Energy+Environmental Economics

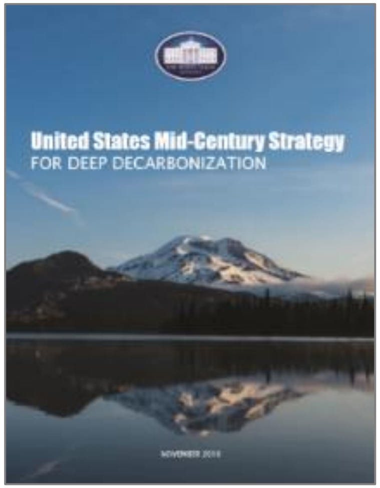
New York State Decarbonization Pathways Analysis

Summary of Draft Findings

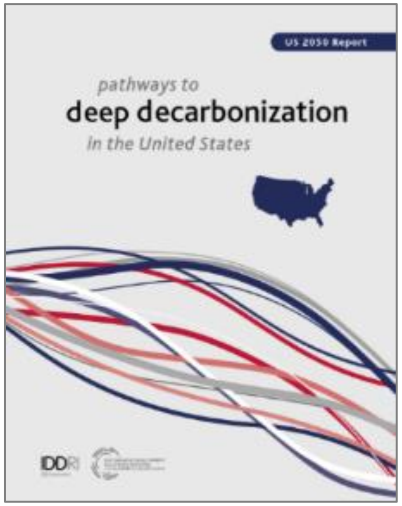
June 24, 2020

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


United States Mid-Century Strategy
FOR DEEP DECARBONIZATION

NOVEMBER 2016


US 2050 Report

pathways to
deep decarbonization
in the United States

IDDRI


McKinsey
& Company

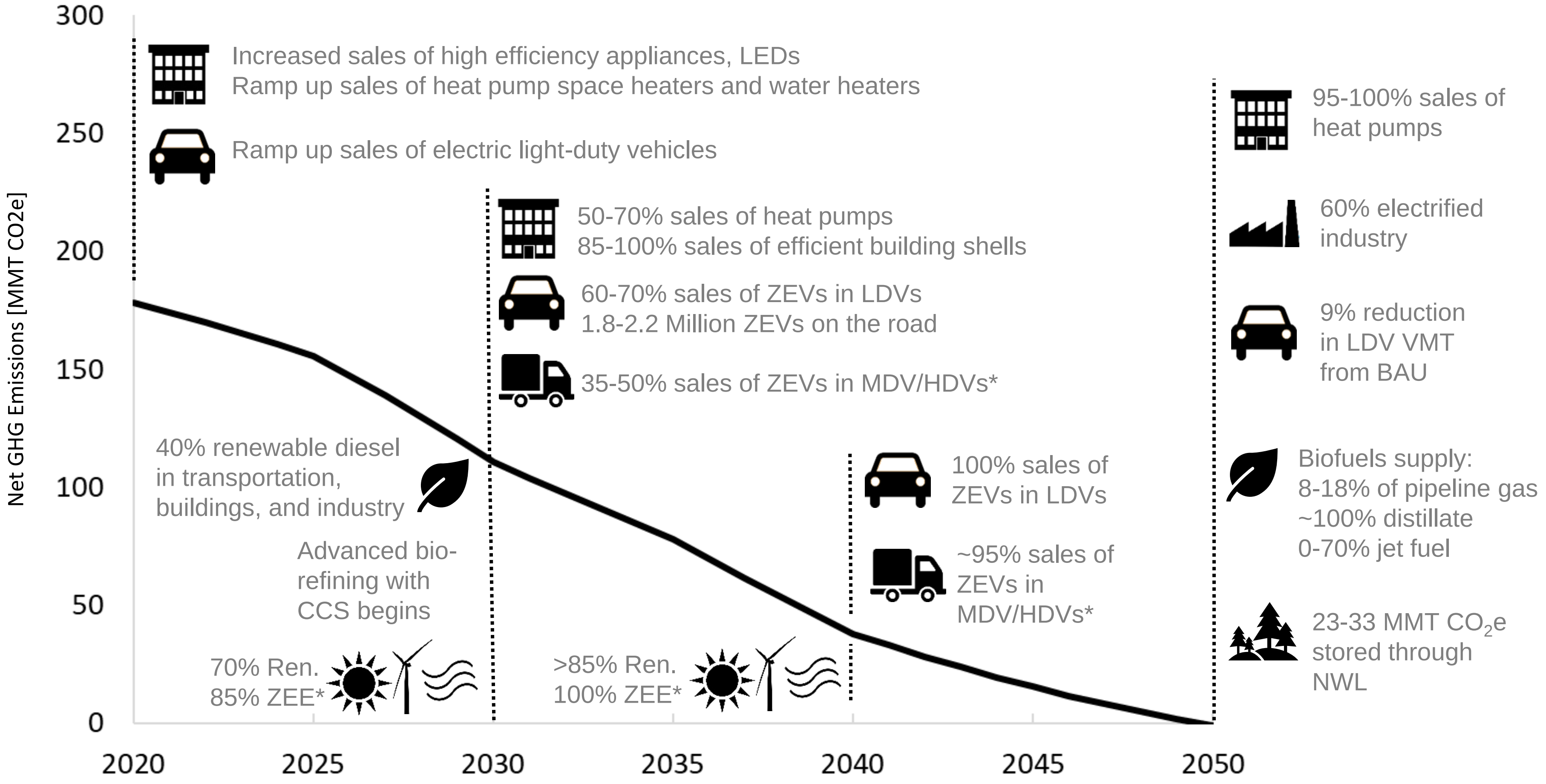
The global relevance
of New York State's
clean-power targets

Key Takeaways

- **This analysis reinforces the conclusion of the reviewed studies: Deep decarbonization is feasible using existing technologies**
- **Some studies rely on technologies that have only been demonstrated in a limited number of applications and require progress before commercial readiness**
- **Although there is no single pathway to a decarbonized economy, all scenarios that achieve carbon neutrality share significant progress in the following four pillars**
  - Energy efficiency, conservation and end-use electrification
  - Switching to low-carbon fuels
  - Decarbonizing the electricity supply
  - Negative emissions measures and carbon capture technologies
- **Review of the literature illustrates that choices exist in the extent and role of each. However, in all studies the scale of the transformation is unprecedented, requiring major investments in new infrastructure across all sectors.**
- **Consumer decision-making plays a large role in the transition, such as in passenger vehicles and household energy use.**
- **Continued research, development, and demonstration will be necessary to advance the full portfolio of options.**

Key Takeaways

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



Increased sales of high efficiency appliances, LEDs
Ramp up sales of heat pump space heaters and water heaters

