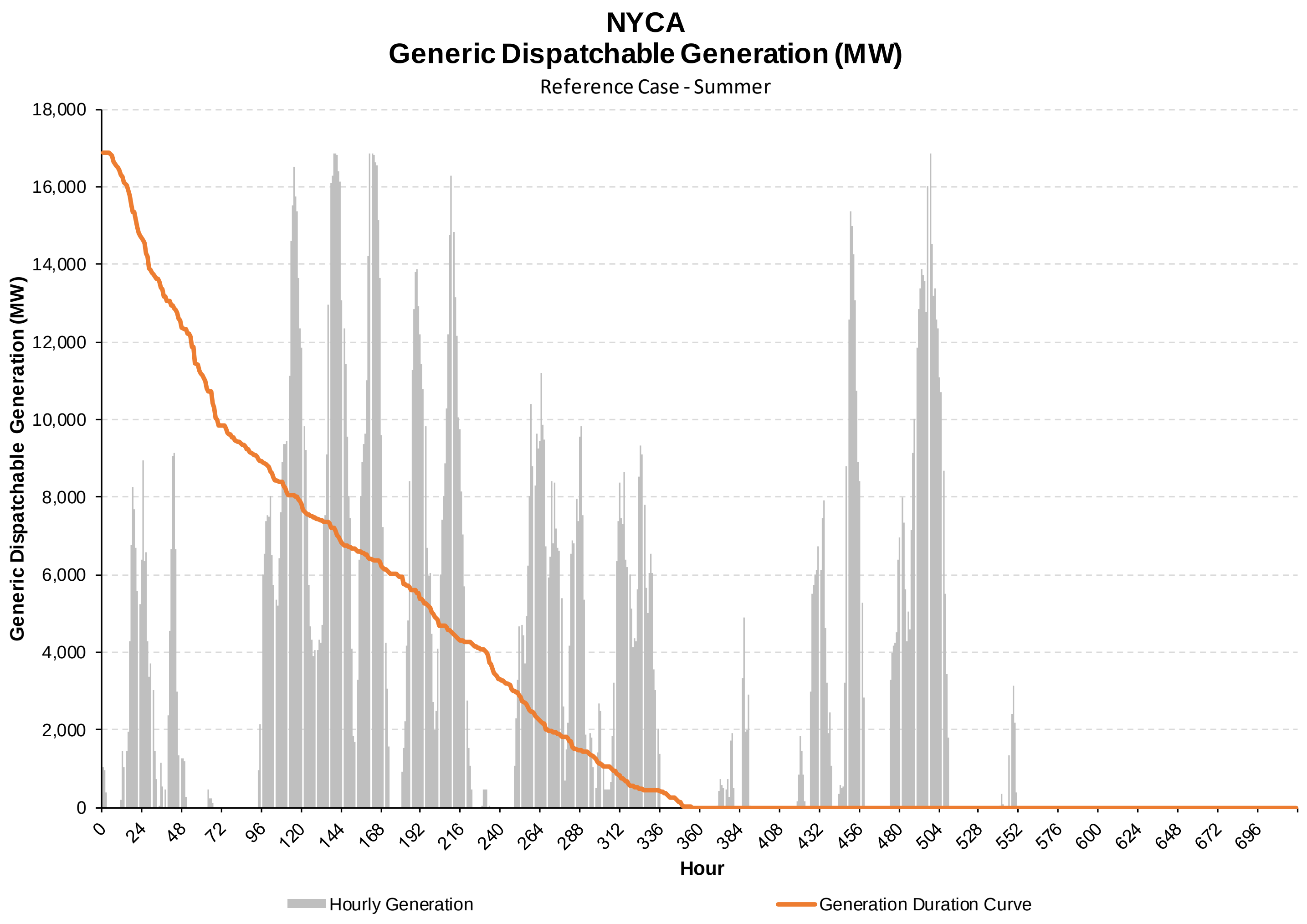
Load Loss During Modeling Period



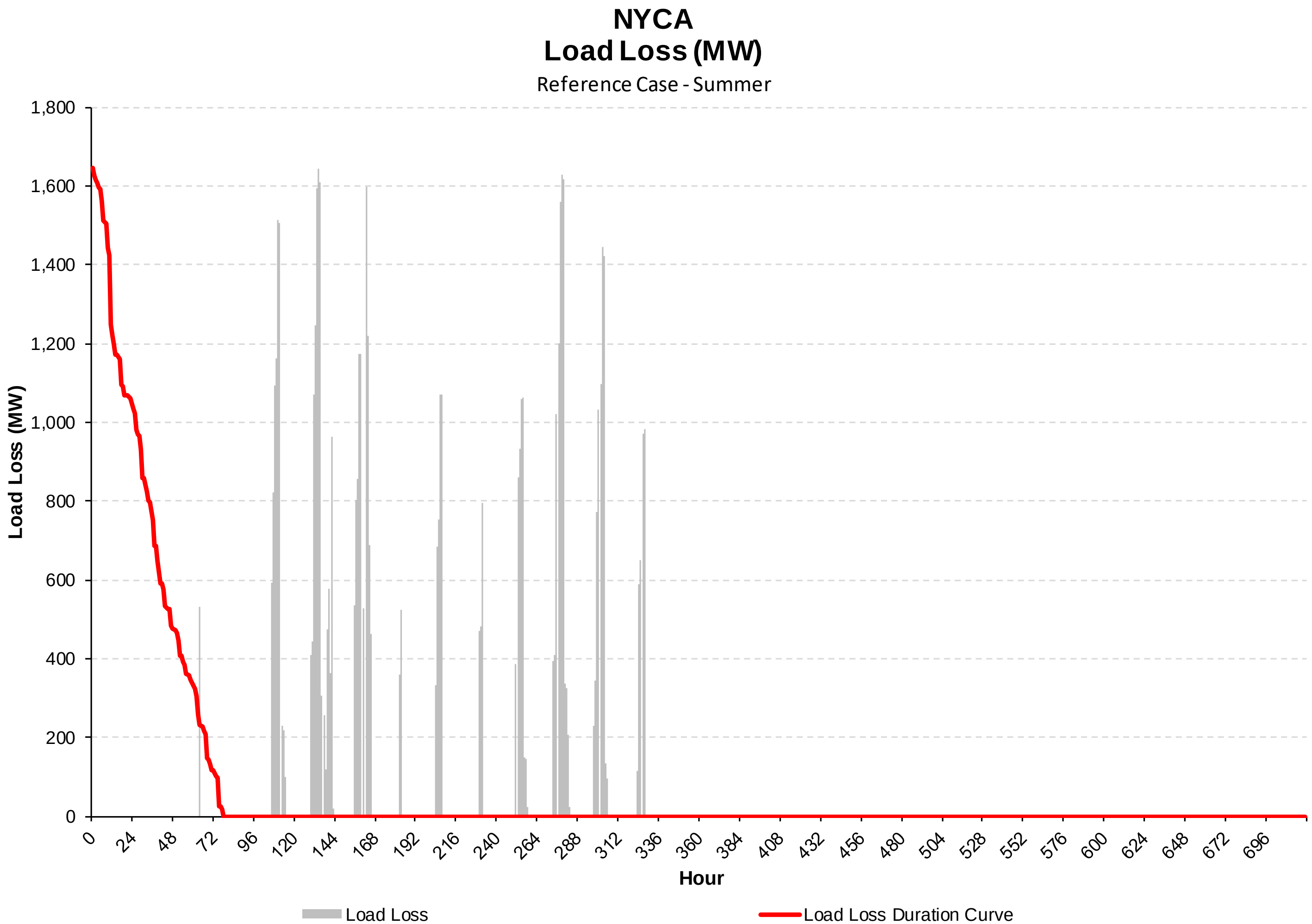
Load Loss	
Total Hrs.	78
Total MWh	57,717
Avg. MW	740.0

Note: Load losses occur in some hours when dispatchable resources are not dispatched at maximum capacity due to local transmission constraints

