Power Generation Advisory Panel

Meeting 1

September 16, 2020

NEW YORK STATE OF OPPORTUNITY. | Climate Action Council

Agenda

Introductions & Panel Member Priorities (30 minutes)

State of the Sector (10 minutes)

Pathways Presentation – E3 (15 minutes)

Work Plan Development Discussion (50 minutes)

Scope Development Discussion (40 minutes)

Timeline (10 minutes)

Next Steps (15 minutes)

Introductions & Panel Member Priorities

Power Generation Panel Members

John Rhodes, Chair
Chair: Public Service Commission

Corinne DiDomenico
Asst. Director, Large Scale Renewables: NYSERDA

William Acker
Executive Director: New York Battery and Energy Storage Consortium

Cecilio Aponte
Senior Analyst: Origination at sPower

Rory Christian
President: Concentric Consulting, LLC

Elizabeth (Betta) Broad
Outreach Director: New Yorkers for Clean Power

Lisa Dix
Sr. NY Representative: Beyond Coal Campaign, Sierra Club

Annel Hernandez
Associate Director: New York City Environmental Justice Alliance

Kit Kennedy
Director of Energy & Transportation Program: NRDC

Emilie Nelson
Executive Vice President: NYISO

John Reese
Senior Vice President: Eastern Generation

Shyam Mehta
Executive Director: NYSEIA

Stephan Roundtree, Jr.
Northeast Director: Vote Solar

Jennifer Schneider
Intl. Representative & Legislative & Political Coordinator for NY: IBEW

Darren Suarez
Manager of Public and Government Affairs: Boralex Inc.

Laurie Wheelock
Litigation and Policy Counsel: Public Utility Law Project

State of the Sector

Climate Leadership and Community Protection Act, Targets Codified into Law

Carbon neutral economy, mandating at least an 85% reduction in emissions below 1990 levels

40% reduction in emissions by 2030

100% zero-carbon electricity by 2040

70% renewable electricity by 2030

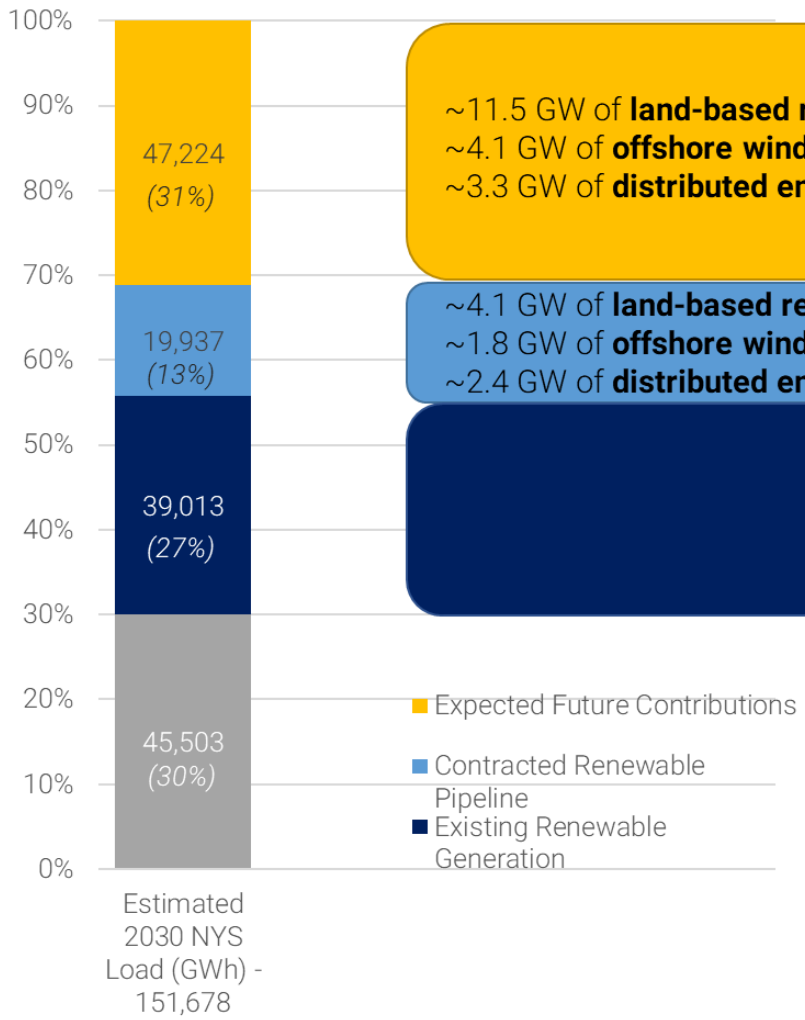
9,000 MW of offshore wind by 2035

6,000 MW of distributed solar by 2025

3,000 MW of energy storage by 2030

185 TBtu on-site energy savings by 2025

Alignment with the CLCPA



~11.5 GW of **land-based renewables**
~4.1 GW of **offshore wind**
~3.3 GW of **distributed energy resources**

Needs to be contracted and constructed by 2030

2,066 MW of energy storage needs to be contracted and constructed by 2030

~4.1 GW of **land-based renewables**
~1.8 GW of **offshore wind**
~2.4 GW of **distributed energy resources**

Under Contract with NYS, needs to be constructed

841 MW of energy storage Under Contract/Construction

Currently generating renewable electricity for NYS

93 MW of Energy Storage Currently Operating (+ 1,400 MW of Pumped Hydro Storage, which does not count towards the Goal)

Accelerated Renewable Energy Growth and Community Benefit Act

- **Three Major Components:**
  - Office of Renewable Energy Siting
  - Clean Energy Resources Development and Incentives (Build-Ready) Program
  - State Power Grid Study and Program
- **The Act will:**
  - advance renewable energy, drive statewide economic growth, and create jobs
  - streamline the process for environmentally responsible and cost-effective siting of large-scale renewable energy projects across the State
  - establish tools for achieving the State mandate to obtain 70 percent of the State's electricity from renewable sources by 2030 and other nation-leading goals of the Climate Leadership and Community Protection Act

Clean Energy Standard Expansion

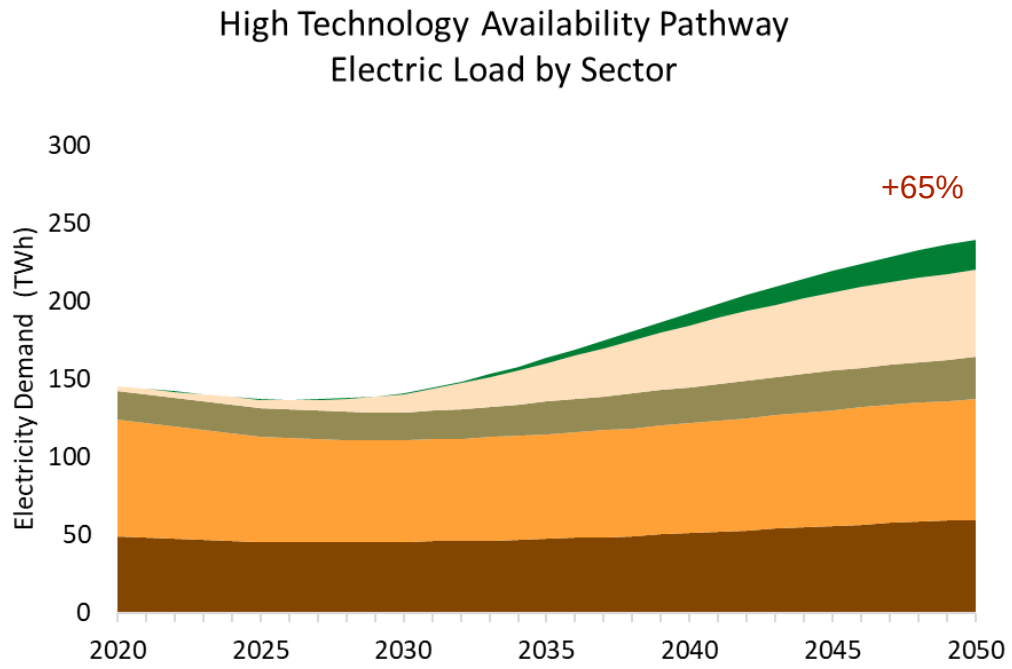
- **Alignment with the CLCPA**
  - Adopts 70 by 30 Goal on the path to 100 by 40
  - Narrows definition of Renewable Energy (per CLCPA)
- **Procurement Targets**
  - Tier 1 Land Based Renewables (Annual Procurements of ~4,500 GWh 2021 – 2026)
  - Offshore Wind (Annual Procurements of ~4,500 GWh from 2020 – 2023)
- **Tier 4 Proposal – Renewables in Zone J, including Canadian Hydropower**
- **Competitive Tier 2 Petition – For Existing Renewables**
- **Repowering Proposal**

Pathways Presentation – E3

Electricity Demand

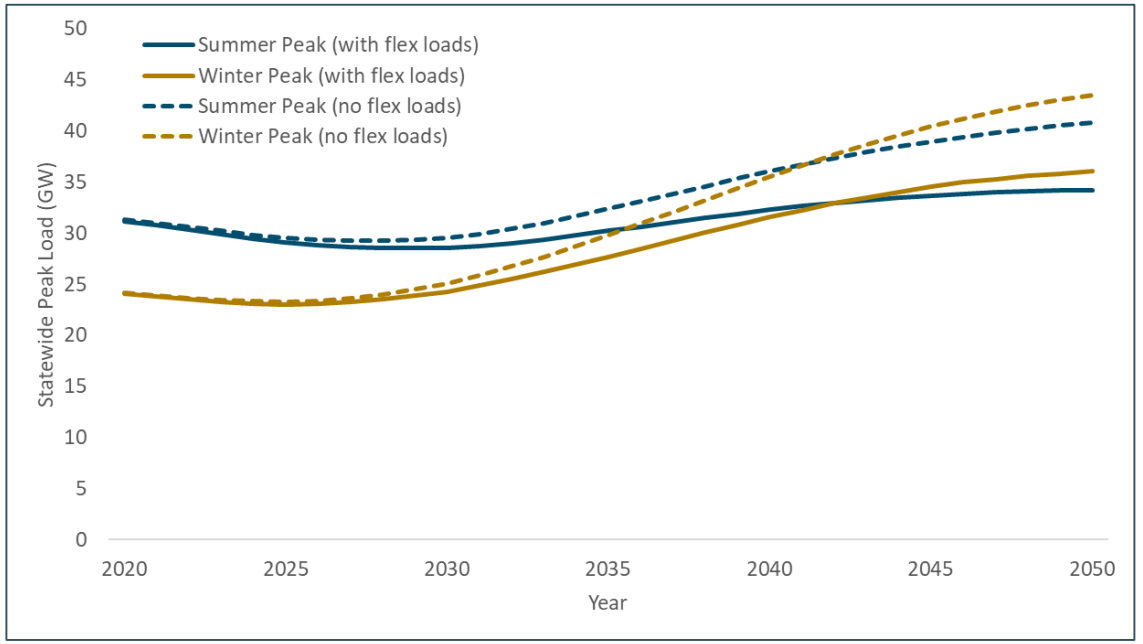
+ Electrification of buildings and transportation drives significant increase in annual electric load

- Analysis within range found in the literature, which project annual load increases ranging 20%–100% by midcentury
- Range primarily reflects extent and timing of end-use electrification, with some studies assuming lower electrification and larger role for renewable gas and/or renewable transportation fuels



+ NYS shifts from summer peak to winter peak around 2040, driven primarily by electrification of heating in buildings and EV battery charging

- Flexibility in electric vehicles and building loads can significantly reduce peak demands and the need for new generation capacity
- Flexible loads can also serve a similar role to battery storage, shifting demand to times of high renewables output