Ramp up sales of electric light-duty vehicles

40% renewable diesel in transportation, buildings, and industry

Advanced bio-refining with CCS begins

70% Ren.
85% ZEE*

50-70% sales of heat pumps
85-100% sales of efficient building shells

60-70% sales of ZEVs in LDVs
1.8-2.2 Million ZEVs on the road

35-50% sales of ZEVs in MDV/HDVs*

>85% Ren.
100% ZEE*

100% sales of ZEVs in LDVs

~95% sales of ZEVs in MDV/HDVs*

95-100% sales of heat pumps

60% electrified industry

9% reduction in LDV VMT from BAU

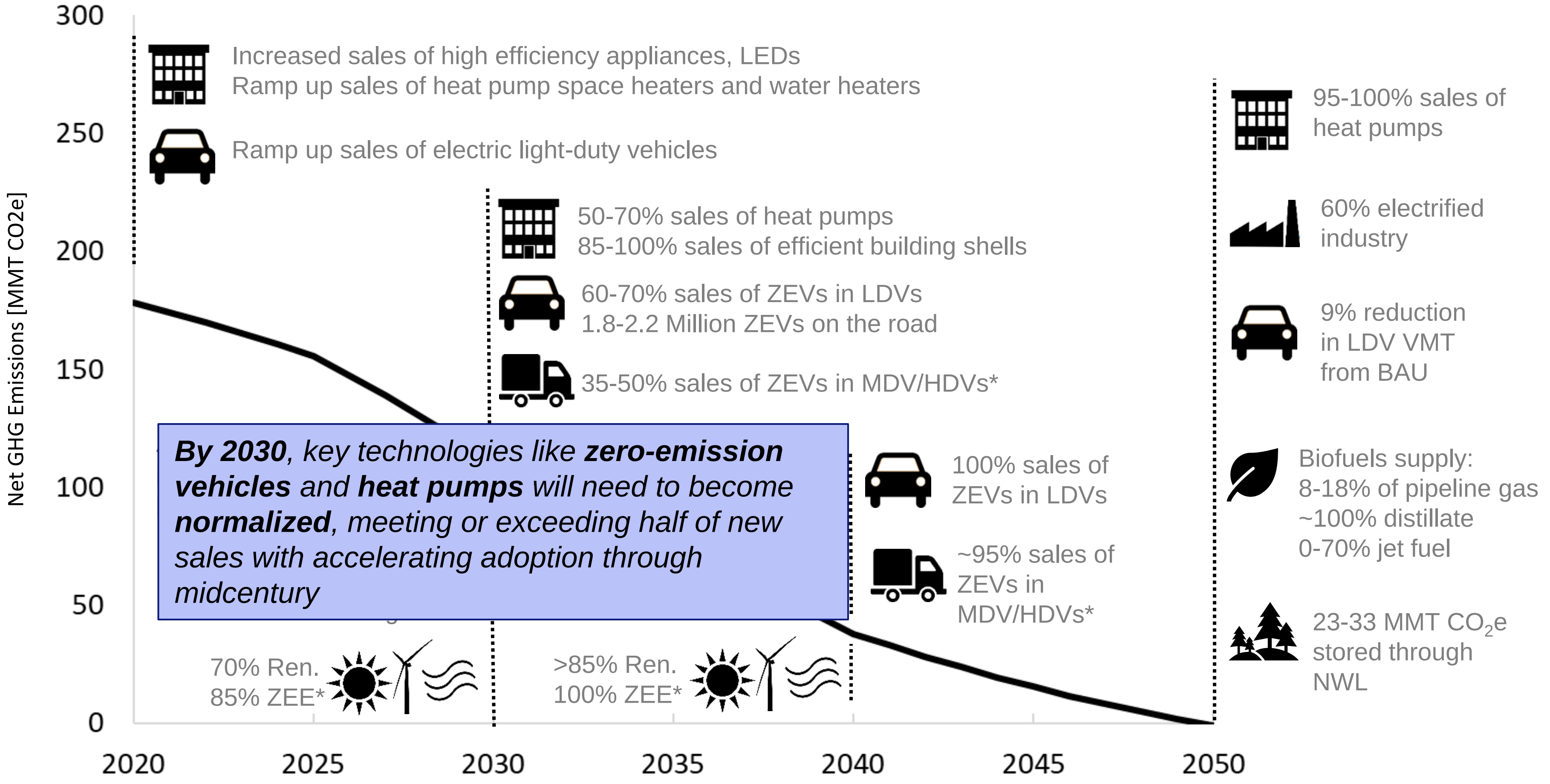
Biofuels supply:
8-18% of pipeline gas
~100% distillate
0-70% jet fuel

23-33 MMT CO_2e stored through NWL

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

Key Takeaways

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



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***By 2030**, key technologies like **zero-emission vehicles** and **heat pumps** will need to become **normalized**, meeting or exceeding half of new sales with accelerating adoption through midcentury*

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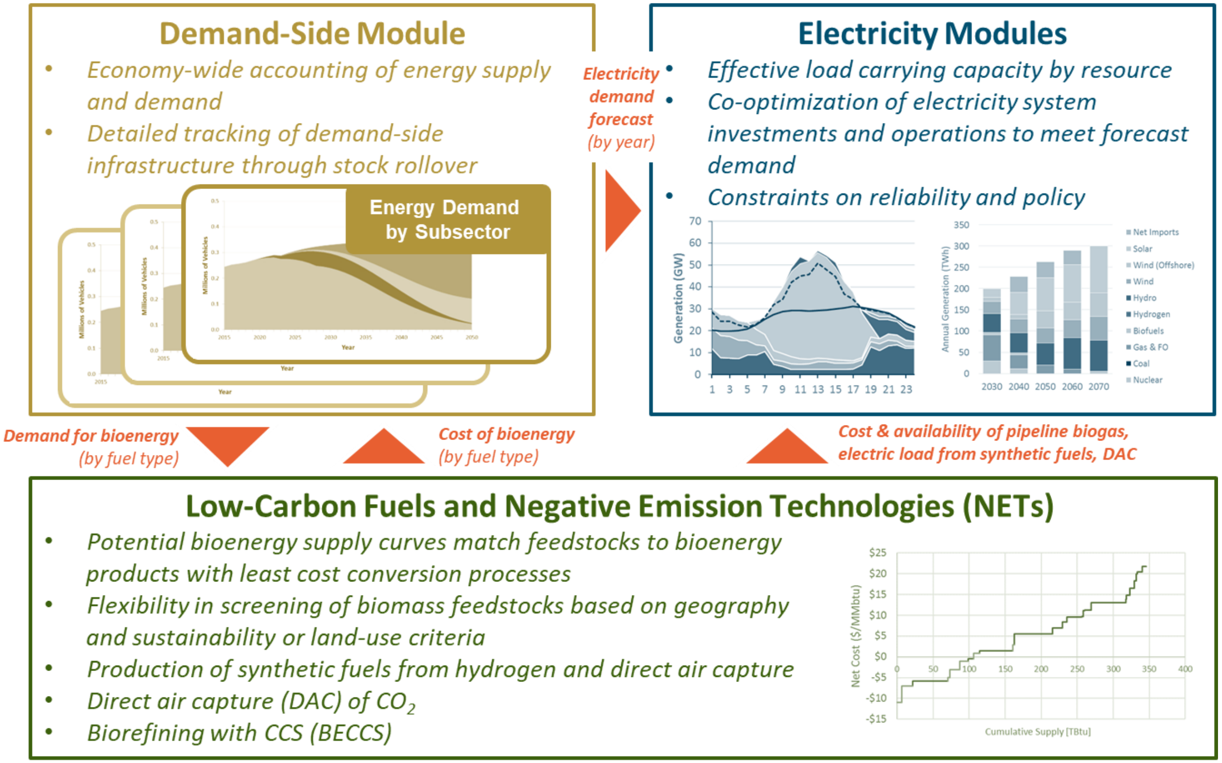
Model Framework

- 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)



Demand-Side Module

- *Economy-wide accounting of energy supply and demand*
- *Detailed tracking of demand-side infrastructure through stock rollover*

Energy Demand by Subsector

Electricity demand forecast *(by year)*

Electricity Modules

- *Effective load carrying capacity by resource*
- *Co-optimization of electricity system investments and operations to meet forecast demand*
- *Constraints on reliability and policy*

Demand for bioenergy *(by fuel type)*

Cost of bioenergy *(by fuel type)*

Cost & availability of pipeline biogas, electric load from synthetic fuels, DAC

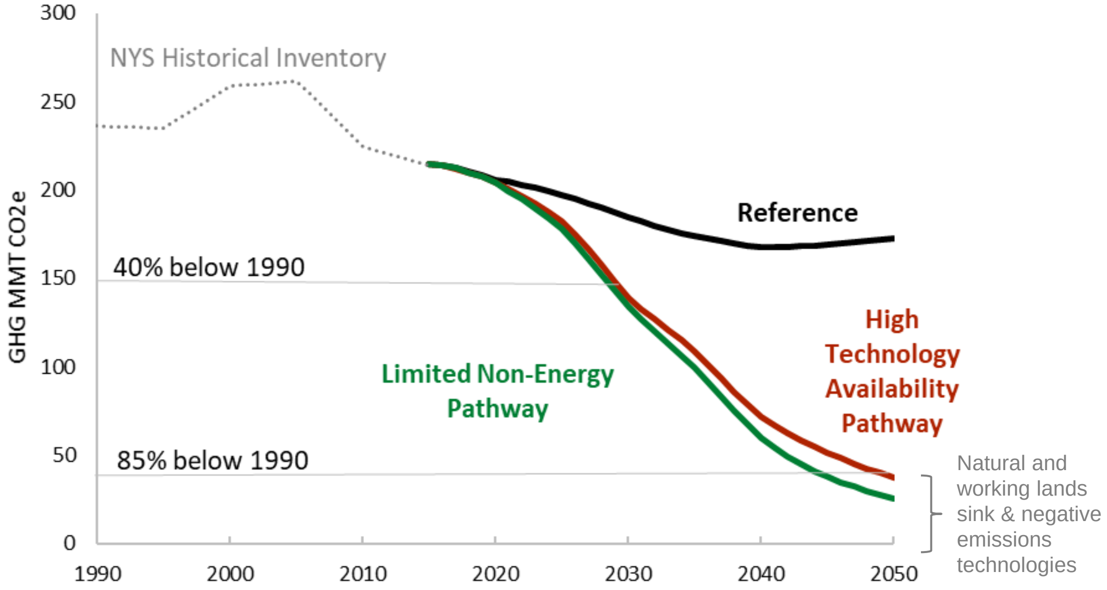
Low-Carbon Fuels and Negative Emission Technologies (NETs)

