Energy+Environmental Economics

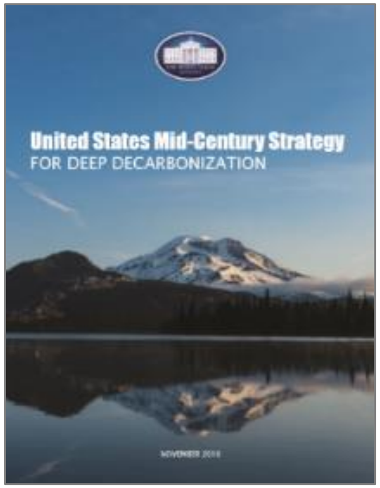
New York State Decarbonization Pathways Analysis

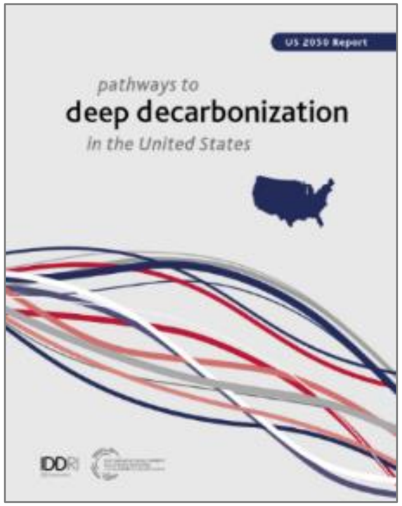
Energy Intensive and Trade Exposed Industries Panel Discussion

September 24, 2020

Analysis Overview

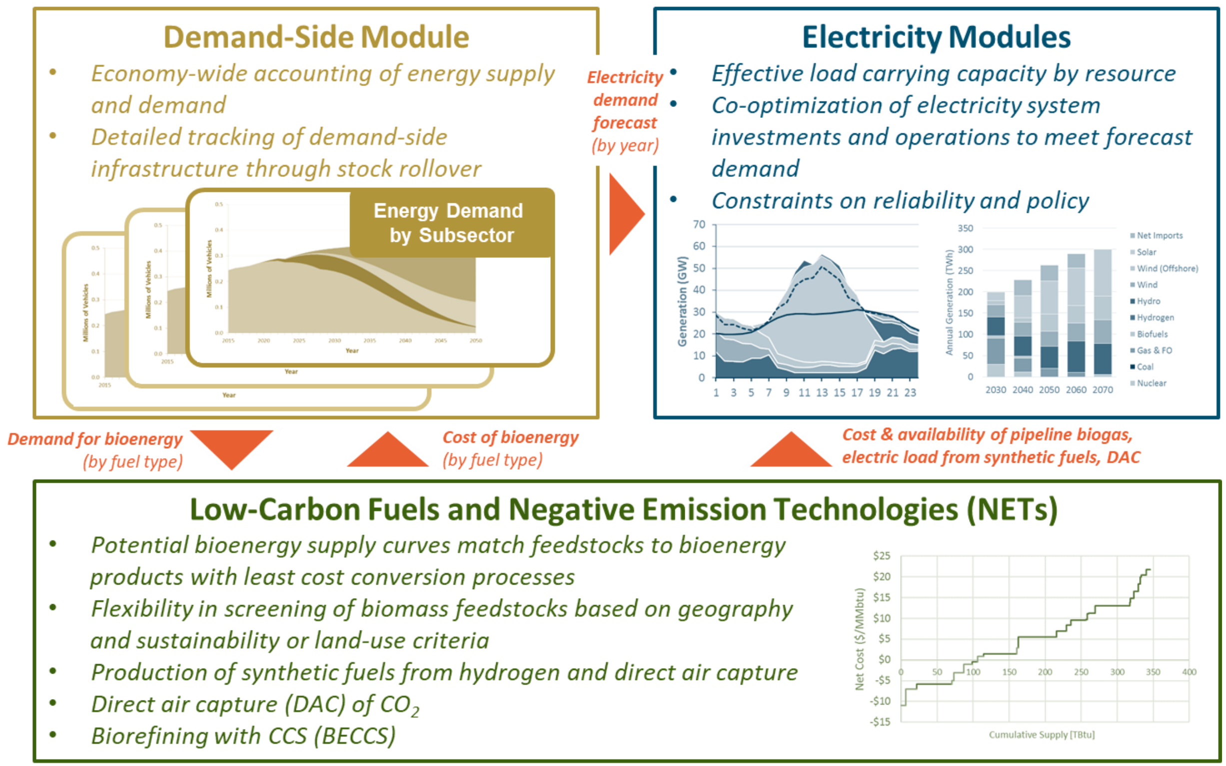
- NYSERDA engaged E3 to develop a strategic analysis of New York's decarbonization opportunities. This ongoing analytic work, initiated prior to the passage of the CLCPA, has modeled existing policies and explored additional actions needed to reach the State's 2030 and 2050 targets and provides a starting 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