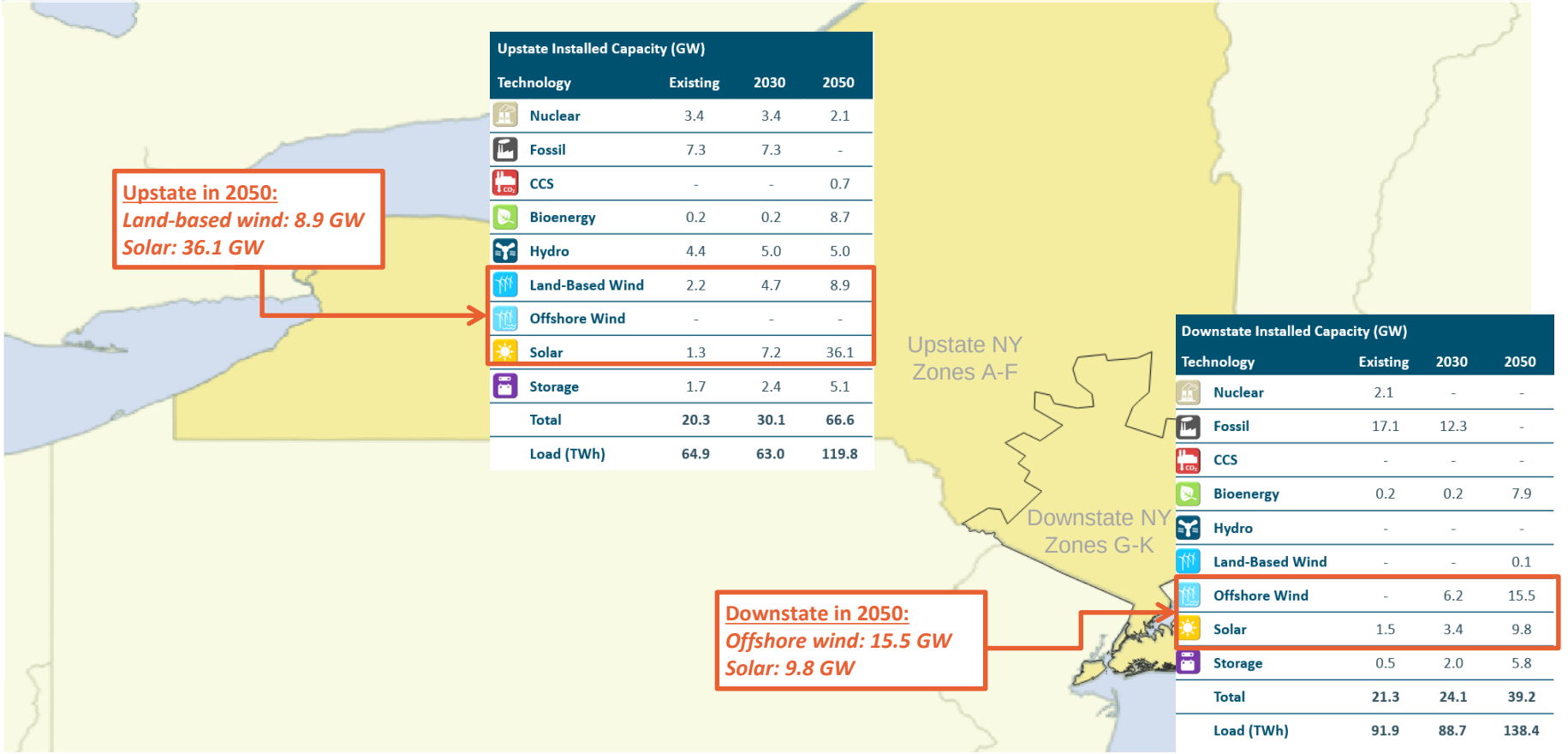
Opportunities to Decarbonize the Electricity Sector

- **Energy efficiency and managed electrification will be critical to mitigating load growth and "peak heat" impacts**
- **To decarbonize electricity supply, New York has access to a diverse portfolio of renewable resources**
- **Battery storage and demand-side flexibility can play a key role in intraday balancing**
- **A number of firm, zero-carbon resources can help solve interday balancing challenges, e.g. multi-day periods of low renewable output**

Resource Type	Examples
Thermal Generation	• Nuclear • Simple cycle combustion turbines (CTs) or combined cycle gas turbines (CCGTs) utilizing zero-carbon fuels • CCGTs with CCS
Renewable Generation	• In-state hydro • Hydro imports • Solar PV (utility-scale and distributed) • Wind (onshore & offshore)
Energy Storage	• Battery storage (>1hr) • Pumped storage (>12hr)
Customer Technologies	• Energy efficiency • Flexible loads

Electricity Supply

- New York State has significant potential renewable energy resources and zero-carbon technology options, as well as access to adjoining states, provinces, and regional transmission systems, which offer additional options for energy supply.
- Significant in-state renewable development will require careful siting considerations



Upstate Installed Capacity (GW)

Technology	Existing	2030	2050
Nuclear	3.4	3.4	2.1
Fossil	7.3	7.3	-
CCS	-	-	0.7
Bioenergy	0.2	0.2	8.7
Hydro	4.4	5.0	5.0
Land-Based Wind	2.2	4.7	8.9
Offshore Wind	-	-	-
Solar	1.3	7.2	36.1
Storage	1.7	2.4	5.1
Total	20.3	30.1	66.6
Load (TWh)	64.9	63.0	119.8

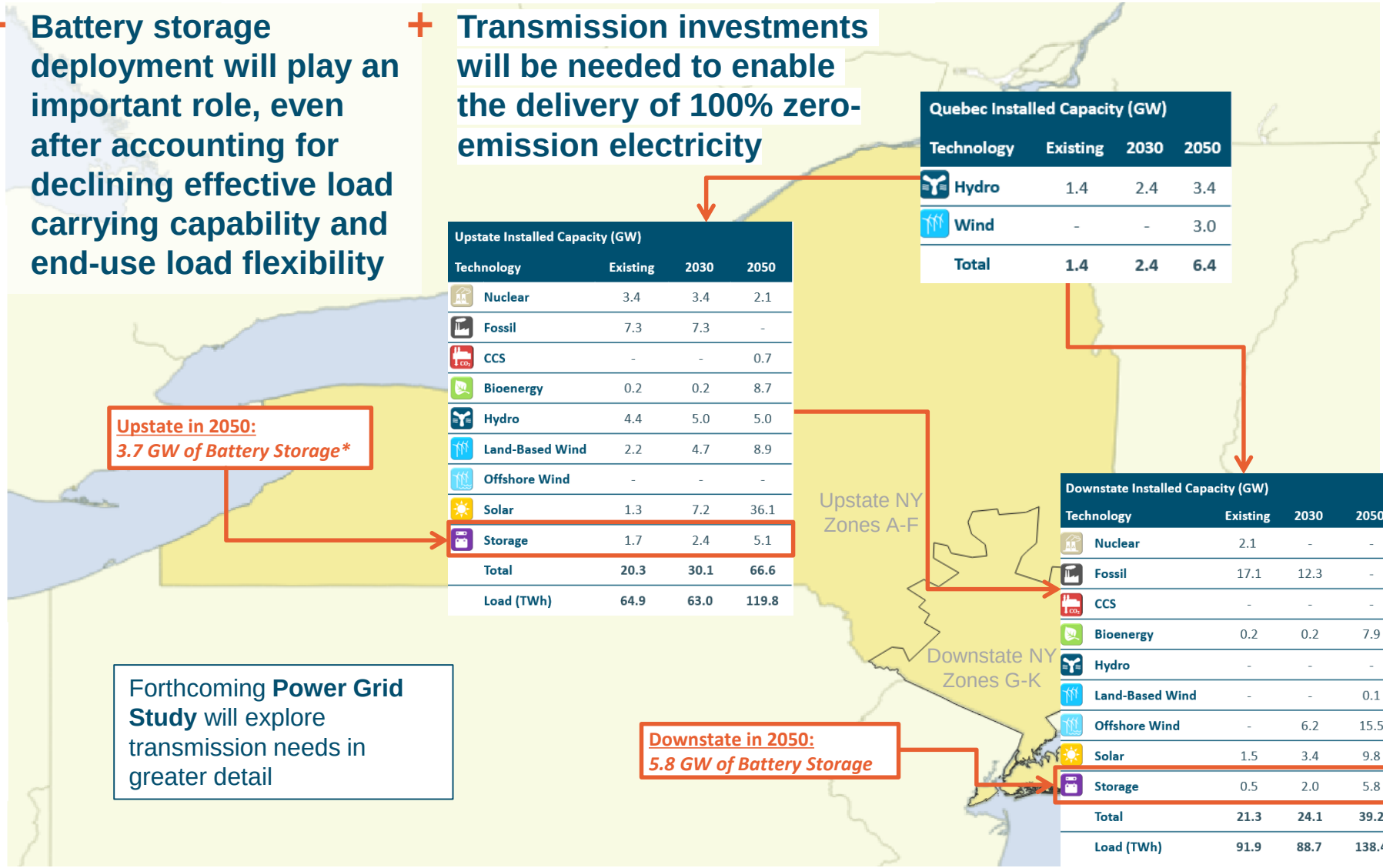
Downstate Installed Capacity (GW)

Technology	Existing	2030	2050
Nuclear	2.1	-	-
Fossil	17.1	12.3	-
CCS	-	-	-
Bioenergy	0.2	0.2	7.9
Hydro	-	-	-
Land-Based Wind	-	-	0.1
Offshore Wind	-	6.2	15.5
Solar	1.5	3.4	9.8
Storage	0.5	2.0	5.8
Total	21.3	24.1	39.2
Load (TWh)	91.9	88.7	138.4

Electricity Supply

+ **Battery storage deployment will play an important role, even after accounting for declining effective load carrying capability and end-use load flexibility**

+ **Transmission investments will be needed to enable the delivery of 100% zero-emission electricity**



Quebec Installed Capacity (GW)

Technology	Existing	2030	2050
Hydro	1.4	2.4	3.4
Wind	-	-	3.0
Total	**1.4**	**2.4**	**6.4**

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Upstate in 2050:
3.7 GW of Battery Storage*

Downstate in 2050:
5.8 GW of Battery Storage

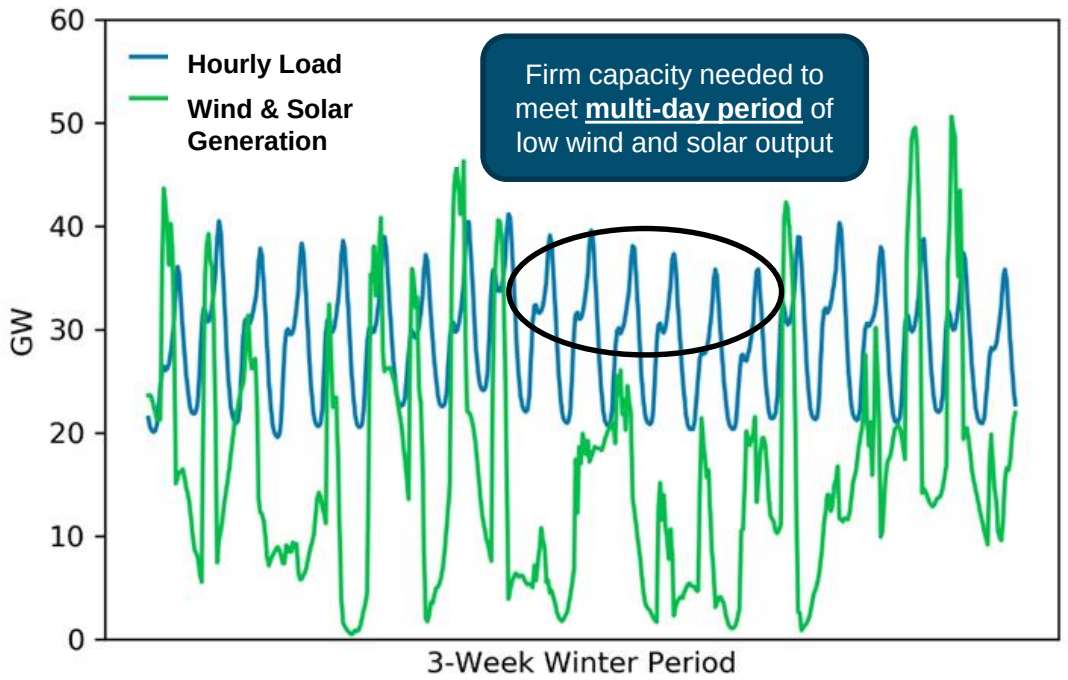
Forthcoming **Power Grid Study** will explore transmission needs in greater detail

*Total 5.1 GW includes existing pumped storage capacity

Electricity Supply – Firm Capacity

- As the share of intermittent resources like wind and solar grows substantially, some studies suggest that complementing with firm, zero-emission resources, such as bioenergy, synthesized fuels such as hydrogen, hydropower, carbon capture and sequestration, and nuclear generation could provide a number of benefits[1,2,3]
- The need for dispatchable resources is most pronounced during winter periods of high demand for electrified heating and transportation and lower wind and solar output

NYS Electric Load and Wind + Solar Generation in 2050 Pathway



Hourly loads based on six years of historical weather 2007-2012

[1] Sepulveda, N., J. Jenkins, F. de Sisternes, R. Lester. (2018) The Role of Firm Low-Carbon Electricity Resources in Deep Decarbonization of Power Generation. Joule, 2(11), pp. 2403-2420. DOI: https://doi.org/10.1016/j.joule.2018.08.006.
[2] Jenkins, J., M. Luke, S. Thernstrom. (2018) Getting to Zero Carbon Emissions in the Electric Power Sector. Joule, 2(12), pp. 2498-2510. DOI: https://doi.org/10.1016/j.joule.2018.11.013.
[3] E3. 2019. Resource Adequacy in the Pacific Northwest. https://www.ethree.com/wp-content/uploads/2019/03/E3_Resource_Adequacy_in_the_Pacific-Northwest_March_2019.pdf