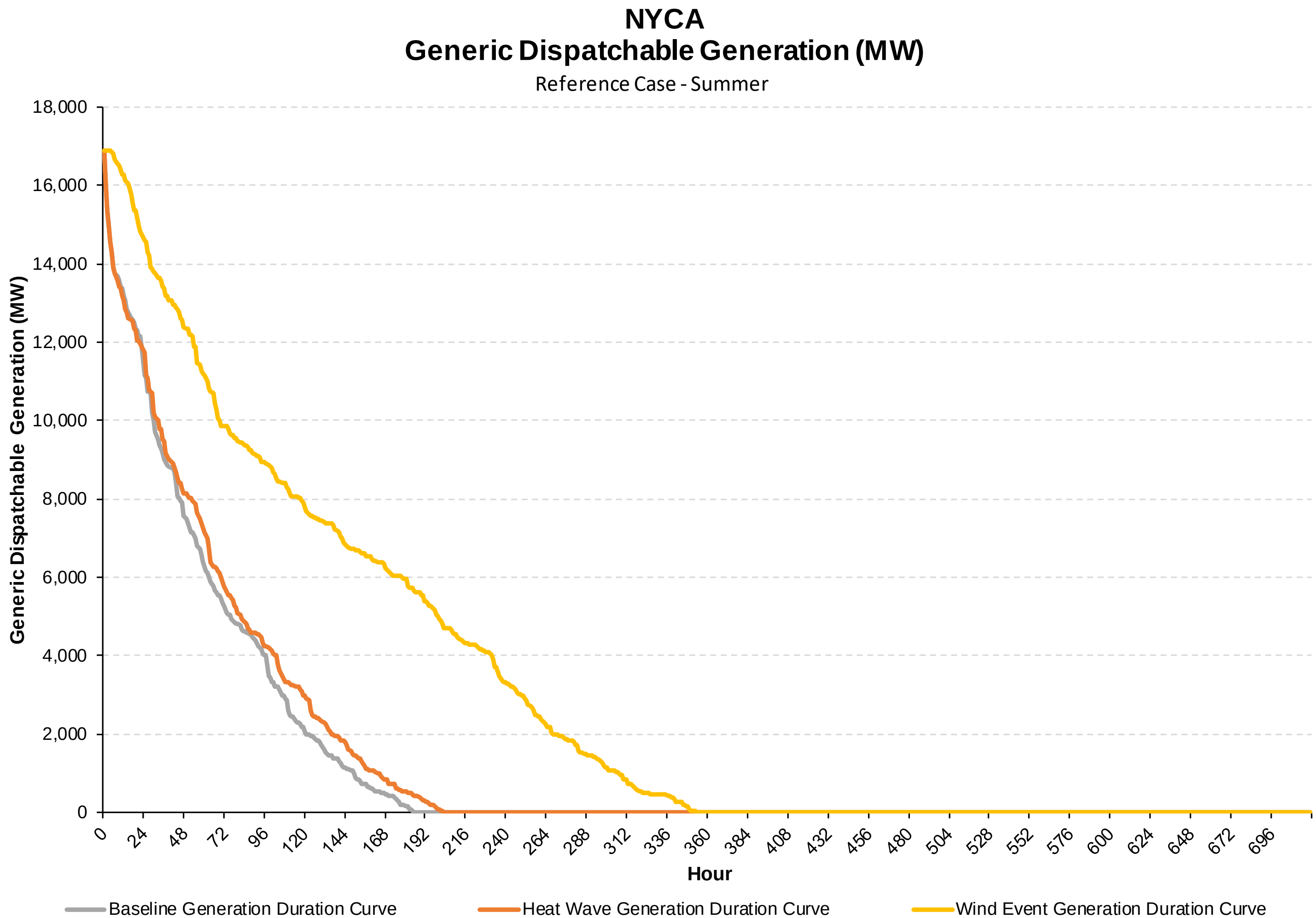
Climate Disruption Example Case #2 Sample Output



Climate Disruption Example Case #2 Sample Output



Climate Disruption Cases #1 and #2 Sample Summary



Appendix: Additional Comparison of Analysis Group Resource Set with Grid in Transition Study Resource Set (Reference Case)

Comparison of Resources – Reference Case

Comparison of Reference Case 2040 Nameplate Capacity (MW)