Model Framework

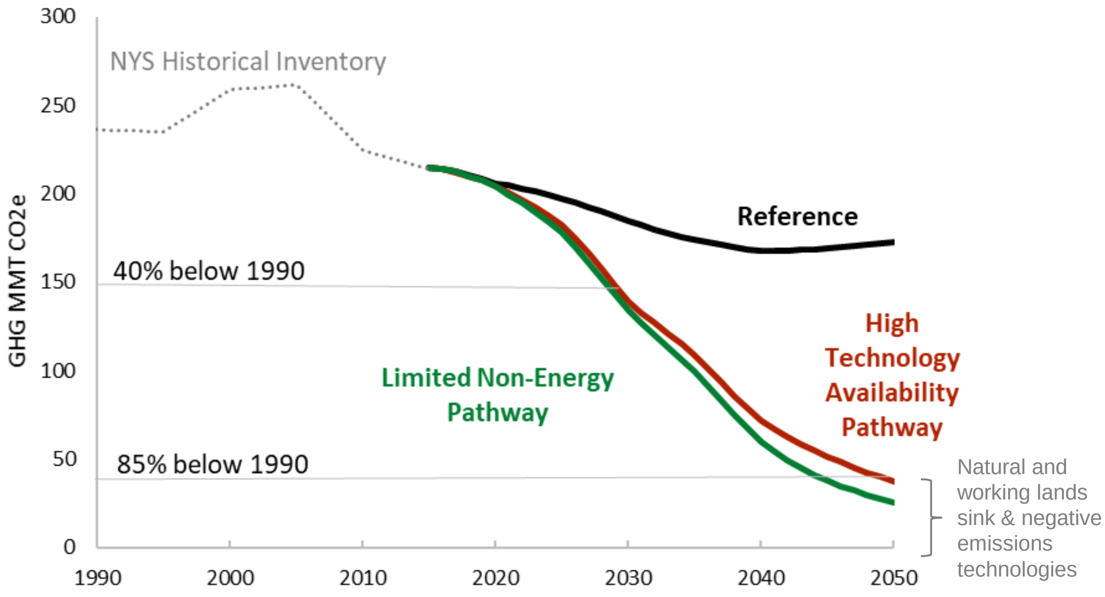
- Pathways analysis uses bottom-up, user-defined scenarios to test “what if” questions—or “**backcasting**”—to compare long-term decarbonization options and allows for development of realistic & concrete GHG reduction roadmaps.
- Bottom-up **stock rollover** modeling approach (based on EIA Nat’l Energy 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

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

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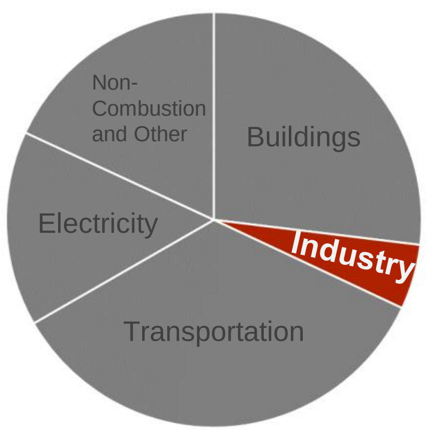
Characterization of the Industrial Sector