Work Plan Development

Advisory Panel Work Product

- **Develop sector-specific strategies to achieve 53–56% reduction in GHG emissions from 2016 level by 2030 (100% by 2050)**
- **Present a list of recommendations for emissions reducing policies, programs or actions, for consideration by the Climate Action Council for inclusion in the Scoping Plan.**
  - Recommendations should identify the estimated scale of impact, knowable costs to achieve, ease of deployment or commercial availability, potential co-benefits to emissions reduction, advancement of climate justice outcomes, and impacts to businesses.
  - Recommendations may be informed by quantitative analysis or qualitative assessment.
- **Produce sector-based recommendations.**
  - The Panels should not rely on economy-wide policies to achieve emission reduction goals but can recommend that the Council consider economy-wide policies if needed to advance certain sector-specific policies.
  - Cross-sector recommendations should be advanced only after consultation with the appropriate Panels (e.g. beneficial electrification and/or fossil fuel transitions with Transportation and Energy Efficiency/Housing, or renewables siting with Land Use & Local Governments)

Advisory Panel Expectations

Each Advisory Panel shall:

- **Meet at least once per month and provide regular updates to the Council on the advancement of its work.**
  - Present (oral or written) progress reports at Council meetings and solicit feedback.
  - Provide final recommendations in accordance with the Scoping Plan development schedule.
- **Consult with the Climate Justice and Just Transition Working Groups to inform its recommendations for the Climate Action Council.**
- **Seek public input to inform the development of recommendations to the Council for consideration.**
  - Panels may seek input from selected expertise in a subject area, as determined necessary by the members.
  - Panels shall, during the next six months, hold at least one forum to receive broad-based public input.
  - Provide transparency by making meetings open to public viewing and/or publishing minutes of deliberations.
- **Make available information regarding advisory panel public meetings and comment opportunities on the climate.ny.gov webpage.**

Recommendations Overview

- **Evaluate the costs and benefits of recommended strategies, informed by the Value of Carbon established in accordance with Section 75-0113 of the CLCPA.**
- **Identify measures to reduce greenhouse gas emissions and co-pollutants in disadvantaged communities**
- **Include climate adaptation and resilience considerations.**
- **Consider approaches taken by different states and nations.**
- **Identify potential sources of funding necessary to implement the recommended policies.**

Scope Development – Initial Thoughts

- **Clean Energy Siting**
- **Transmission**
- **Electrification of Buildings and Transportation**
- **Natural Gas System**
- **Carbon Pricing**
- **Downstate Peakers**
- **Equity Issues**
- **Reliability of the Future Grid – Storage, Flexible/Dispatchable Resources**
- **Instate Renewables**
- **Downstate Renewables**
- **"Last" Clean Megawatts (Final X%)**
- **Resource Transition/Ramping Fossils Down**
- **Encouraging the Needed Investment**
- **Markets for the Future (Including Resource Adequacy)**
- **Affordability**
- **Jobs/Prevailing Wage**

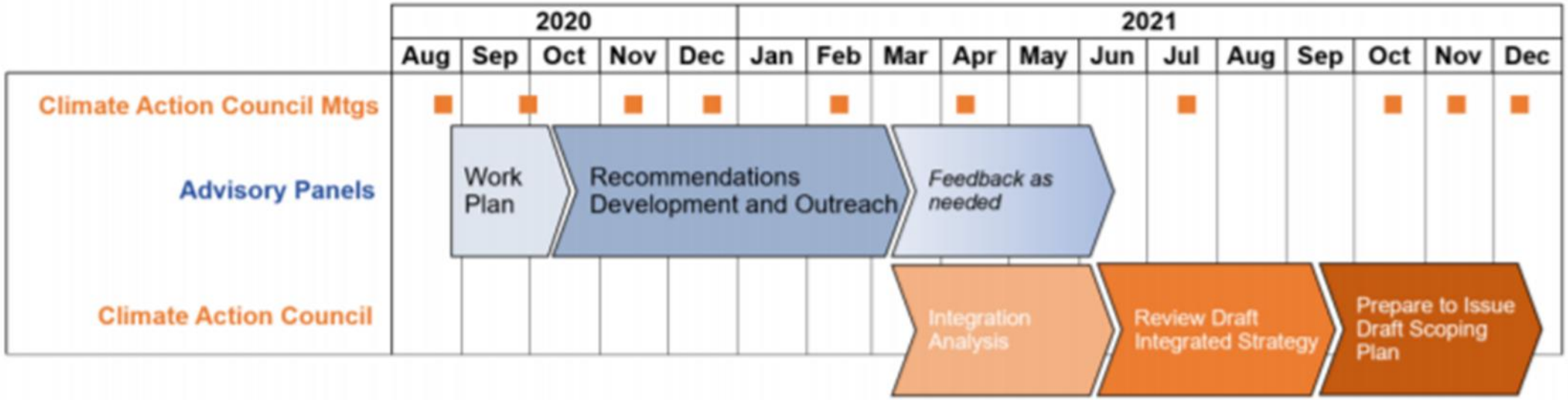
Timeline

> **Important Deadlines:**

October 2020: Work Plan finalized

December 2020: Briefing on priority policies/strategies

March 2021: Final Recommendations to CAC



Timeline of Advisory Panel Work

	Oct. 2020	Nov. 2020	Dec. 2020	Jan. 2021	Feb. 2021	Mar. 2021
Milestones	**Finalized Work Plan**		**Briefing for CAC and CJWG on priority policies/ strategies**			**Final Recommendations to CAC**
External Engagement	Seek written input on priority policies/ strategies	Collaboration with outside experts		Open public forum on priority policies/ strategies under consideration		
Meetings with CJWG and EJAP	Seek written input on priority policies/ strategies			Seek input on priority policies/ strategies under consideration		
Briefings of Council	Present Work Plan	Seek input on priority policies/strategies and progress towards Recommendations			Seek input from Council on progress	Present Recommendations

Next Steps

Next Steps: For Discussion

- **Any topic adds, at this stage of meeting?**
- **How do we want to calendar and organize meetings?**
- **Desired information that Panel members would like to receive?**
- **What thoughts on our public engagement session(s)? (Must have at least one)**
- **Interaction with the Climate Justice Working Group and the Environmental Justice Advisory Panel**
- **Briefings for Council**
- **Schedule and methods for exchange and review of drafts**
- **What cross-sectoral issues can we anticipate/identify now?**
- **Other points?**

Appendix

Full Power Generation Presentation – E3

Energy+Environmental Economics

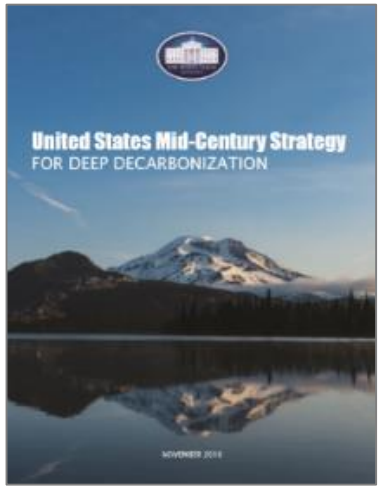
New York State Decarbonization Pathways Analysis

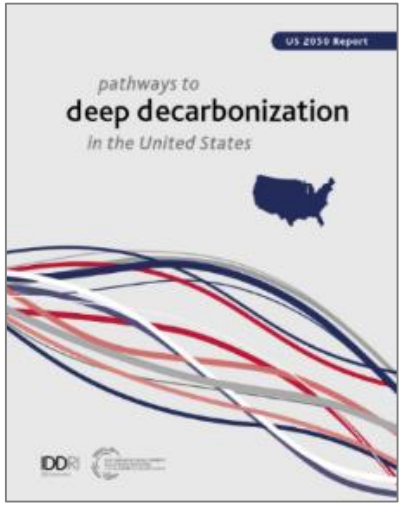
Power Generation Advisory Panel Discussion

September 16, 2020

Analysis Overview

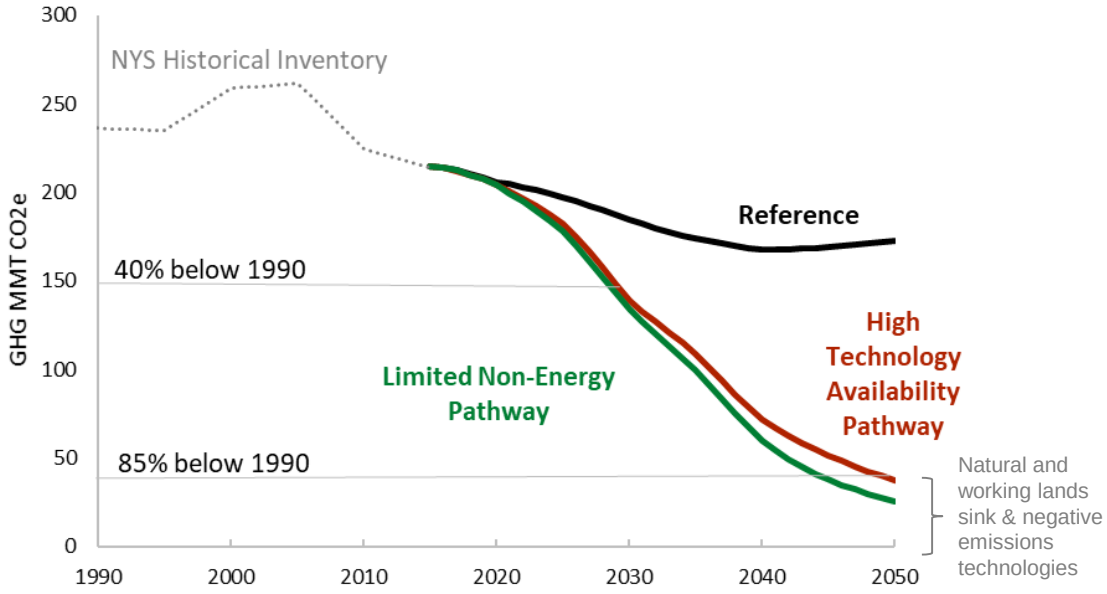
- NYSERDA engaged E3 to develop a strategic analysis of New York's decarbonization opportunities. This ongoing analytic work, initiated prior to the passage of the CLCPA, has modeled existing policies and explored additional actions needed to reach the State's 2030 and 2050 targets and provides a starting point to inform the work of the Climate Action Council
- E3 reviewed the literature on deep decarbonization and highly renewable energy systems and gained additional insights from discussions with leading subject matter experts
- Further work will be needed to fully incorporate GHG accounting requirements of the CLCPA and re-calibrate to DEC's forthcoming rulemaking establishing the statewide GHG emission limits





Scenario Development

- **Reference Case** includes **pre-** CLCPA adopted policies & goals, including 50x30 Clean Energy Standard, 2025 and 2030 energy efficiency targets, zero-emission vehicle mandate
- Range of **pathways** designed to achieve CLCPA GHG targets that include CLCPA electric sector provisions (e.g., 70x30, 100x40, offshore wind & solar)
- **Two "Starting Point" Pathways:**



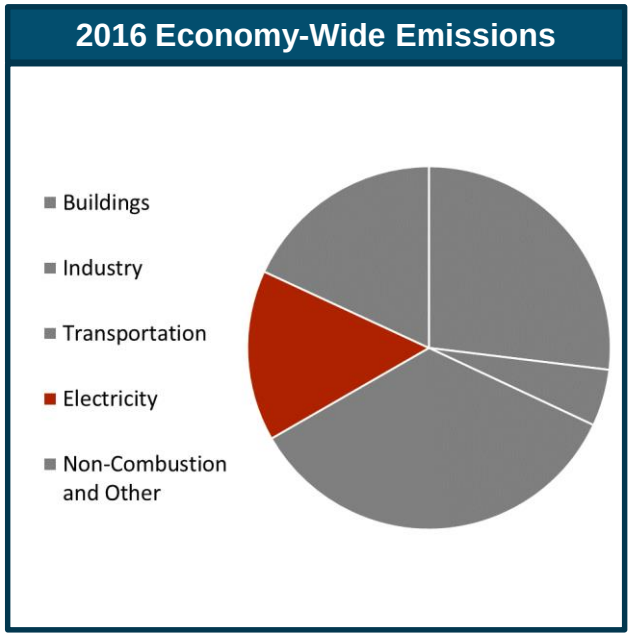
  - **High Technology Availability Pathway:** Emphasizes efficiency and electrification at "natural" end-of-life asset replacement schedule, while also utilizing advanced biofuels, carbon capture and storage (CCS), bioenergy with carbon capture and storage (BECCS), and a high natural and working lands (NWL) sink
  - **Limited Non-Energy Pathway:** Accelerates electrification with more rapid ramp-up of new sales, along with early retirements of older fossil vehicles and building equipment. Additional fossil fuel displacement by advanced biofuels. Greater energy sector emission reductions in case of more limited non-energy reductions and NWL sink contribution