- *Potential bioenergy supply curves match feedstocks to bioenergy products with least cost conversion processes*
- *Flexibility in screening of biomass feedstocks based on geography and sustainability or land-use criteria*
- *Production of synthetic fuels from hydrogen and direct air capture*
- *Direct air capture (DAC) of* CO_2
- *Biorefining with CCS (BECCS)*

- 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

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)



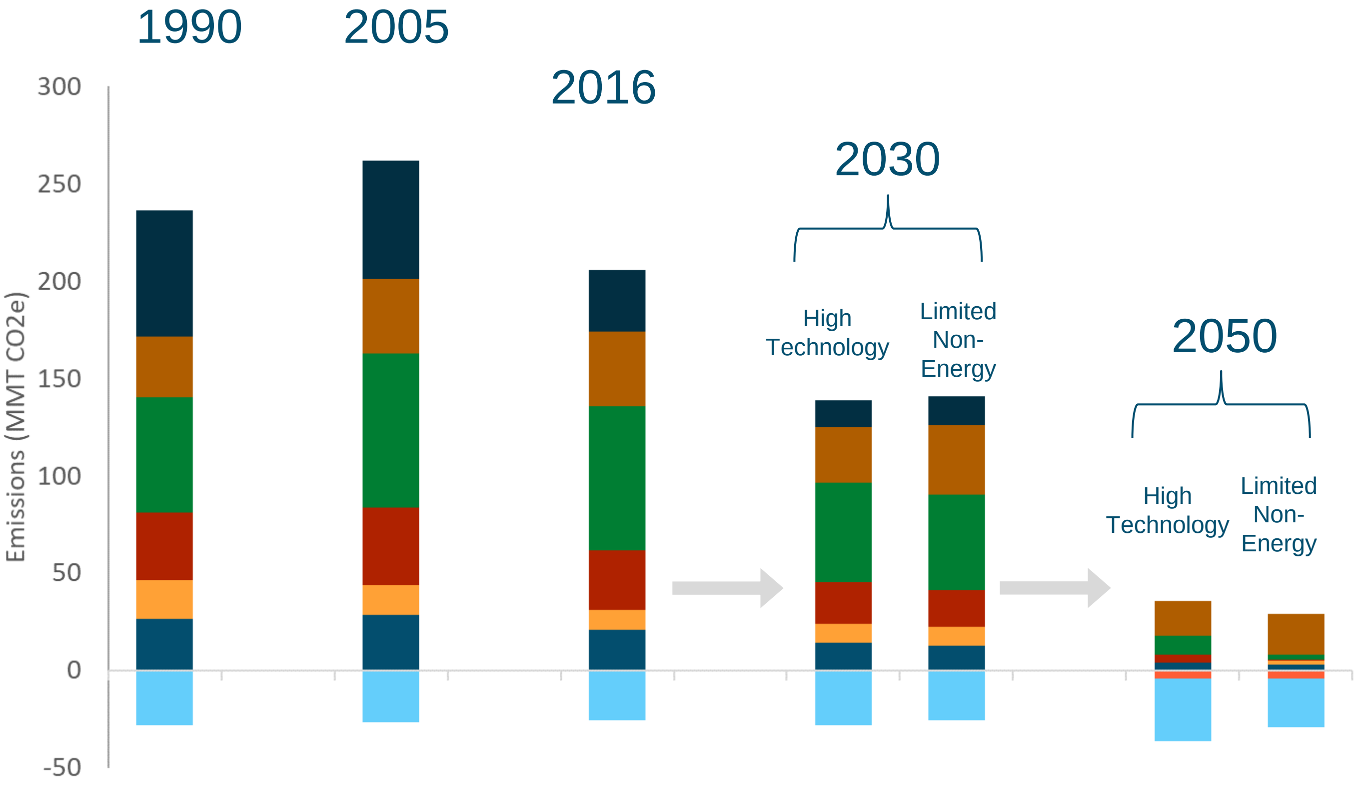
- **Two "Starting Point" Pathways:**
  - **High Technology Availability Pathway:** Emphasizes efficiency and electrification at "natural" end-of-life asset replacement schedule, while also utilizing advanced biofuels, carbon capture and storage (CCS), bioenergy with carbon capture and storage (BECCS), 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

Sectoral Findings

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



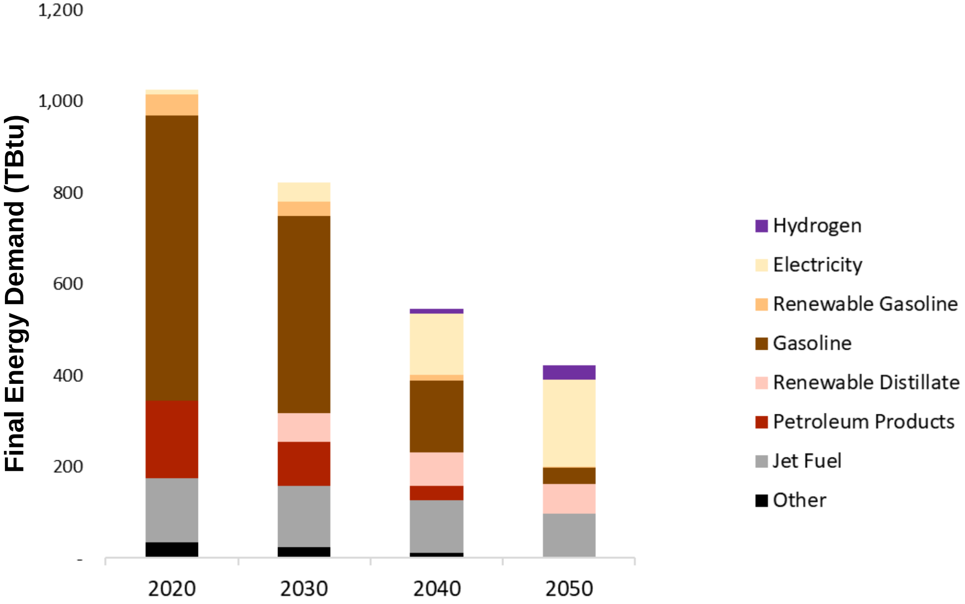
Percent reduction from 2016:

	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		

Transportation

- Major shift to zero-emission vehicles across all vehicle classes
  - 60%-70% new light-duty vehicle sales, 35-50% medium- and heavy-duty vehicle sales by 2030, with increasing rates of adoption thereafter.
  - Mix of plug-in hybrid, battery electric, and hydrogen fuel cell vehicles, depending on vehicle class and duty cycle
  - Charging flexibility helps to maintain system-wide reliability
- Share of remaining combustible fuel use in medium- and heavy-duty fleets met by renewable fuels (*e.g.,* advanced biofuels or synthesized fuels)
- Energy use is reduced over time through increased vehicle efficiency and through substantial reductions in vehicle miles of travel through smart growth, transit, and other transportation demand management measures, including system-wide efficiency improvements
- Non-road transportation, such as marine, rail, and aviation, decarbonized through a combination of renewable fuel utilization, efficiency, and electrification

High Technology Availability Pathway



Metric	2030**	2050**
Percent GHG emissions reduction*	31%-33%	86%-97%
Percent reduction in final energy demand*	23%-24%	63%-67%