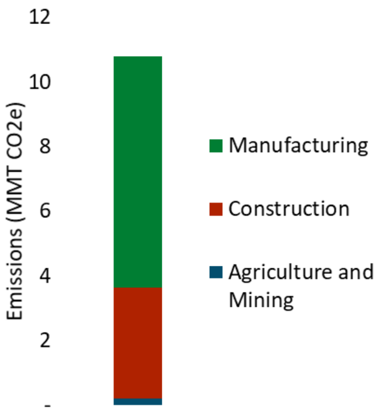
Industry Emissions

+ **Industrial emissions have decreased over 45% relative to 1990 levels and reflect 5% of 2016 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
+ **Energy demand in New York industry is dominated by manufacturing and construction subsectors**
  - Limited public data on industry makes further disaggregation of industrial energy and emissions sources difficult
  - Various NYSERDA studies and data sources used to estimate energy demand by industry category, and non-combustion emissions: Data suggest the majority of manufacturing energy demand is from chemicals manufacturing
+ **Majority of industrial energy emissions come from natural gas combustion, with remainder primarily from distillate and coal**

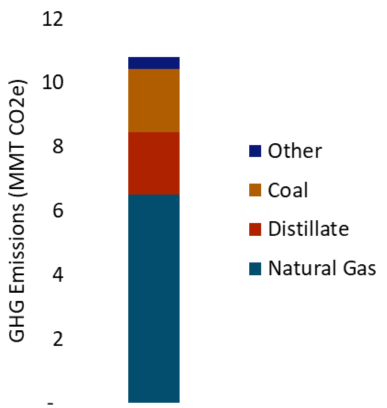
Economywide emissions in 2016



Industrial energy emissions by subsector



Industrial energy emissions by fuel



Notes: Natural gas used in transportation is applied in Industry, emissions associated with electricity consumption is tracked in the electricity generation sector
Emissions benchmarked to the NYSERDA GHG inventory
Energy demand benchmarked Patterns and Trends

Industry Emissions

Categories of emissions associated with industrial activity in NYS

- Direct on-site fossil fuel combustion from manufacturing (e.g. pharmaceuticals, other chemical products; cement, concrete & glass; metals; other), construction, agriculture and mining.
  - Limited public data on industry makes further disaggregation of industrial energy and emissions sources difficult[1]
- Indirect emissions from electricity
  - In this analysis accounted for in the electricity generation sector, but highlights an intersection with the Power Generation Advisory Panel
- Non-combustion emissions associated with heavy industrial processes (e.g., production of aluminum, iron and steel, cement, limestone and dolomite use, soda ash use)

[1]The core data source for energy consumption in industry is the EIA State Energy Data System (SEDS), which does not include additional detail on industrial sectors and end uses. The NYSERDA EE Potential Study has been used to refine segmentation

Future Industry Emission Trends

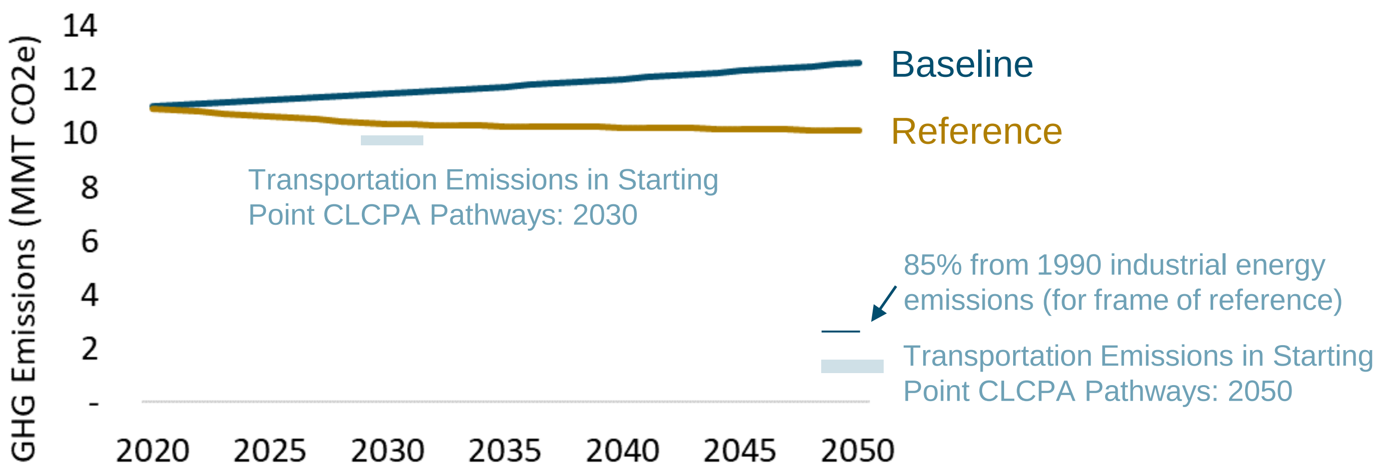
- **National population, state population, and state manufacturing-related GDP growth are key drivers of industrial energy demands**
  - US population projected to grow at 0.6% per year
  - State population projected to grow at 0.19% per year
  - For this analysis, manufacturing-related GDP projected to grow at rate of U.S. population
- **Efficiency improvements, codes and standards**