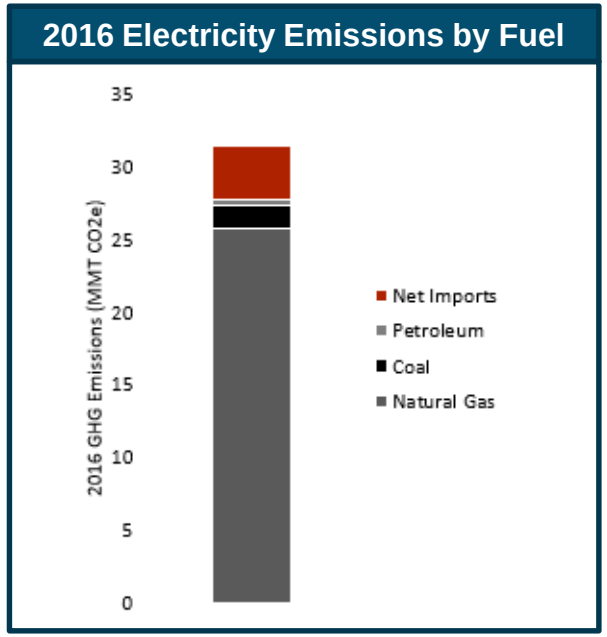
Energy+Environmental Economics

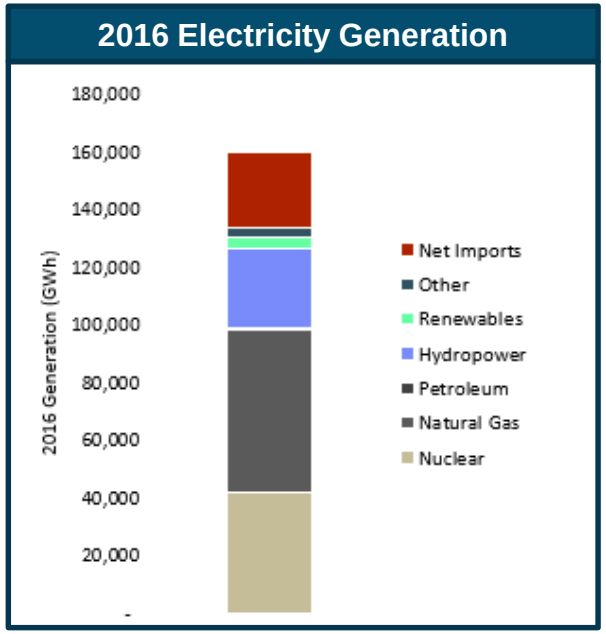
Characterization of the Power Generation Sector

Electric Sector Emissions

- **CLCPA directs New York State to adopt a 20-year global warming potential and incorporate upstream emissions associated with fossil fuels into its GHG emissions accounting framework.**
  - Work to develop this emissions accounting framework is underway. Under this new emissions accounting framework, fossil fuel use, as well as all sources of short-lived climate pollutants, which include methane and HFCs, will carry a higher GHG impact on a tons of carbon dioxide equivalent basis than in the current accounting framework used in this analysis
- **With coal phased out of the electricity mix, natural gas represents primary source of emissions from power generation**
- **Non-hydro renewables represent small share of current generation and need to be scaled up rapidly to meet 70x30 target**





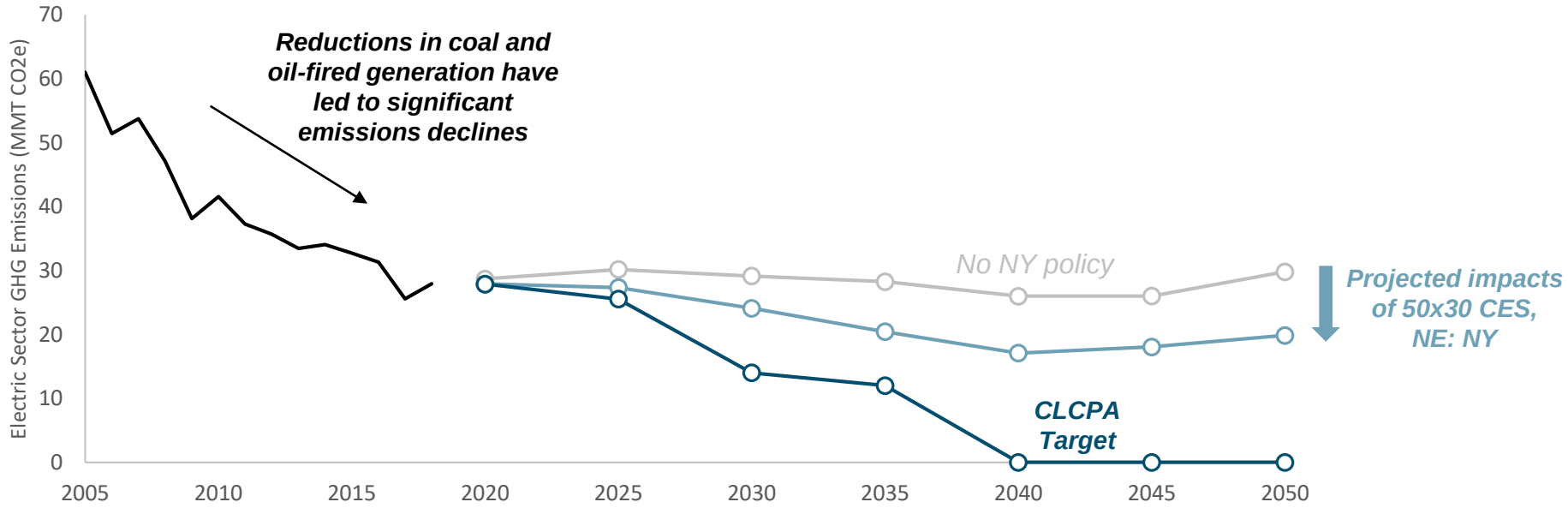


Notes: SF6 associated with transmission and distribution is accounted for in Industrial Processes in the NY GHG Inventory

Electric Sector Emissions Over Time

- Emissions have been dropping primarily as a result of eliminating coal and reducing oil-fired generation in the New York system
- Load is projected to decline over the forecast period as a result of New York's energy efficiency investments
- In the absence of the CLCPA, renewable capacity additions occur primarily in the 2020-2030 timeframe to meet 50x30 CES goal and technology-specific targets

New York Electric Sector Emissions



Energy+Environmental Economics

Opportunities for Decarbonization

Pillars of Deep Decarbonization in Electricity

Energy Efficiency and Conservation

+ Demand-side energy efficiency will be key to mitigating impacts of electrification
+ Building shell measures and balanced heat pump adoption can reduce “peak heat” impacts of building electrification

Switching to Low Carbon Fuels

+ Electrification of buildings and transportation will drive significant load growth
+ Renewable natural gas and hydrogen can serve as zero-carbon fuels for existing gas generators, providing key source of firm, zero-carbon capacity

Decarbonizing Electricity Supply

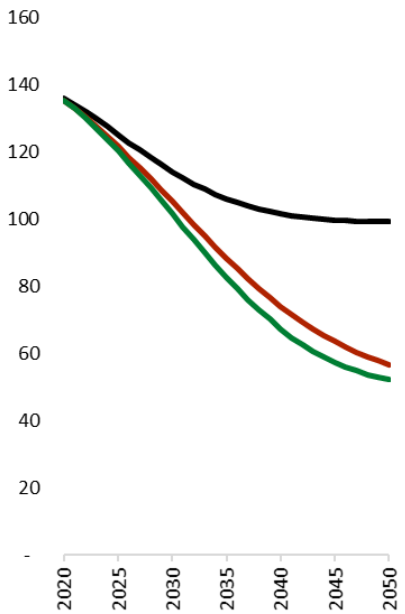
+ Transforming New York’s electricity supply to a zero-carbon system will be the lynchpin of economy-wide decarbonization
+ New York can rely on a diverse mix of resources, including wind, solar, nuclear, hydro, onshore and offshore wind, hydro, CCS, biofuels, hydrogen, battery storage, and others

Pillars of Carbon Neutrality

Energy Efficiency and Conservation

[site energy consumed per person]

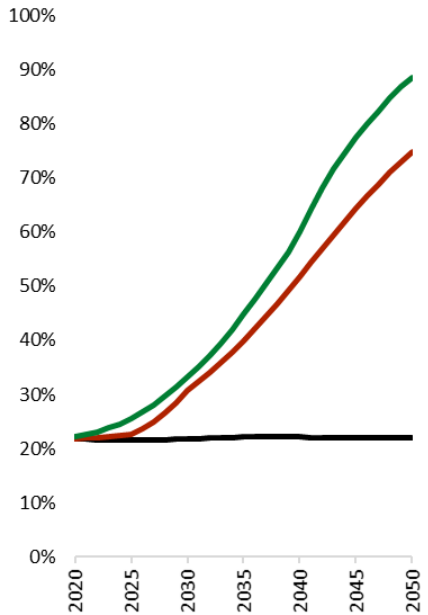
Unit: MMBTU/capita



Switching to Low Carbon Fuels

[% site energy consumed as electricity, biofuels, hydrogen, synthetic fuels]

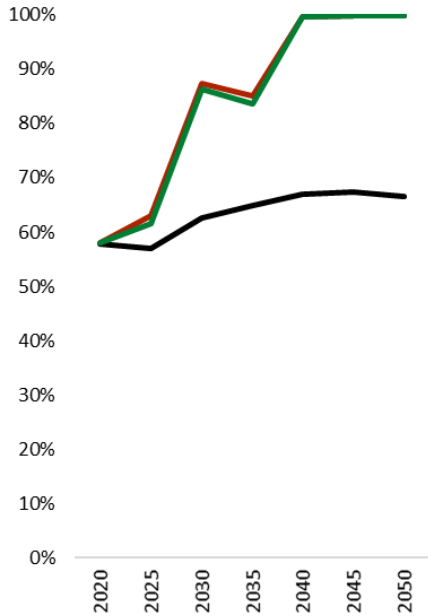
Unit: % site energy consumed



Decarbonizing Electricity Supply

[% electricity supplied by wind, solar, hydro, nuclear, CCS, biofuels, hydrogen]

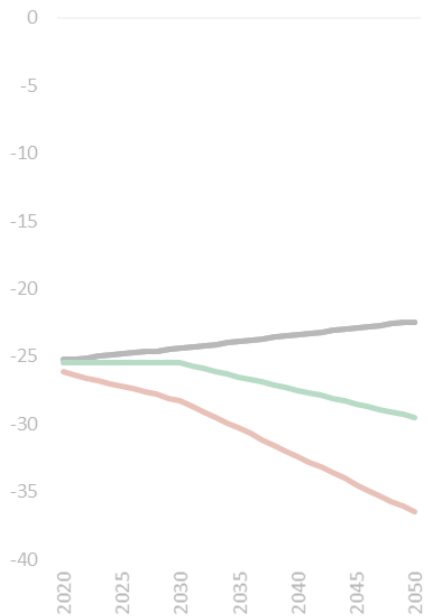
Unit: % electricity supplied



Negative Emissions

[total emission reductions from net land use sink, BECCS, DAC]