Grid in Transition Resource Set		Climate Change Phase II Resource Set		Difference
Resource Type	**NYS Total (MW) [A]**	**Resource Type**	**NYS Total (MW) [B]**	**NYS Total (MW) [B] - [A]**
Hydro	5,018	Hydro	4,486	-532
Renewable Gas Total	20,618	Dispatchable Total	22,471	+1,852
Nuclear	2,096	Nuclear	3,364	+1,268
Pumped Storage	1,171	Pumped Storage	1,170	-1
Grid-Connected Solar	30,043	Grid-Connected Solar	34,354	+4,312
BTM Solar	6,113	BTM Solar	6,351	+238
Storage 2-Hour	6,736			
Storage 4-Hour	4,000	Battery Storage	7,800	-2,936
Offshore Wind	13,767	Offshore Wind	20,250	+6,483
Land-based Wind	9,755	Land-based Wind	19,712	+9,957
Imports	1,100	Imports	2,810	+1,710
Demand Response + Flexible Load	3,163	Price Responsive Demand - Summer	2,618	-545
Total	**103,580**		**125,386**	**+21,806**

Notes:

[1] Climate Change Phase II price responsive demand in the winter is 1,706 MW, 1,457 MW less than in *Grid in Transition*.

[2] Climate Change Phase II model assumes 8-hour storage.

Comparison of Transmission – Reference Case

Comparison of Reference Case 2040 Transmission Limits (MW)

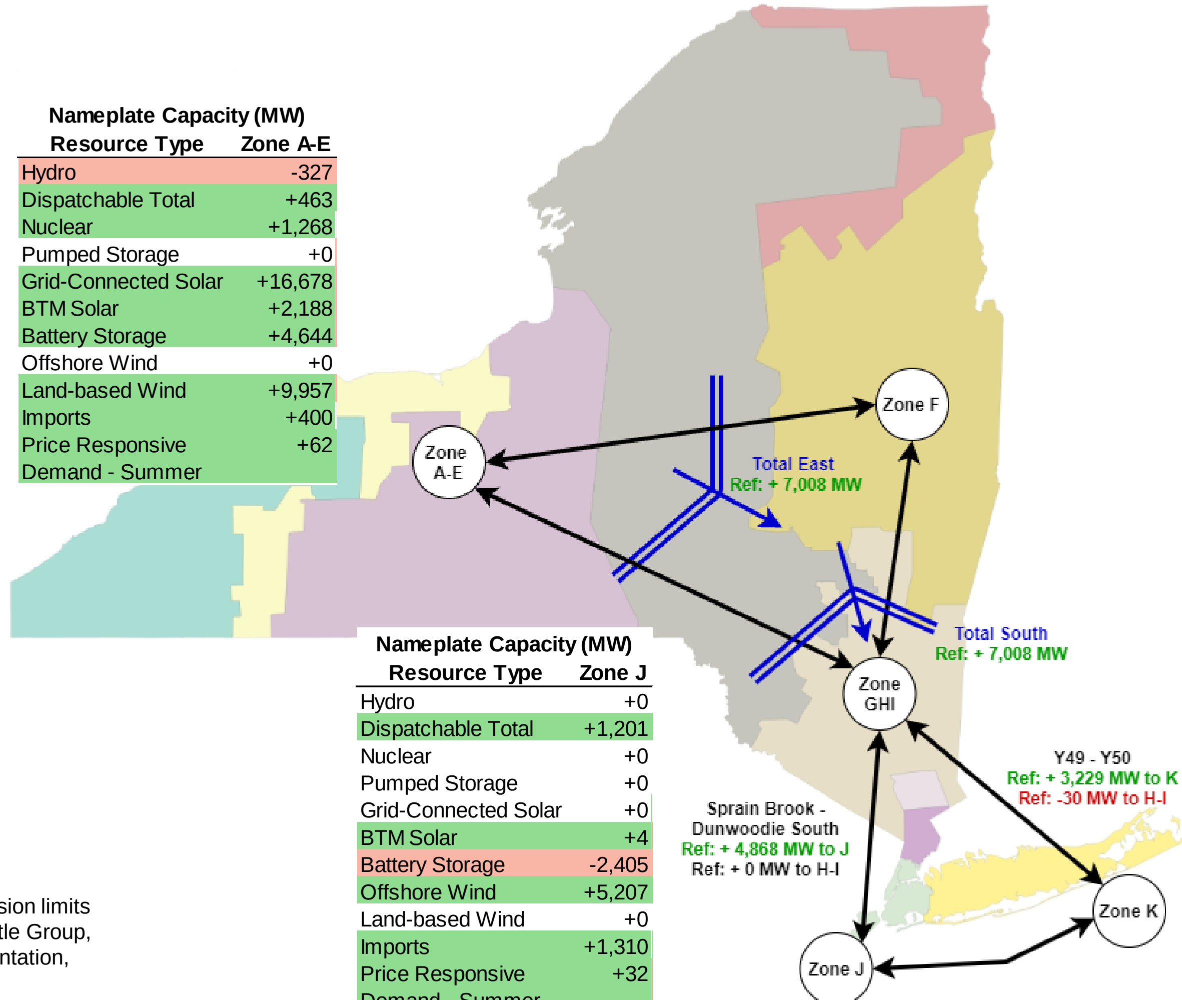
Grid in Transition Resource Set			Climate Change Phase II Resource Set			
Transmission Interface		Line Limit (MW) [A]	Transmission Interface		Line Limit (MW) [B]	Difference (MW) [B] - [A]
Total East	E to F + E to G	5,500	Total East	E to F + E to G	12,508	+7,008
Total South	E to G + F to G	6,500	Total South	E to G + F to G	13,508	+7,008
Sprain Brook -	I to J	3,900	Sprain Brook -	I to J	8,768	+4,868
Dunwoodie	J to I	2,000	Dunwoodie South	J to I	2,000	+0