Notes: US population growth rate obtained from EIA AEO 2019
New York State population growth rate sourced from Cornell population forecast
State GDP growth is calculated by correlating US GDP growth to population with NYS population forecast

Industrial Sector Emissions Over Time

- **Baseline scenario represents a business as usual future, with no state decarbonization policies included**
  - Industrial energy demand shows continued growth in industry, across all fuel types, as population and GDP growth drivers continue to increase industrial fuel consumption
- **Reference scenario includes significant energy efficiency measures, consistent with statewide goals as of May 2019**
  - Consistent with energy efficiency targets set in New Efficiency: New York framework for 2025 and 2030

Industrial GHG emissions from fuel combustion



Opportunities for Decarbonization

Pillars of Deep Decarbonization in Industry

Energy Efficiency and Conservation	Switching to Low Carbon Fuels	Decarbonizing Electricity Supply	Negative Emissions and CCS

• Processes, lighting, and HVAC efficiency gains to reduce electricity usage
• Improved device efficiency in boilers and process heat to reduce natural gas demand
	• Electrification
	  • Especially for low-temperature processes
	• Low-carbon fuels
	  • Renewable natural gas
	  • Hydrogen substitution for some processes (e.g., coal -> H_2), as well as pipeline hydrogen (up to pipeline blend limit)
		• Reducing emissions at power plants to avoid emissions associated with industrial electricity use
		• Flexible industrial operations to reduce electricity use during peak demand periods
			• Carbon Capture and Storage (CCS) on appropriate industries and fuel demands with concentrated CO2 streams
			• Bioenergy with CCS for in-state feedstocks acts as a net negative emissions technology

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

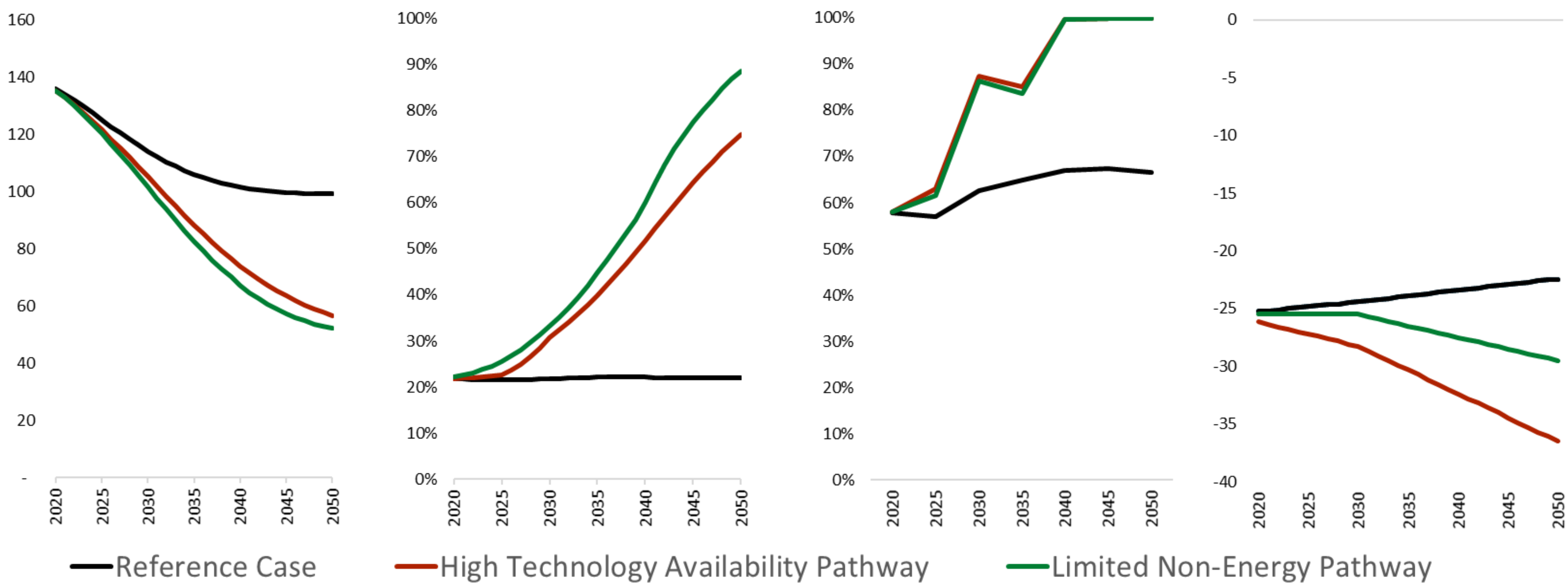
[% electricity supplied by wind, solar, hydro, nuclear, CCS, biofuels, hydrogen]