Unit: MMT CO2e



Reference Case High Technology Availability Pathway Limited Non-Energy Pathway

Opportunities to Decarbonize the Electricity Sector

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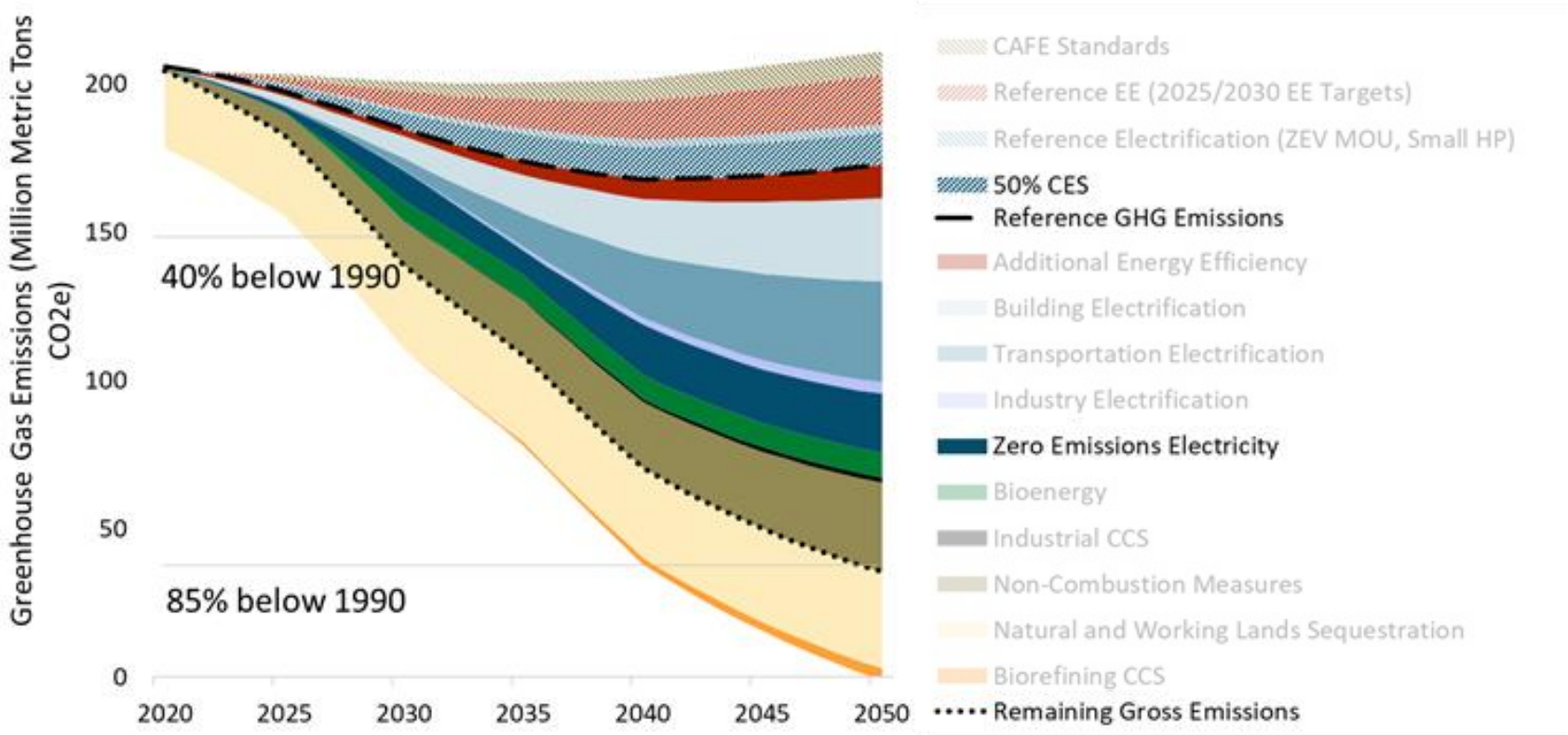
Energy Storage	• Battery storage (>1hr) • Pumped storage (>12hr)
Customer Technologies	• Energy efficiency • Flexible loads

Energy+Environmental Economics

Sectoral Findings

Emissions Reductions by Measure

High Technology Availability Pathway

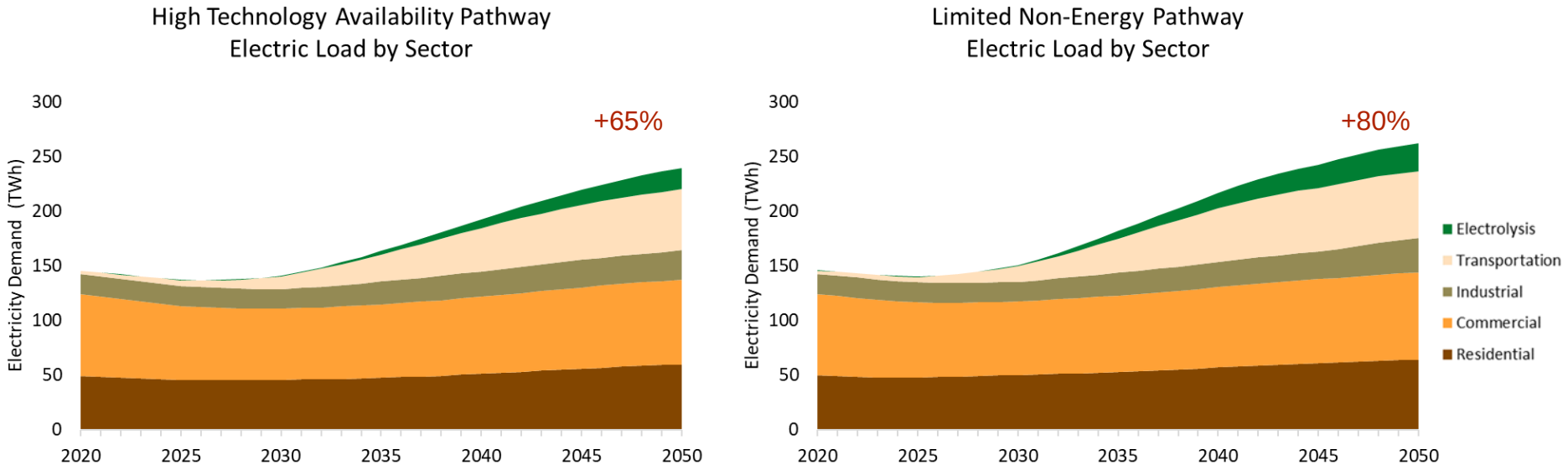


+ **Zero carbon electricity is a lynchpin of pathways to reach CLCPA goals**

Annual Electricity Demand

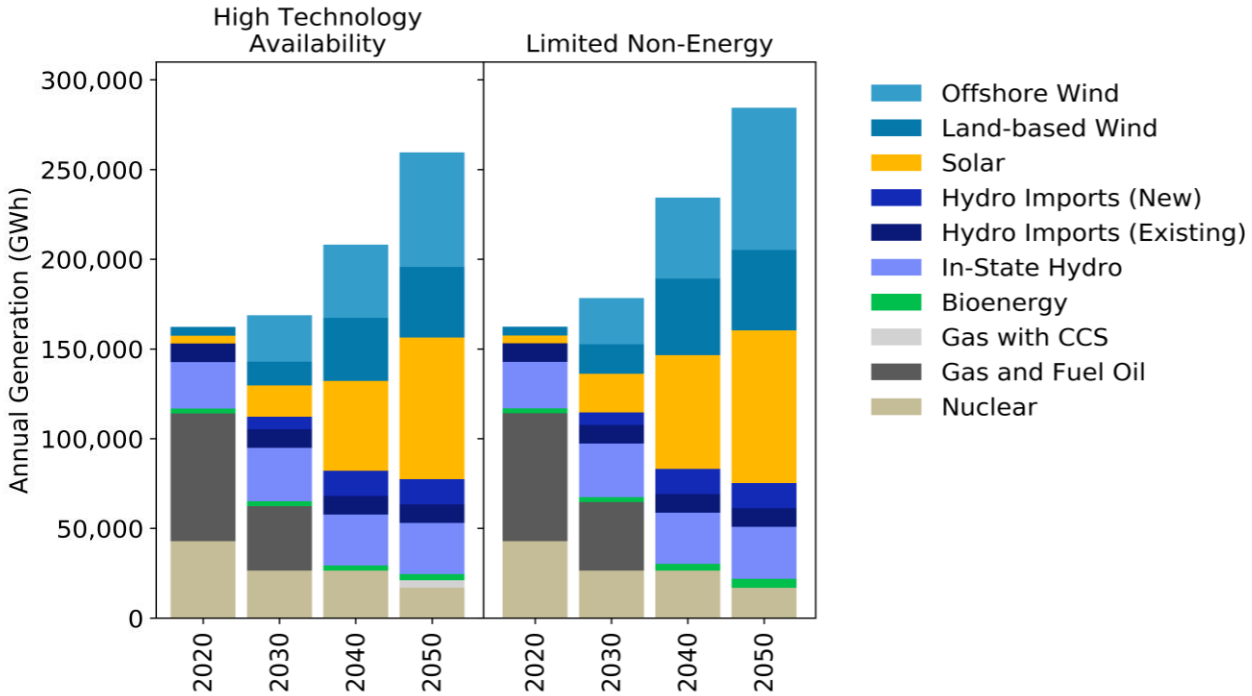
+ Electrification of buildings and transportation drives significant increase in electric load

- Analysis within range found in the literature, which project annual load increases ranging 20%-100% by midcentury
- Range primarily reflects extent and timing of end-use electrification, with some studies assuming lower electrification and larger role for renewable gas and/or renewable transportation fuels



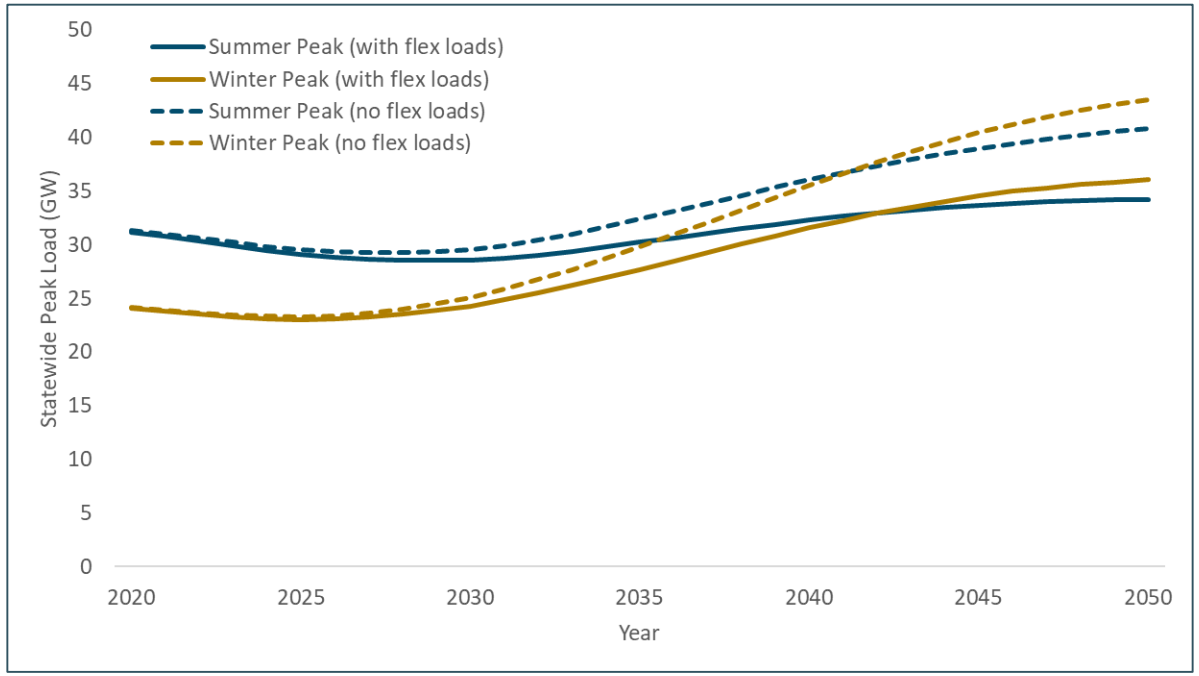
Decarbonization of the Electricity Sector

- To decarbonize electricity supply, New York must meet rapidly growing loads while transforming
- Battery storage and demand-side flexibility can play a key role in balancing output of high levels of variable renewables