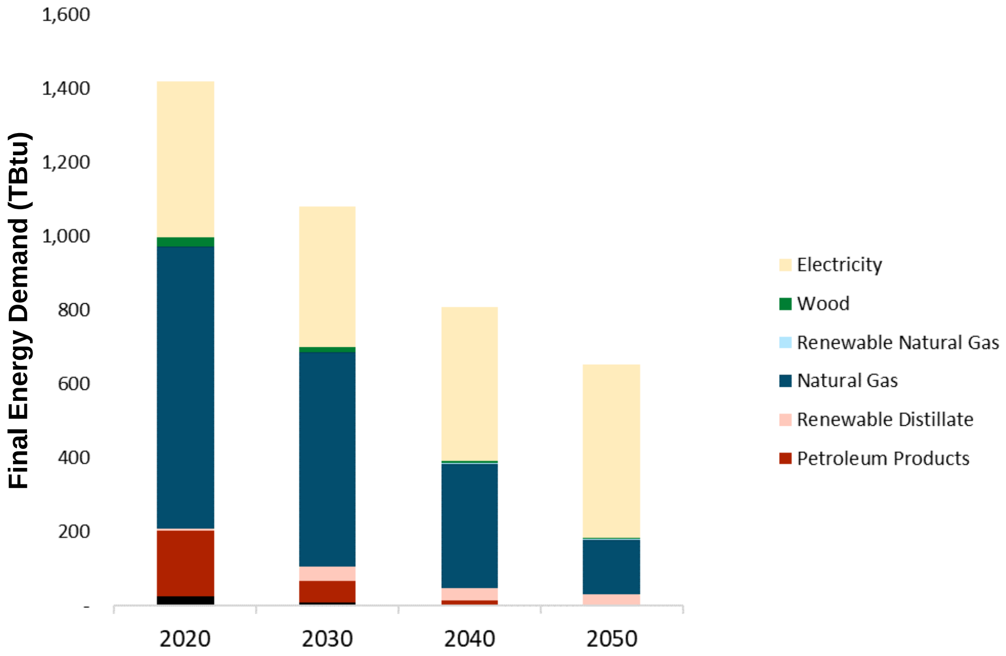
** Relative to 2016*

*** Range of values includes limited non-energy pathway*

Buildings

- Efficiency across all end-uses and building shell scales dramatically
- Major shift to end-use electrification, particularly in space and water heating
  - 50%-70% new heating system sales by 2030 with increasing rates of adoption thereafter
  - End-use electrification drives trend toward a winter peaking system
  - Magnitude of winter peak varies by study, but investment in ground-source heat pumps or onsite combustion backup systems using fossil fuel, bioenergy, or synthesized fuel, such as hydrogen, may mitigate excessive peak electricity demand
- Flexibility of end-use electric loads helps to maintain system-wide reliability
- Shift to low-GWP refrigerants crucial to ensure maximum GHG emissions benefits from heat pump adoption
  - Further analysis needed to explore full range of mitigation options, timing, and potential barriers

High Technology Availability Pathway



Metric	2030**	2050**
Percent GHG emissions reduction*	31%-39%	85%-93%
Percent reduction in final energy demand*	26%-31%	55%-59%

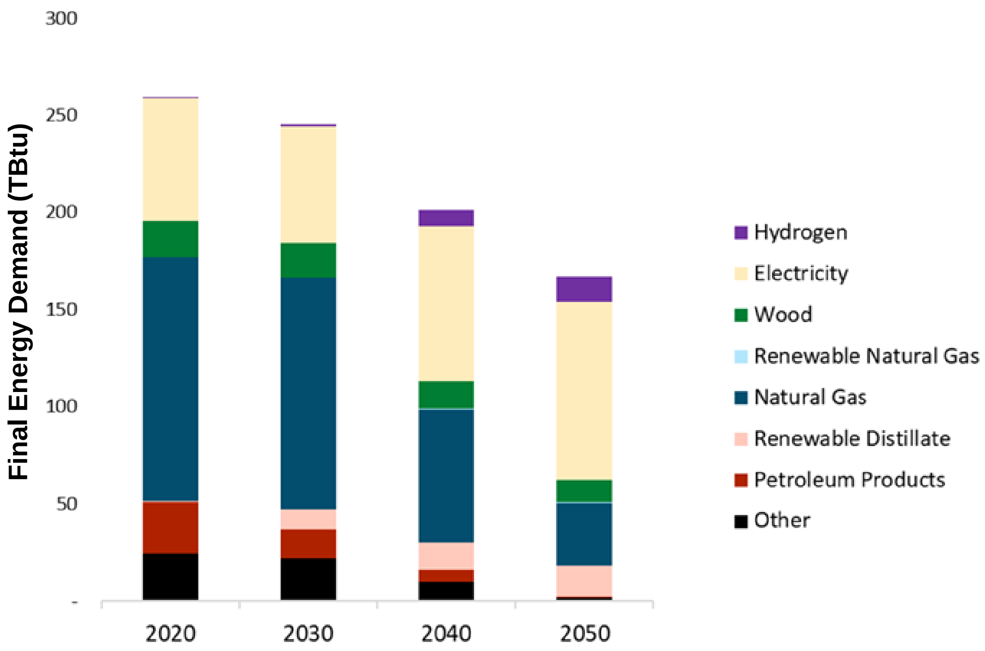
** Relative to 2016*

*** Range of values includes limited non-energy pathway*

Industry

- 2030 goals are met primarily by continued investment in energy efficiency and some replacement of fossil fuels with low-carbon, renewable fuels, allowing more time for innovation to meet the 2050 goals.
- Electrification (including process energy requirements) increases toward midcentury
  - Full extent of industrial electrification potential varies by study and location
- In addition to efficiency, electrification, and utilization of low-carbon, renewable fuels (e.g., renewable diesel, renewable natural gas, and hydrogen), carbon capture, storage, and utilization (CCSU) is a key industrial sector decarbonization measure over time

High Technology Availability Pathway



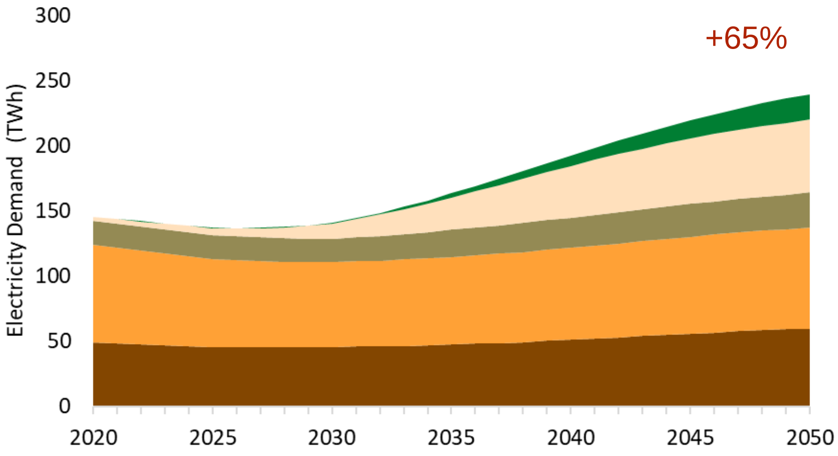
Metric	2030**	2050**
Percent GHG emissions reduction*	6%	81%-82%
Percent reduction in final energy demand*	4%	39%-40%

** Relative to 2016*

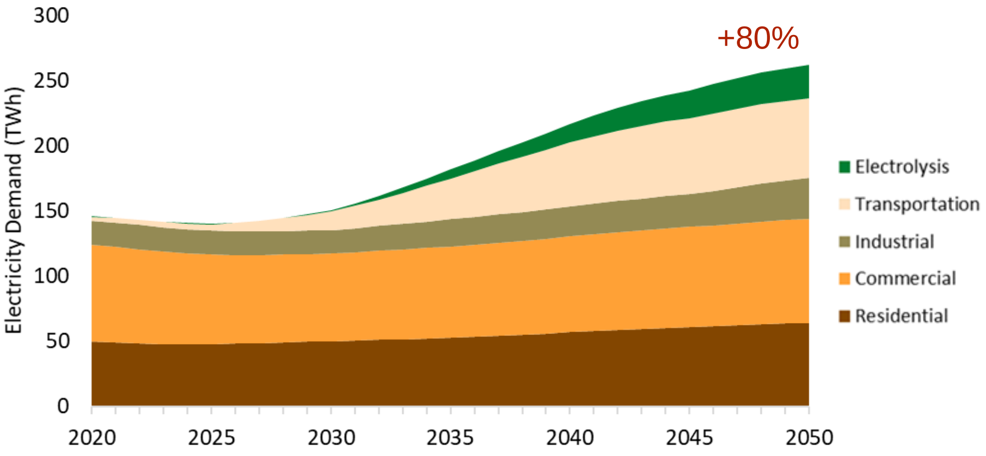
*** Range of values includes limited non-energy pathway*