Notes:

[1] Climate Change Phase II resource set reflects limits when transmission constraints are relaxed to bind in less than 10% of the hours which would otherwise experience loss of load due to constrained transmission.

[2] Grid in Transition transmission limits are from The Brattle Group, Introduction to GridSim Presentation, March 6, 2020, Slide 21.

Comparison of Resources – Reference Case Difference (Climate Impact minus *Grid in Transition*)



Nameplate Capacity (MW)

Resource Type	Zone A-E
Hydro	-327
Dispatchable Total	+463
Nuclear	+1,268
Pumped Storage	+0
Grid-Connected Solar	+16,678
BTM Solar	+2,188
Battery Storage	+4,644
Offshore Wind	+0
Land-based Wind	+9,957
Imports	+400
Price Responsive Demand - Summer	+62

Nameplate Capacity (MW)

Resource Type	Zone F
Hydro	-203
Dispatchable Total	+350
Nuclear	+0
Pumped Storage	-1
Grid-Connected Solar	-12,682
BTM Solar	-1,641
Battery Storage	-2,577
Offshore Wind	+0
Land-based Wind	-0
Imports	+0
Price Responsive Demand - Summer	+1

Nameplate Capacity (MW)

Resource Type	Zone GHI
Hydro	-2
Dispatchable Total	-318
Nuclear	+0
Pumped Storage	+0
Grid-Connected Solar	+237
BTM Solar	+709
Battery Storage	-677
Offshore Wind	+0
Land-based Wind	-0
Imports	+0
Price Responsive Demand - Summer	-99

Nameplate Capacity (MW)

Resource Type	Zone J
Hydro	+0
Dispatchable Total	+1,201
Nuclear	+0
Pumped Storage	+0
Grid-Connected Solar	+0
BTM Solar	+4
Battery Storage	-2,405
Offshore Wind	+5,207
Land-based Wind	+0
Imports	+1,310
Price Responsive Demand - Summer	+32

Nameplate Capacity (MW)

Resource Type	Zone K
Hydro	+0
Dispatchable Total	+156
Nuclear	+0
Pumped Storage	+0
Grid-Connected Solar	+78
BTM Solar	-1,022
Battery Storage	-1,921
Offshore Wind	+1,276
Land-based Wind	+0
Imports	+0
Price Responsive Demand - Summer	-541

Note: Differences in transmission limits calculated based on The Brattle Group, Introduction to GridSim Presentation, March 6, 2020, Slide 21.

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