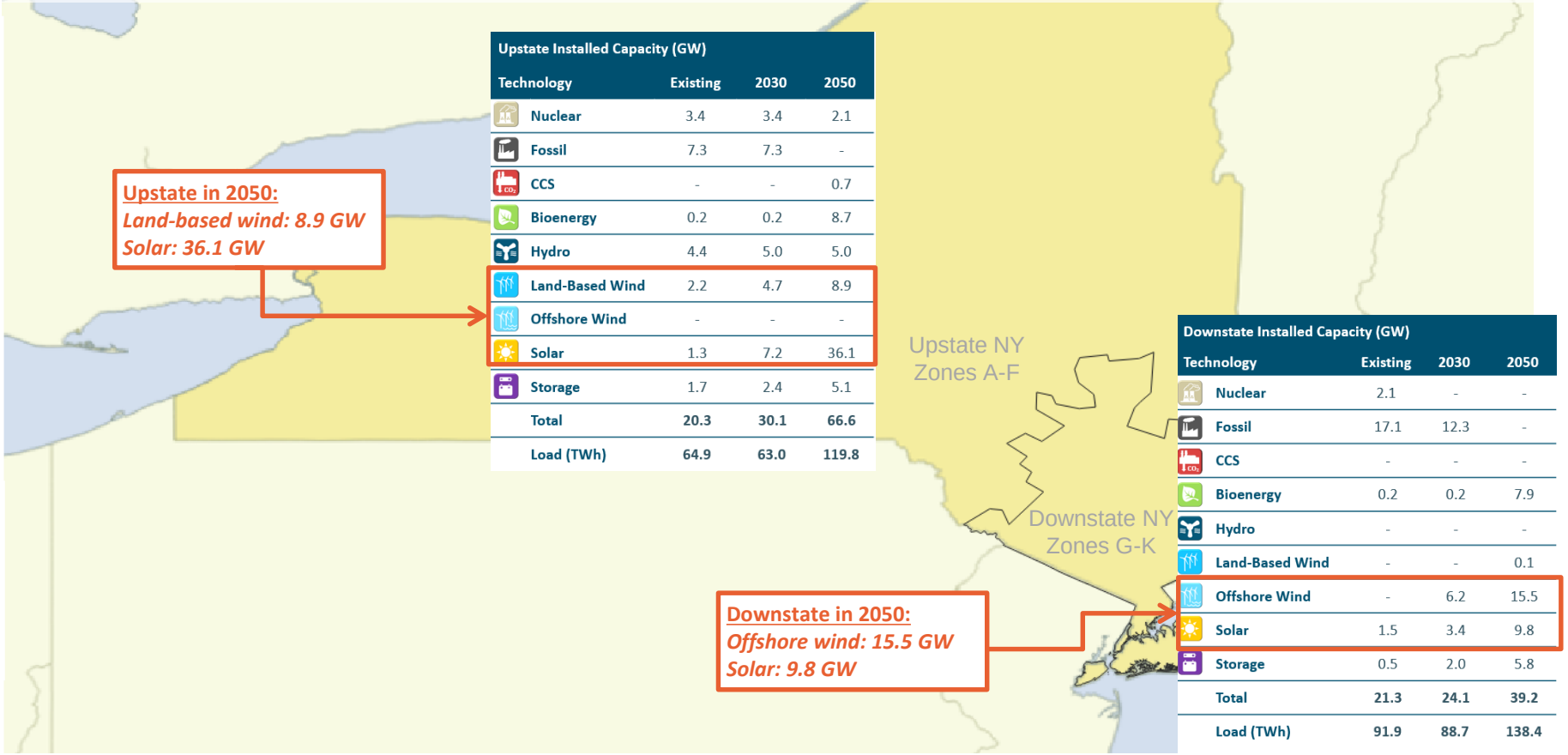
Peak Electricity Demand

- NYS shifts from summer peak to winter peak around 2040, driven primarily by electrification of heating in buildings and EV battery charging
- Flexibility in electric vehicles and building loads can significantly reduce peak demands and the need for new generation capacity



Electricity Supply

- New York State has significant potential renewable energy resources and zero-carbon technology options, as well as access to adjoining states, provinces, and regional transmission systems, which offer additional options for energy supply.
- Significant in-state renewable development will require careful siting considerations



Upstate Installed Capacity (GW)

Technology	Existing	2030	2050
Nuclear	3.4	3.4	2.1
Fossil	7.3	7.3	-
CCS	-	-	0.7
Bioenergy	0.2	0.2	8.7
Hydro	4.4	5.0	5.0
Land-Based Wind	2.2	4.7	8.9
Offshore Wind	-	-	-
Solar	1.3	7.2	36.1
Storage	1.7	2.4	5.1
Total	20.3	30.1	66.6
Load (TWh)	64.9	63.0	119.8

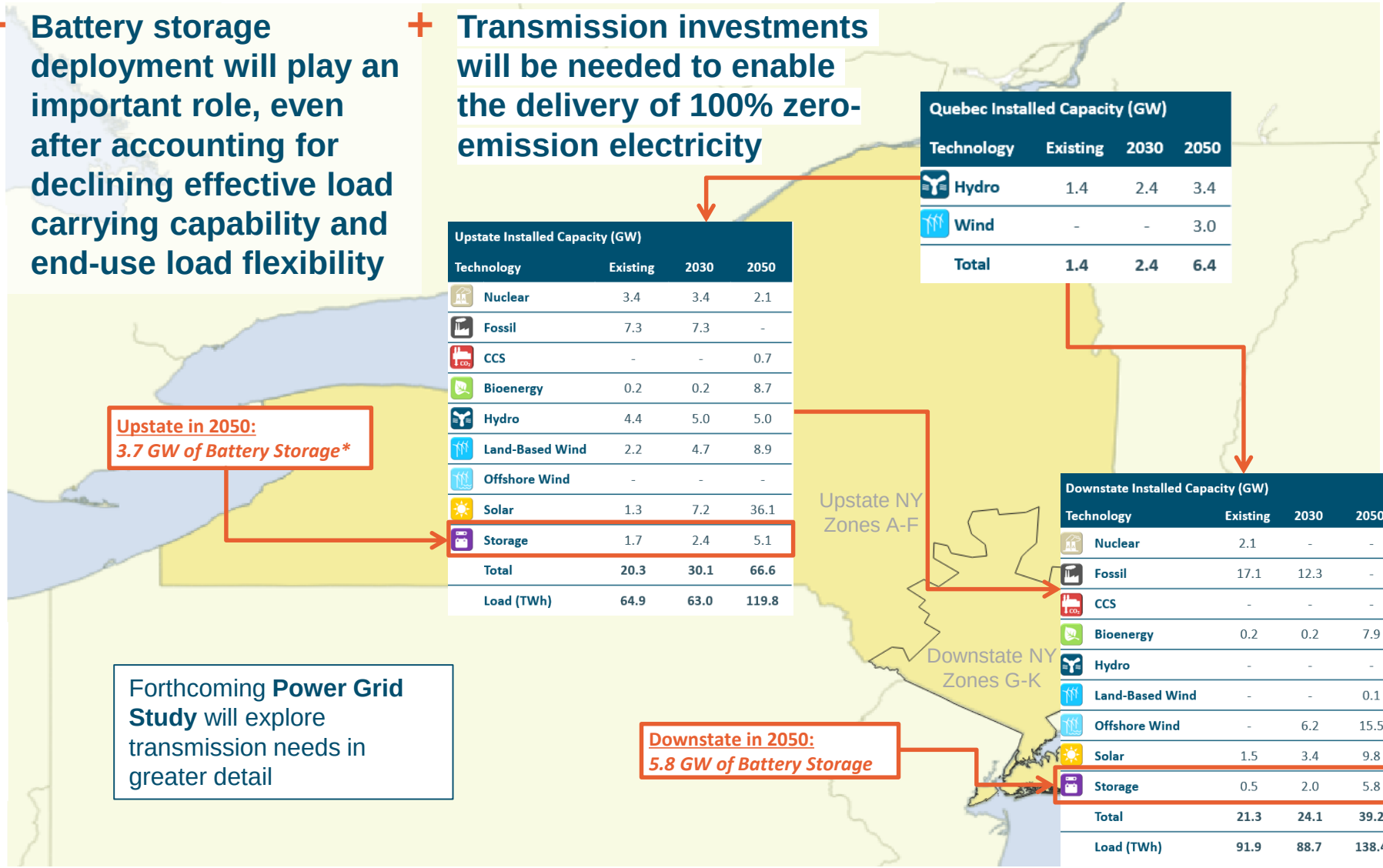
Downstate Installed Capacity (GW)

Technology	Existing	2030	2050
Nuclear	2.1	-	-
Fossil	17.1	12.3	-
CCS	-	-	-
Bioenergy	0.2	0.2	7.9
Hydro	-	-	-
Land-Based Wind	-	-	0.1
Offshore Wind	-	6.2	15.5
Solar	1.5	3.4	9.8
Storage	0.5	2.0	5.8
Total	21.3	24.1	39.2
Load (TWh)	91.9	88.7	138.4

Electricity Supply

+ **Battery storage deployment will play an important role, even after accounting for declining effective load carrying capability and end-use load flexibility**

+ **Transmission investments will be needed to enable the delivery of 100% zero-emission electricity**



Quebec Installed Capacity (GW)

Technology	Existing	2030	2050
Hydro	1.4	2.4	3.4
Wind	-	-	3.0
Total	**1.4**	**2.4**	**6.4**

Upstate Installed Capacity (GW)

Technology	Existing	2030	2050
Nuclear	3.4	3.4	2.1
Fossil	7.3	7.3	-
CCS	-	-	0.7
Bioenergy	0.2	0.2	8.7
Hydro	4.4	5.0	5.0
Land-Based Wind	2.2	4.7	8.9
Offshore Wind	-	-	-
Solar	1.3	7.2	36.1
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Total	**20.3**	**30.1**	**66.6**
Load (TWh)	**64.9**	**63.0**	**119.8**

Downstate Installed Capacity (GW)

Technology	Existing	2030	2050
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Total	**21.3**	**24.1**	**39.2**
Load (TWh)	**91.9**	**88.7**	**138.4**

Upstate in 2050:
3.7 GW of Battery Storage*

Downstate in 2050:
5.8 GW of Battery Storage

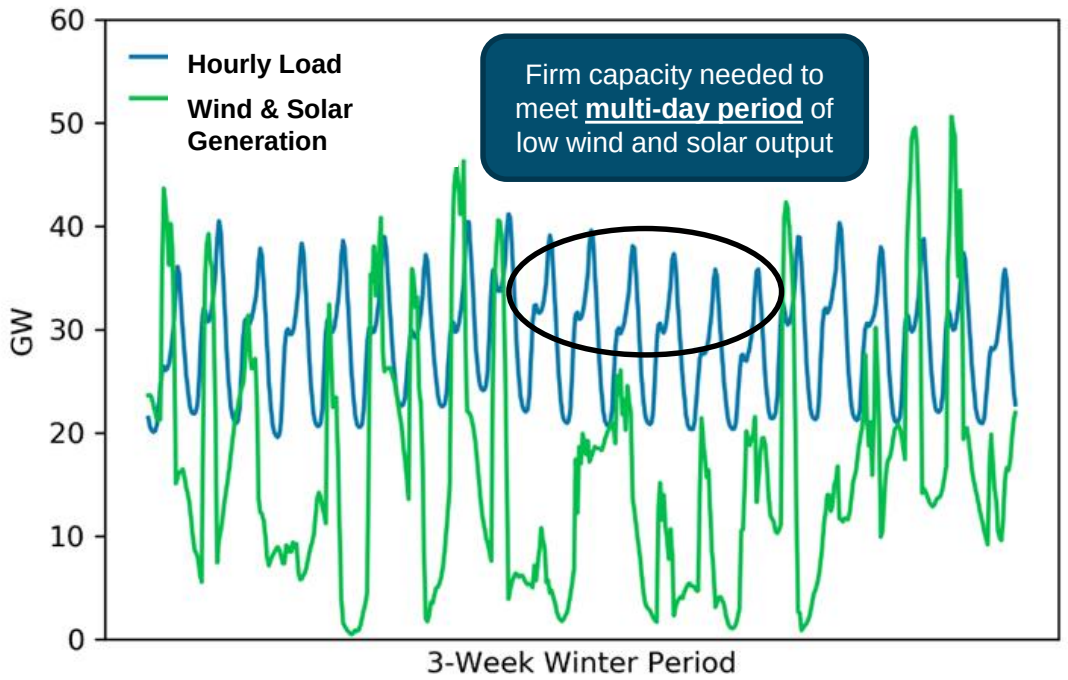
Forthcoming **Power Grid Study** will explore transmission needs in greater detail

*Total 5.1 GW includes existing pumped storage capacity

Electricity Supply – Firm Capacity

- As the share of intermittent resources like wind and solar grows substantially, some studies suggest that complementing with firm, zero-emission resources, such as bioenergy, synthesized fuels such as hydrogen, hydropower, carbon capture and sequestration, and nuclear generation could provide a number of benefits[1,2,3]
- The need for dispatchable resources is most pronounced during winter periods of high demand for electrified heating and transportation and lower wind and solar output