Annual Electricity Demand

- Further decarbonization of the power sector only gets us a fraction of the way toward the economy-wide goal
- However, end-use electrification to eliminate GHG emissions drives 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



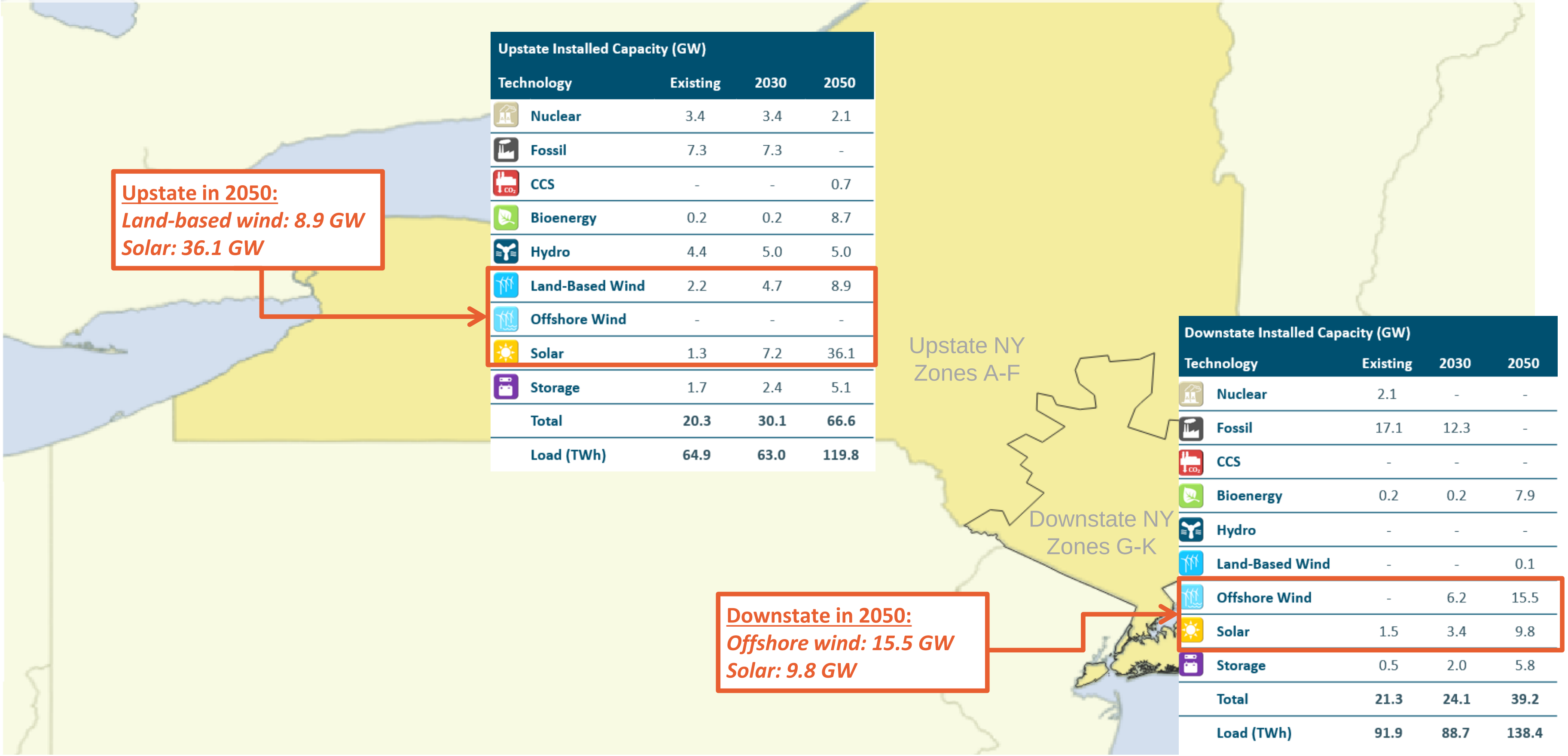
High Technology Availability Pathway
Electric Load by Sector



Limited Non-Energy Pathway
Electric Load by Sector

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 in 2050:
Land-based wind: 8.9 GW
Solar: 36.1 GW

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**

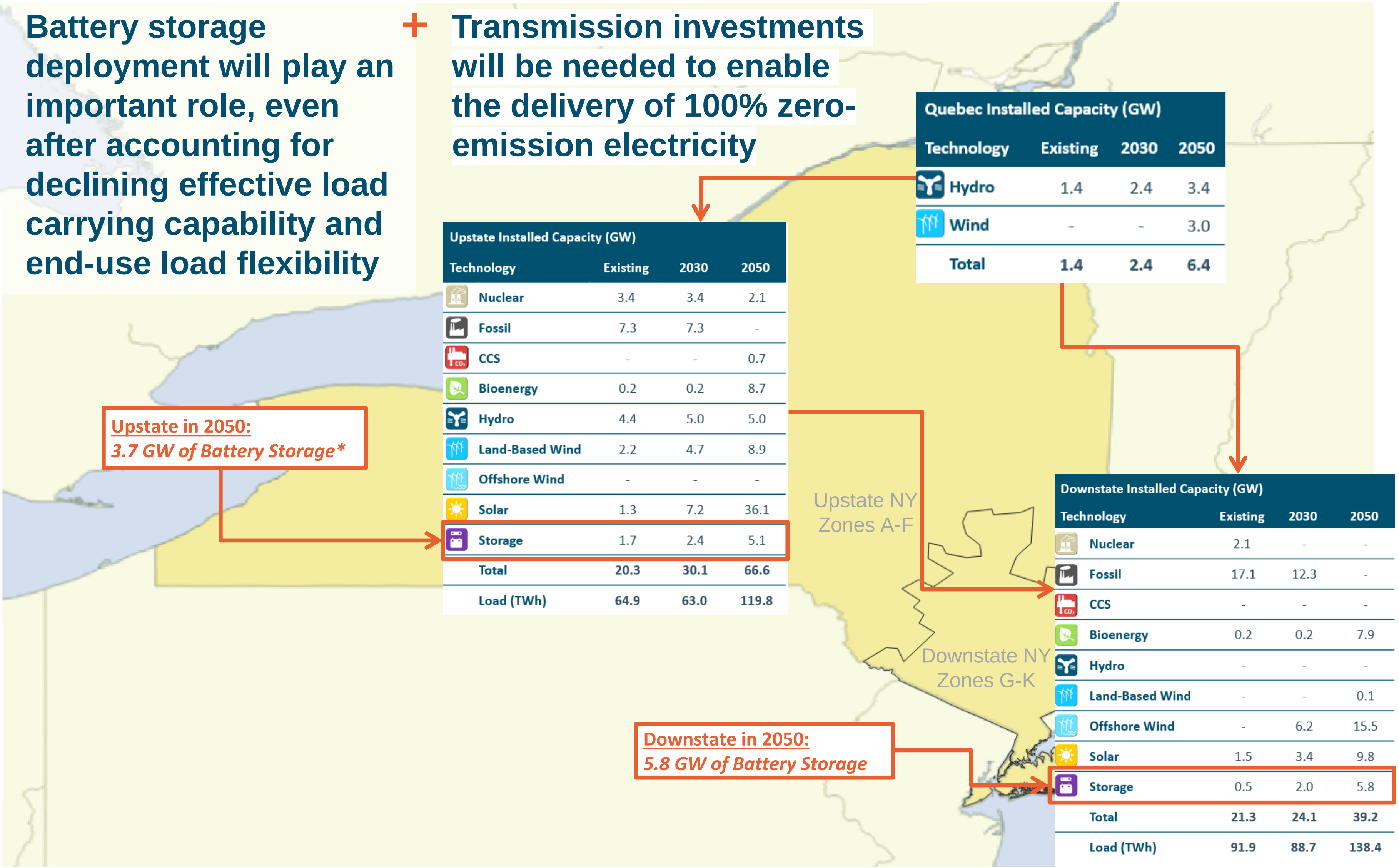
Downstate in 2050:
Offshore wind: 15.5 GW
Solar: 9.8 GW

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
Storage	1.7	2.4	5.1
Total	**20.3**	**30.1**	**66.6**
Load (TWh)	**64.9**	**63.0**	**119.8**

Upstate in 2050:
3.7 GW of Battery Storage*

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**
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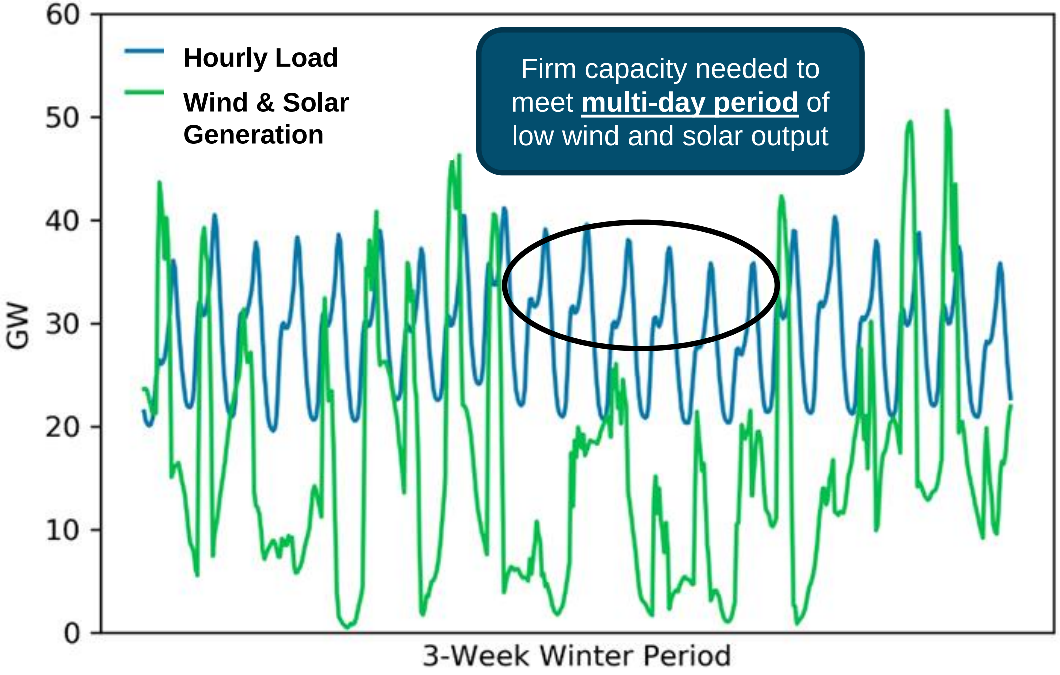
Downstate in 2050:
5.8 GW of Battery Storage

*Total 5.1 GW includes existing pumped storage capacity

Electricity Supply - Flexibility

- 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

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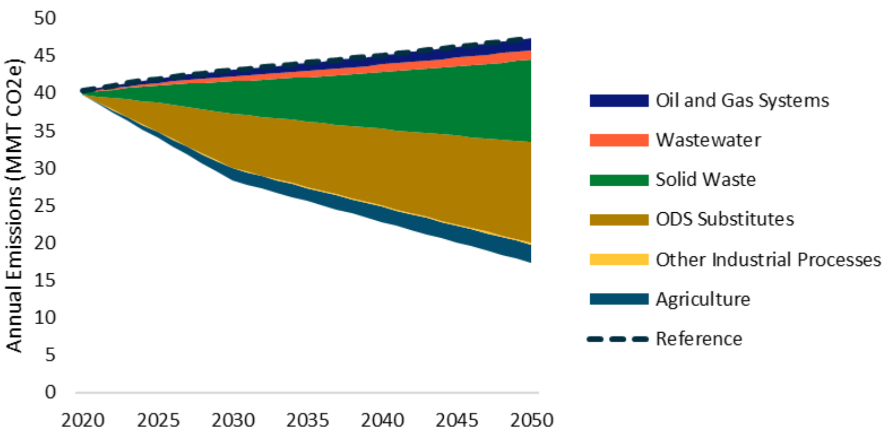
[1] Sepulveda, N., J. Jenkins, F. de Sisternes, R. Lester. (2018) The Role of Firm Low-Carbon Electricity Resources in Deep Decarbonization of Power Generation. Joule, 2(11), pp. 2403-2420. DOI: https://doi.org/10.1016/j.joule.2018.08.006.

[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.

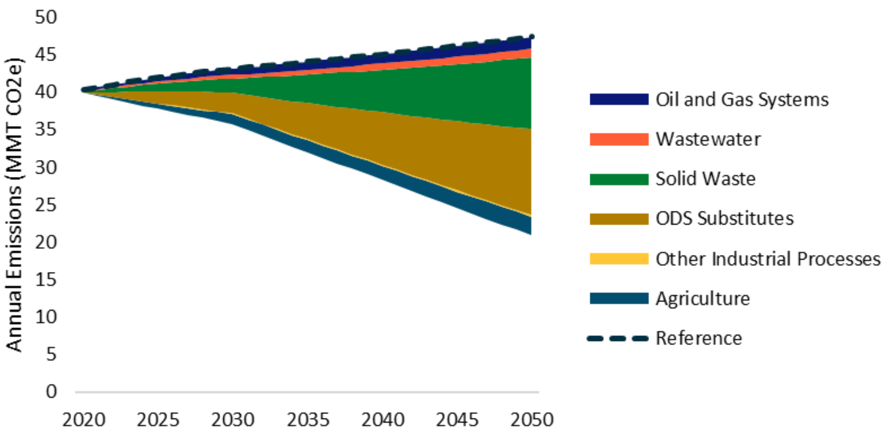
[3] E3. 2019. Resource Adequacy in the Pacific Northwest. https://www.ethree.com/wp-content/uploads/2019/03/E3_Resource_Adequacy_in_the_Pacific-Northwest_March_2019.pdf

Non-Combustion Sources

- Non-combustion emissions are projected to increase over time. To bend the curve, significant reductions are needed across non-combustion emissions sources, which include landfills, farms, industrial facilities, and natural gas infrastructure.
- Mitigation of short-lived climate pollutants is key, with a focus on methane mitigation and climate-friendly refrigerants (ODS Substitutes). Further analysis needed to identify full range of mitigation options and strategies in these areas.



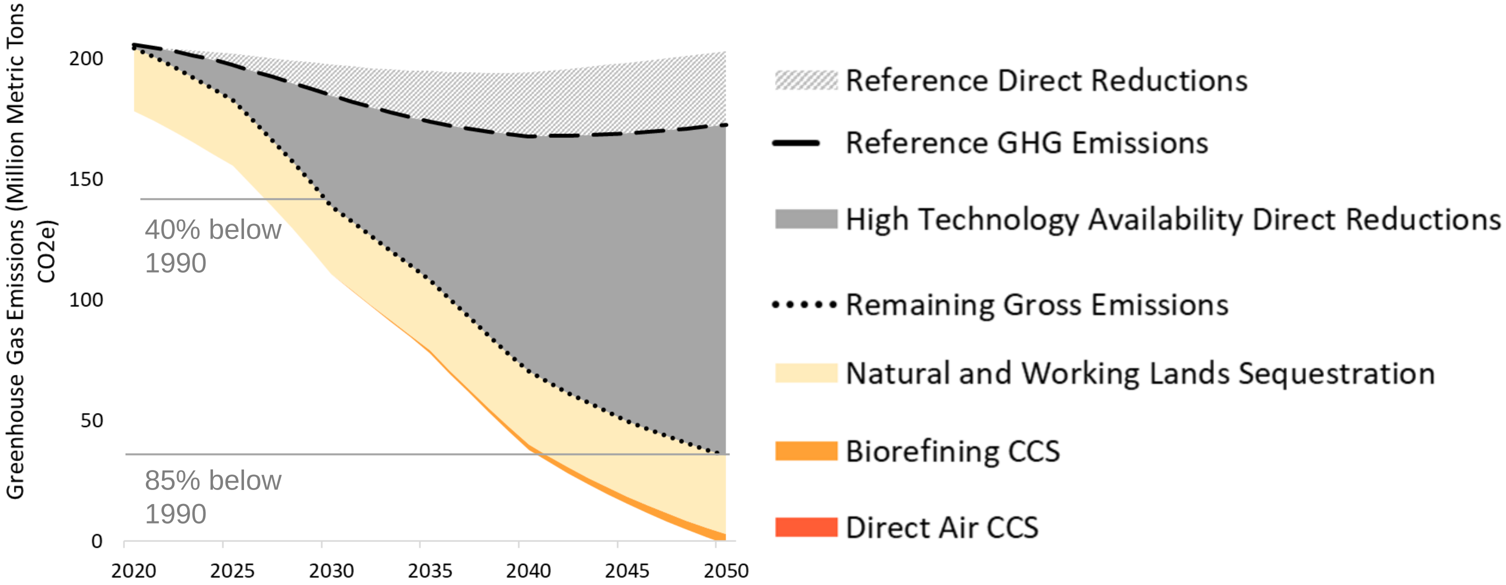
High Technology Availability Pathway:
Non-Combustion Emissions Reductions