NYS Electric Load and Wind + Solar Generation in 2050 Pathway

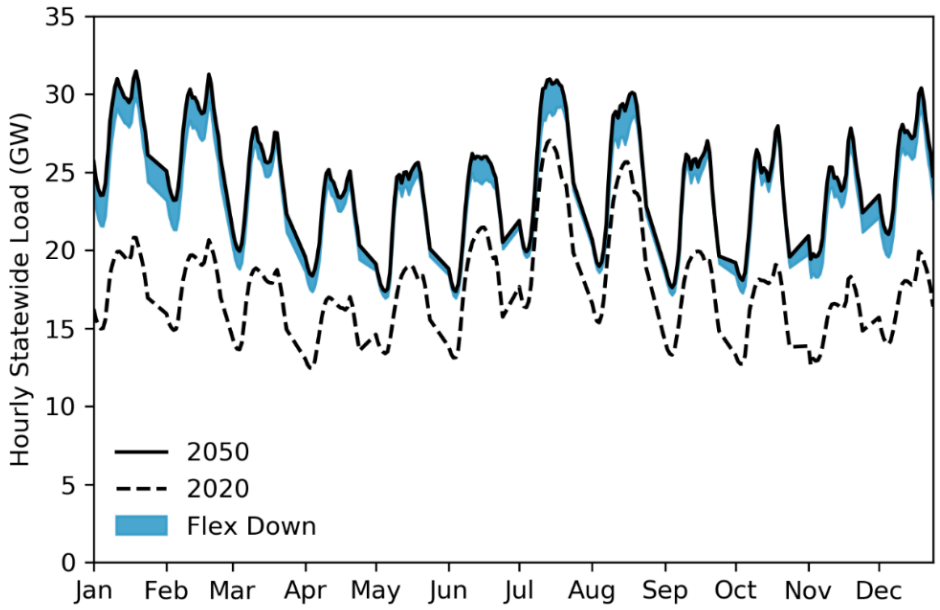


Hourly loads based on six years of historical weather 2007-2012

[1] Sepulveda, N., J. Jenkins, F. de Sisternes, R. Lester. (2018) The Role of Firm Low-Carbon Electricity Resources in Deep Decarbonization of Power Generation. Joule, 2(11), pp. 2403-2420. DOI: https://doi.org/10.1016/j.joule.2018.08.006.
[2] Jenkins, J., M. Luke, S. Thernstrom. (2018) Getting to Zero Carbon Emissions in the Electric Power Sector. Joule, 2(12), pp. 2498-2510. DOI: https://doi.org/10.1016/j.joule.2018.11.013.
[3] E3. 2019. Resource Adequacy in the Pacific Northwest. https://www.ethree.com/wp-content/uploads/2019/03/E3_Resource_Adequacy_in_the_Pacific-Northwest_March_2019.pdf

Peak Electricity Demand

- NYS shifts from summer peak to winter peak around 2040, driven primarily by electrification of heating in buildings and EV battery use
- Flexibility in electric vehicles and building loads can significantly reduce peak demands and the need for new generation capacity
- Flexible loads can also serve a similar role to battery storage, shifting demand to times of high renewables output



Note: the chart above contains a 24-hour set of hourly loads for each month, representing an approximate monthly average hourly load; as a result, the chart above will not capture seasonal peaks. The “flex down” area represents the portion of load that can be reduced in that hour and shifted to other times of day.

Energy+Environmental Economics

Next Steps

Next Steps

- ***Adding CLCPA GHG Accounting Viewpoint***
  - *Upstream emissions from imported fuels*
  - *20-year Global Warming Potential*
- ***Review of performance and cost assumptions***
- ***Exploration of limits to bioenergy***
- ***Incorporation of Panel input into integrated, economy-wide pathways analysis***

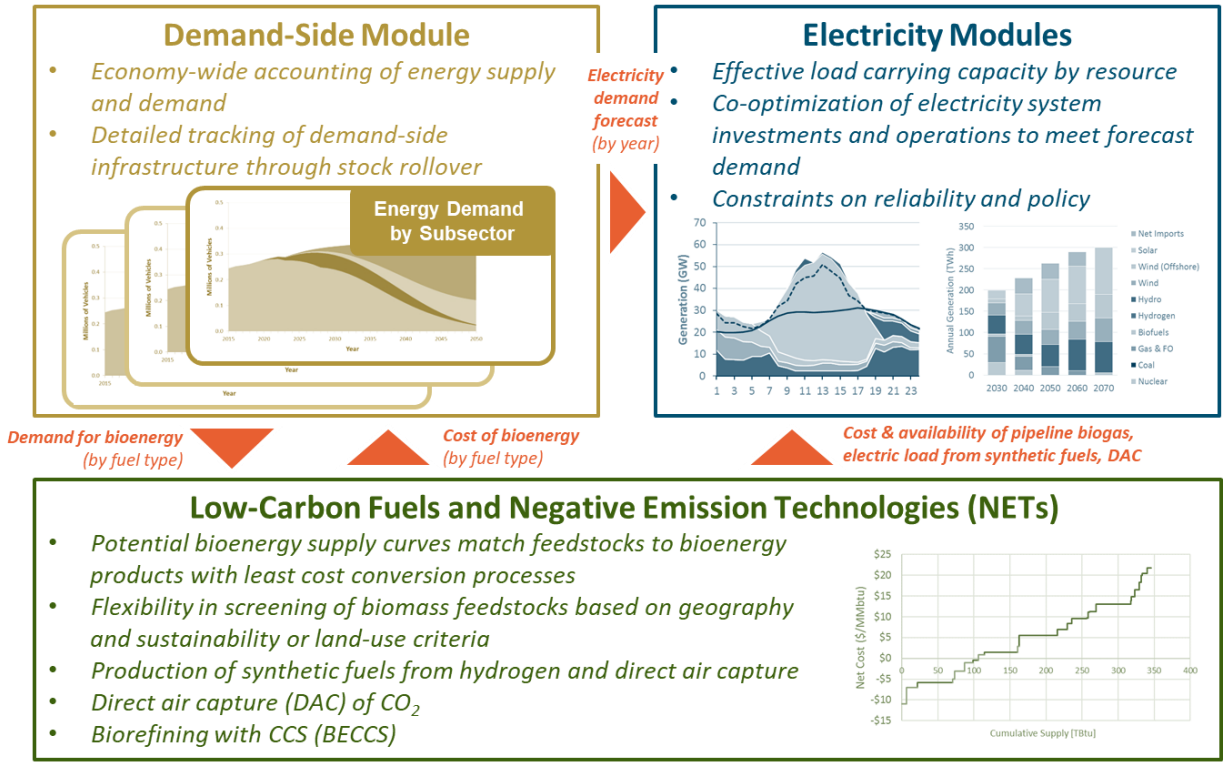
Questions?

Energy+Environmental Economics

Appendix

Model Framework

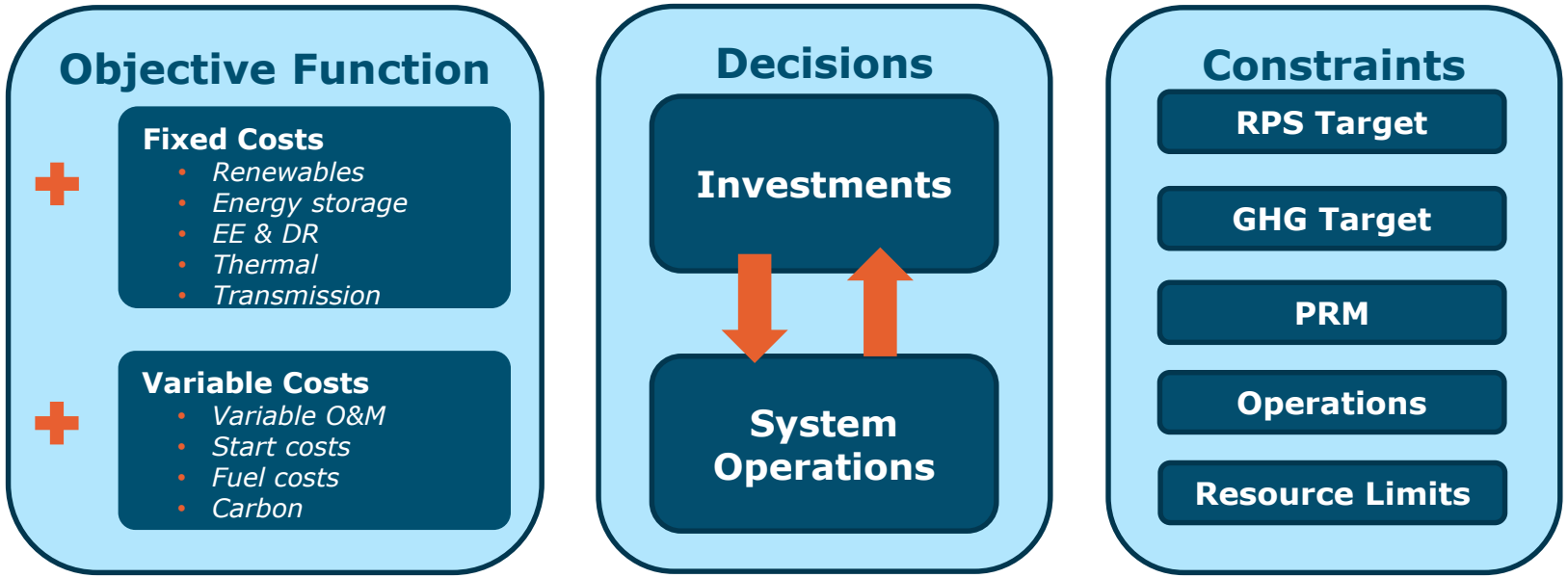
- Pathways analysis uses bottom-up, user-defined scenarios to test "what if" questions—or "**backcasting**"—to compare long-term decarbonization options and allows for development of realistic & concrete GHG reduction roadmaps.
- Bottom-up **stock rollover** modeling approach (based on EIA Nat'l Energy Modeling System and NYS-specific inputs) validated with top-down benchmarking (NYS actuals and forecasts)



- Model framework incorporates **interactions** between demand- and supply-side variables, with constraints and assumptions informed by existing analyses of resource availability, technology performance, and cost

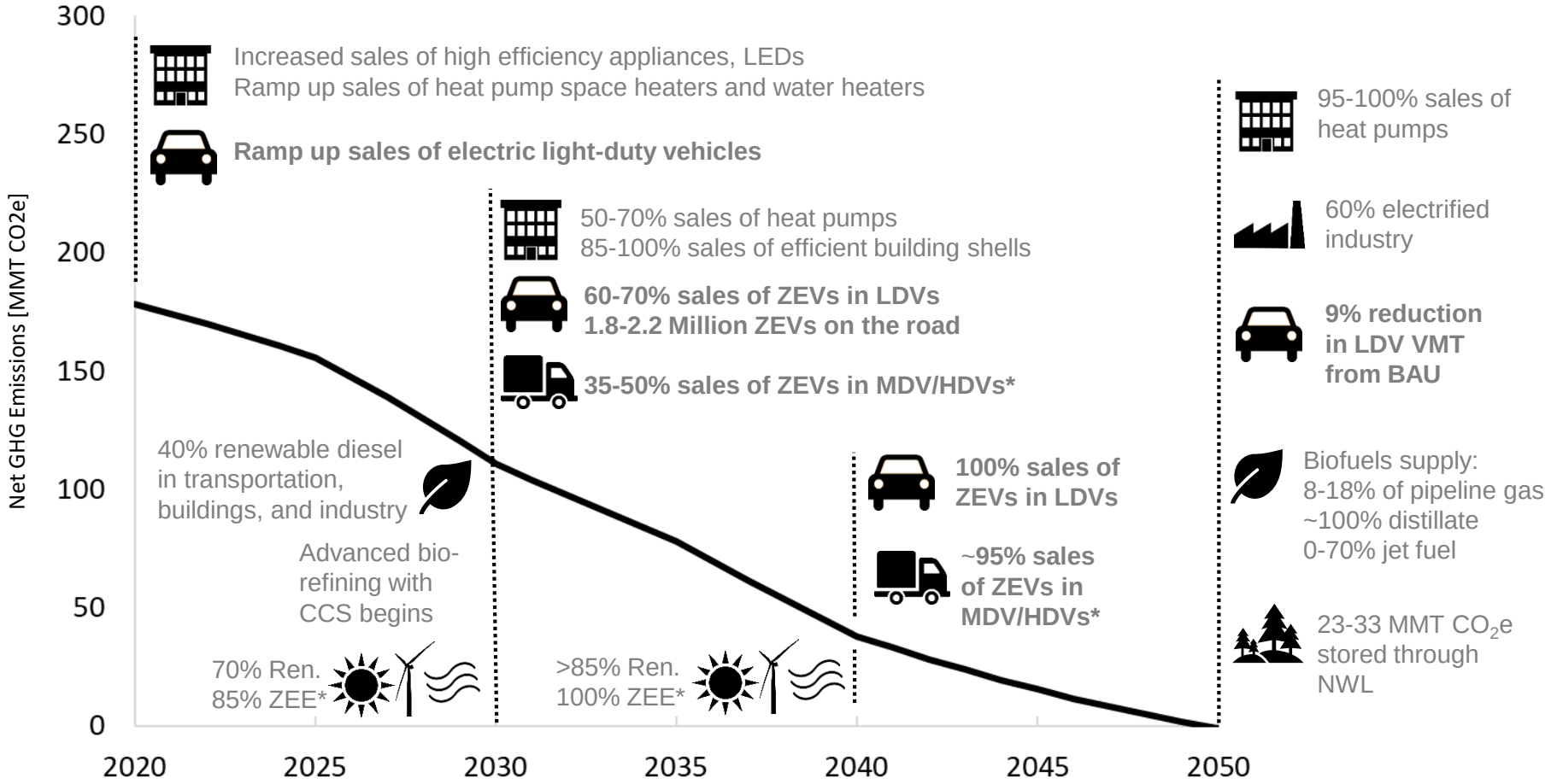
Electricity Modeling Approach

- **Analysis uses E3's RESOLVE model to develop optimal resource portfolios under varying levels of decarbonization and different sectoral transformations and strategies**
- **Load forecasts from PATHWAYS are fed directly into RESOLVE, which is used to analyze the least-cost resource portfolios and overall costs of electric sector transformation**
- **RESOLVE modeling relies on the following key inputs:**
  - **Characterization of existing generators**: NYISO Gold Book
  - **Costs of candidate resources**: NYISO Demand Curve Study (gas CCGTs and CTs); Clean Energy Standard Whitepaper and NREL Annual Technology Baseline (renewables); Lazard Levelized Cost of Storage and NYSERDA Storage Roadmap (battery storage)
  - **Fuel prices**: NYISO CARIS Study, EIA Annual Energy Outlook