Limited Non-Energy Pathway:
Non-Combustion Emissions Reductions

Negative Emissions

- Negative emissions have an important role to play in carbon neutrality
- With nearly 20 million acres of forest, New York State's natural and working lands sink provides between 23 to 33 MMT CO2e of negative emissions across scenarios
- Biorefining with CCS and direct air capture can provide additional negative emissions to offset remaining emissions in the energy and non-combustion sectors.



Conclusions & Next Steps

Conclusions

- ***Analysis finds that deep decarbonization in New York is feasible using existing technologies, which reinforces conclusion of a number of studies***
  - **Continued research, development, and demonstration is key to advancing a full portfolio of options.** *Some studies and scenarios rely on technologies that have only been demonstrated in a limited number of applications and require progress before commercial readiness*
- ***There are different pathways to the future: A 30-year transition demands action now but affords some degrees of flexibility***
  - *The "four pillars" of decarbonization" – efficiency and conservation (55%-58% reduction in final energy demand by 2050), switching to low-carbon fuels (75%-88% share by 2050), decarbonized electric supply (100% by 2040), and negative emissions technologies (27–37 MMT by 2050) – will all be critical to achieving carbon neutrality*
- ***Consumer decision-making drives the pace of decarbonization, particularly in buildings and on-road transportation.***
  - *By 2030, key technologies like plug-in electric vehicles, electric heat pump space and water heaters, and other electric appliances in the home (e.g., stoves, clothes dryers) will need to become normalized, meeting or exceeding half of new sales with accelerating adoption through midcentury.*

Conclusions

- ***Flexibility along multiple dimensions is key to maintaining reliability and reducing cost of a 100% zero-emission electricity system***
  - *Flexible end-use loads and battery storage can provide sufficient short-term (intraday) flexibility to balance high levels of variable renewable output.*
  - *The more difficult challenge is during winter periods with high heating loads and very low renewable energy production, which can occur over several days. The long-duration (interday) challenge can be solved through a combination of large-scale hydro resources, renewable natural gas (RNG) or synthetic fuels such as hydrogen, carbon capture and storage (CCS), and nuclear power.*
- ***Managed electrification can help mitigate the risk of very high winter peaks.***
  - *In addition to end-use load flexibility, investments in a balanced mix of electric heating system configurations and investment in research and development to improve cold climate heat pump performance can help to mitigate potential risk associated with unintended consequences of unmanaged electrification.*

Next Steps

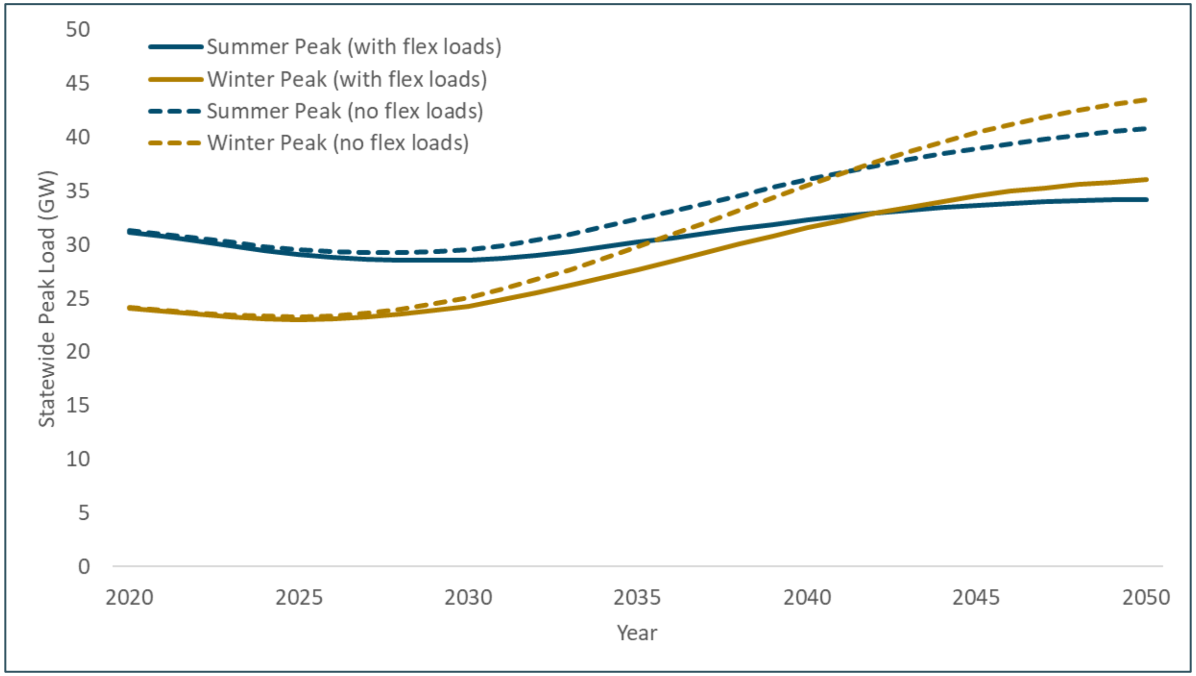
- ***Adding CLCPA GHG Accounting Viewpoint***
  - *Upstream emissions from imported fuels*
  - *20-year Global Warming Potential*
- ***Additional Scenario Development***
  - *In-State transmission*
  - *Carbon capture and sequestration*
  - *Electric generation mix (availability of in-state/regional resources)*
  - *Managed/unmanaged electrification*
  - *Limits of electrification*
  - *Mobility demand & outlook for vehicle miles traveled*
  - *Bioenergy availability*

Questions?

Appendix

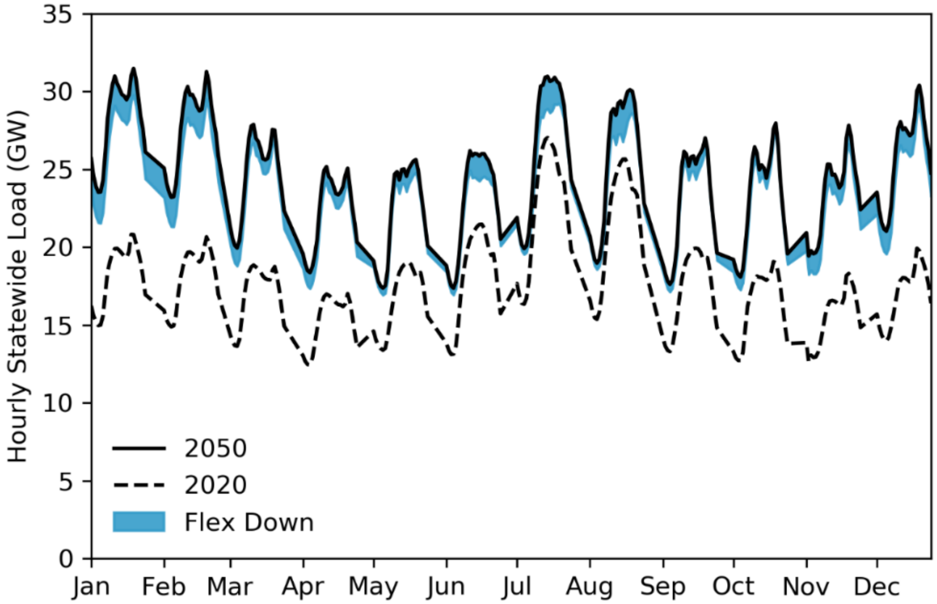
Peak Electricity Demand

- 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



Peak Electricity Demand

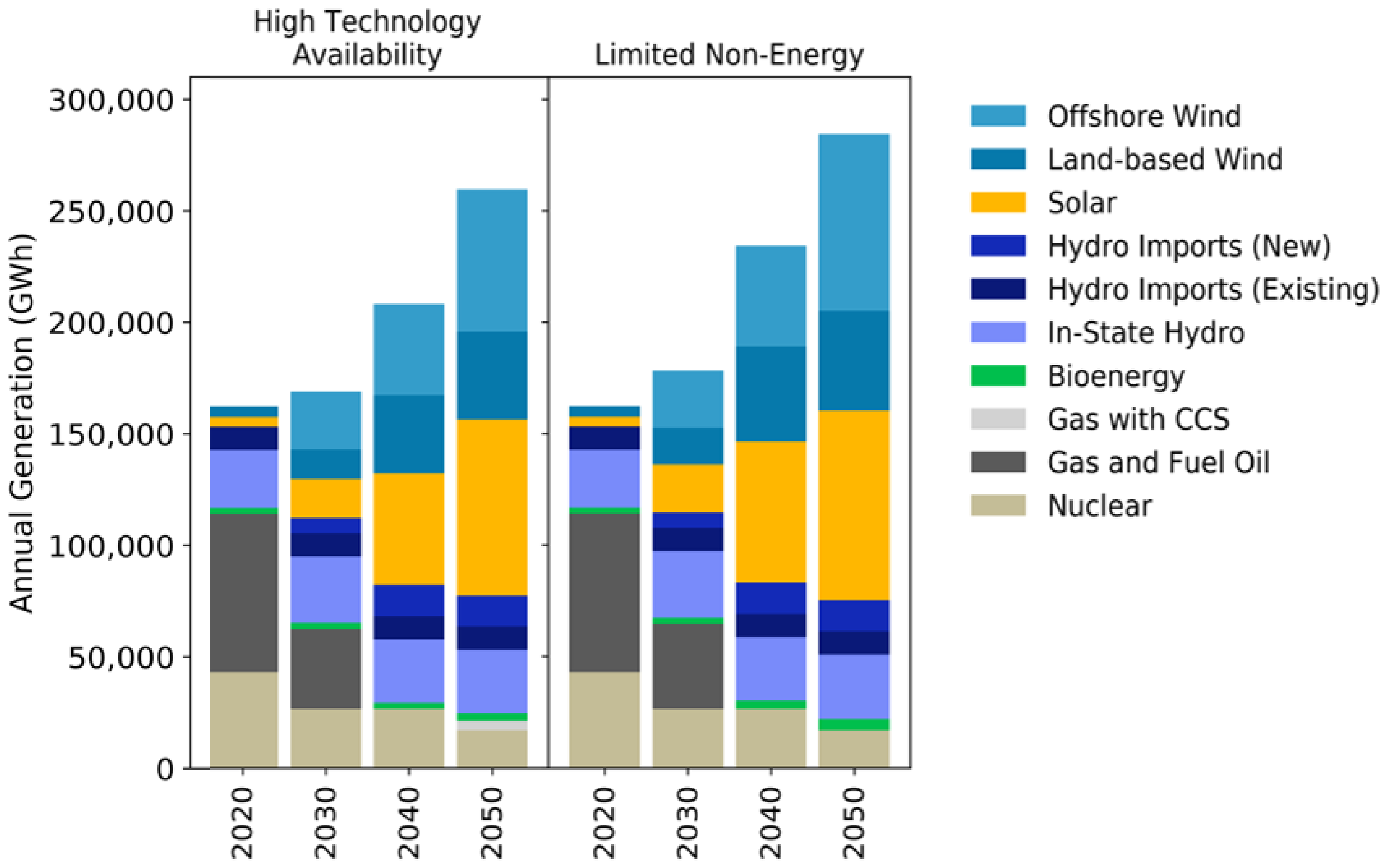
- NYS shifts from summer peak to winter peak around 2040, driven primarily by electrification of heating in buildings and EV battery use
- Flexibility in electric vehicles and building loads can significantly reduce peak demands and the need for new generation capacity
- Flexible loads can also serve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

Electricity Generation

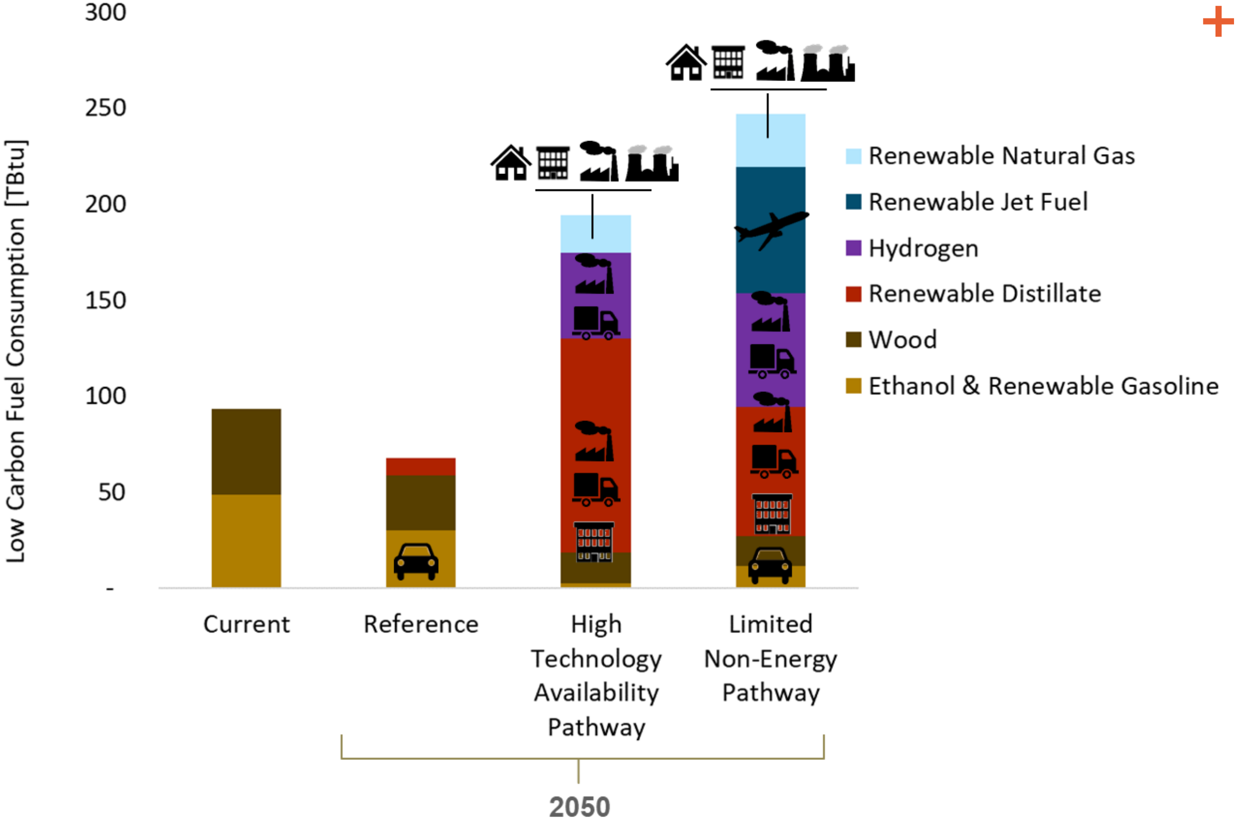
- Zero-emissions electricity is met with a diverse mix of resources, including onshore and offshore wind, solar, hydro, and existing nuclear



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

Biofuel Consumption in 2050



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