Key Takeaways

+ **Achievement of emissions reductions to meet state law requires action in all sectors**
+ **A 30-year transition demands that action begin now**

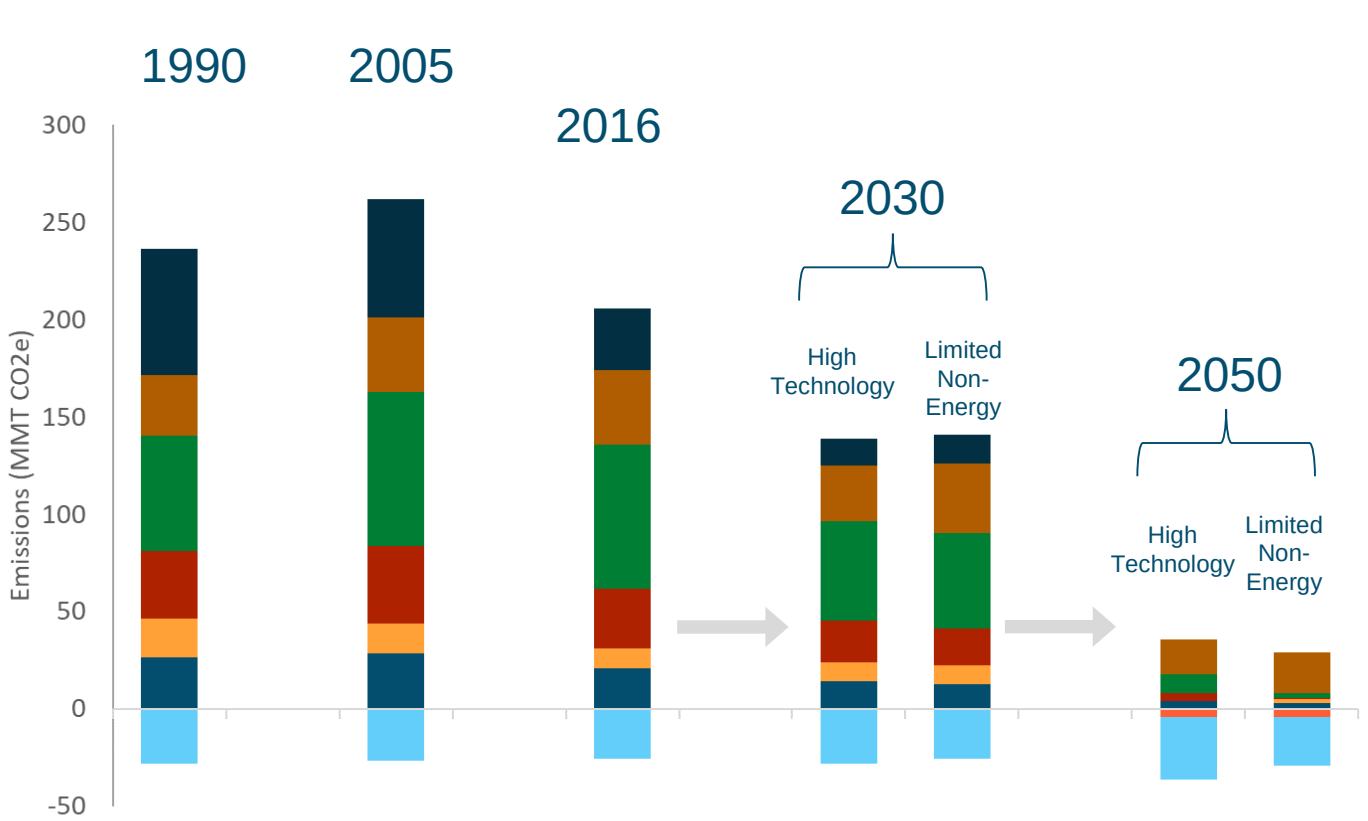


*Zero-Emissions Electricity (ZEE) includes wind, solar, large hydro, nuclear, CCS, and bioenergy; MDV includes buses

Greenhouse Gas Emissions

New York Net Greenhouse Gas Emissions for Selected Years by Scenario

Note: CO2e calculations do not fully reflect methodology required by CLCPA



Percent reduction from 2016:	2030	2050
Electricity	53%-56%	100%
Non Combustion and Other Energy	4%-26%	47%-54%
Transportation	31%-33%	86%-97%
Residential	30%-40%	88%-97%
Industry	6%	81%-82%
Commercial	32%-38%	81%-86%
BECCS		
Natural and Working Lands		

Key Assumptions

Sector	Strategy	Expressed as	Reference	High Technology Availability	Limited Non-Energy
Electricity Demand	Building Shell Efficiency	Efficient shell sales share	75% by 2030	85% by 2030, 100% by 2045	*Same as HTA*
	Appliance Efficiency (non-HVAC)	Efficient appliance sales share	100% by 2025	90% by 2023, 100% by 2025	*Same as HTA*
	Building Electrification	Electric heat pump sales share	6% by 2025	50% by 2030, 95% by 2050,	70% by 2030, 100% by 2045*
	Vehicle Electrification	ZEV sales share	LDA: 25% by 2025; LDT: 8% by 2025; MDV/Bus: 2% by 2050	LDV: 60% by 2030, 100% by 2040; Bus: 60% by 2030, 100% by 2040; MDV/HDV: 35% by 2030; 95% by 2040	LDV: 70% by 2030, 100% by 2035; Bus: 70% by 2030, 100% by 2035; MDV/HDV: 50% by 2030; 95% by 2040*
Electricity Supply	Clean Electricity Generation	Share of renewable/zero-emission generation	50% renewable by 2030	70% renewable by 2030, 100% zero-emission by 2040	*Same as HTA*
	Technology-specific targets	Offshore wind capacity	2.4 GW by 2030	9 GW by 2035	*Same as HTA*
		Behind-the-meter solar PV	3 GW by 2023	6 GW by 2025	*Same as HTA*
		Energy storage	3 GW by 2030	3 GW by 2030	*Same as HTA*

End Use Flexible Loads

- **End use flexible loads can play an important role in renewables balancing and peak mitigation**
- **We include significant amounts of flexibility in both buildings and transportation**
- **We assume that by 2050:**
  - 40% of space heating load can be shifted by up to 3 hours
  - 50% of light-duty EVs could charge flexibly and have access to chargers during the workday

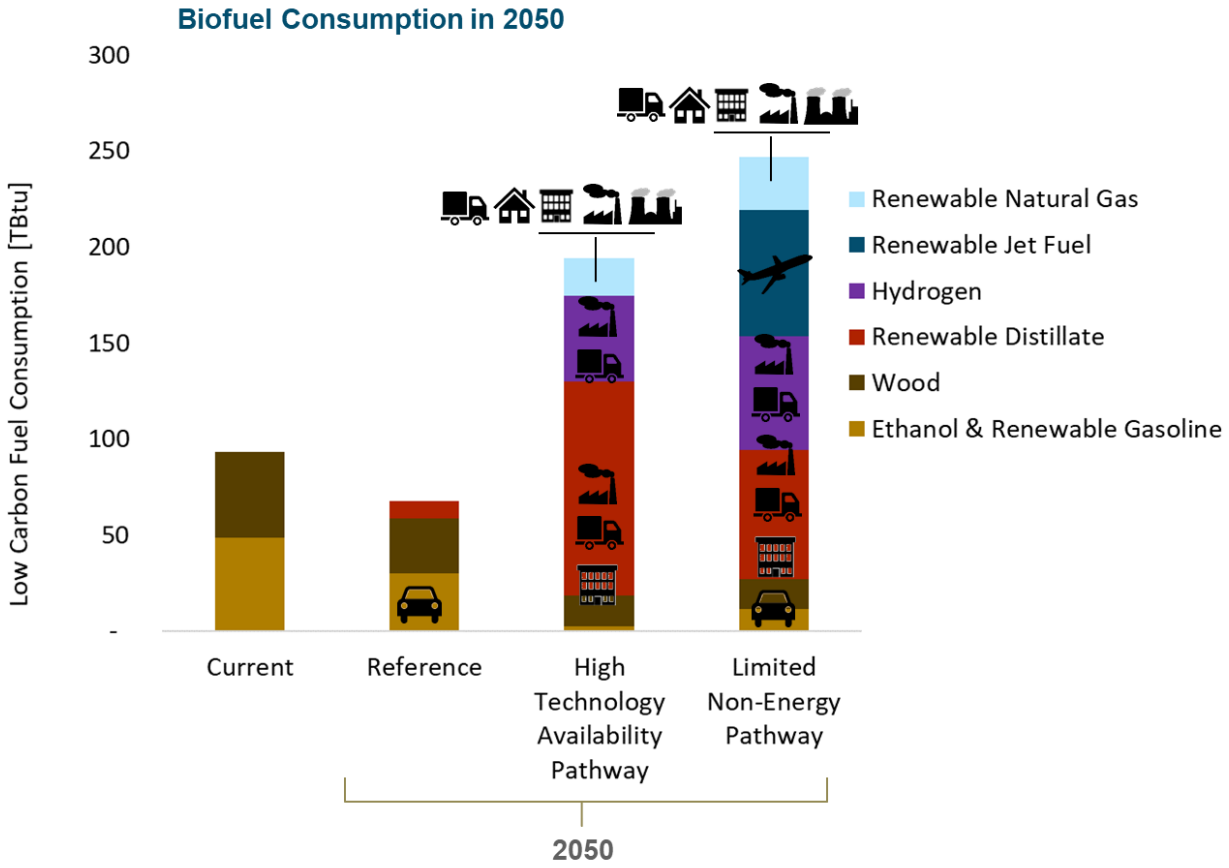
Sector	End use category	2030 - downstate (% flexible)	2030 – upstate (% flexible)	2050 - downstate (% flexible)	2050 – upstate (% flexible)	Hours Shiftable Daily
Residential	Space Cooling	10%	10%	60%	60%	3
	Space Heating	10%	10%	40%	40%	3
	Water Heating	10%	10%	40%	40%	3
	Refrigerators	20%	20%	60%	60%	2
Commercial	Space Cooling	20%	20%	60%	60%	3
	Space Heating	10%	10%	60%	40%	3
	Water Heating	10%	10%	60%	40%	3
	Refrigeration	20%	20%	60%	60%	2
Transportation	LDV EVs	25%	25%	50%	50%	12*
Other	Industry	0%	0%	0%	0%	0
	Electrolysis	100%	100%	100%	100%	12*
	Direct Air Capture	100%	100%	100%	100%	12*

Note:

*This is a simplification for vehicle charging, electrolysis, and direct air capture. More details on the flexibility parameters and constraints of transportation, electrolysis, and direct air capture are provided in sections 7.6.3 and 7.6.4.

Low-Carbon Fuels

+ **Advanced low-carbon liquid and gaseous fuels are key to decarbonizing sectors where electrification is challenging, such as freight transportation, aviation, marine, and high-temperature industrial applications**



+ **"Starting Point" pathways can achieve deep decarbonization using in-state feedstocks for advanced biofuels**