Unit: % electricity supplied

Negative Emissions

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

Unit: MMT CO2e



Opportunities to Decarbonize the Industrial Sector

+ Potential industry sector emissions reductions

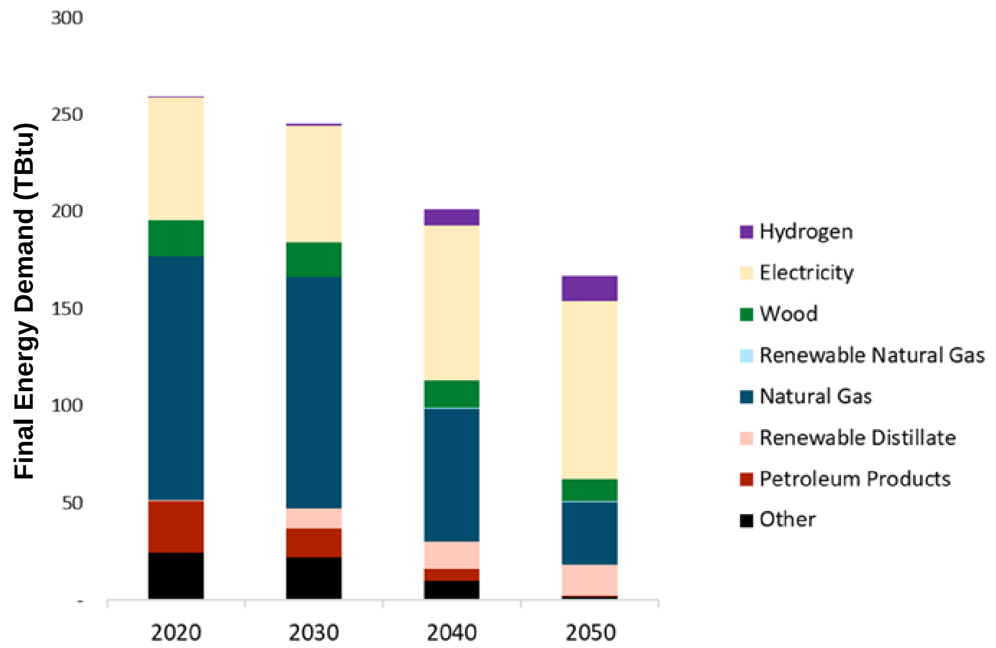
- Industrial energy consumption decarbonization will require energy efficiency and electrification
  - NYSERDA EE Potential Study suggests a large pool of economic and achievable energy efficiency potential available in industrial sector
  - Literature suggests a variety of industrial demands can be electrified, such as space heating and low-temperature process heat (suitable for manufacturing sectors like electronics & equipment, machinery & transportation, food processing and pulp & paper, some chemicals)
- For demands which are not good candidates for electrification, low-carbon fuel substitution or carbon capture and storage (CCS) are decarbonization options
  - Hydrogen and renewable natural gas are options to displacing fossil natural gas
  - Natural gas combustion, aluminum smelting, and steel mill process emissions may be good candidates for Industry CCS in New York

Sectoral Findings

Emissions Reductions in Industrial Applications

- 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*

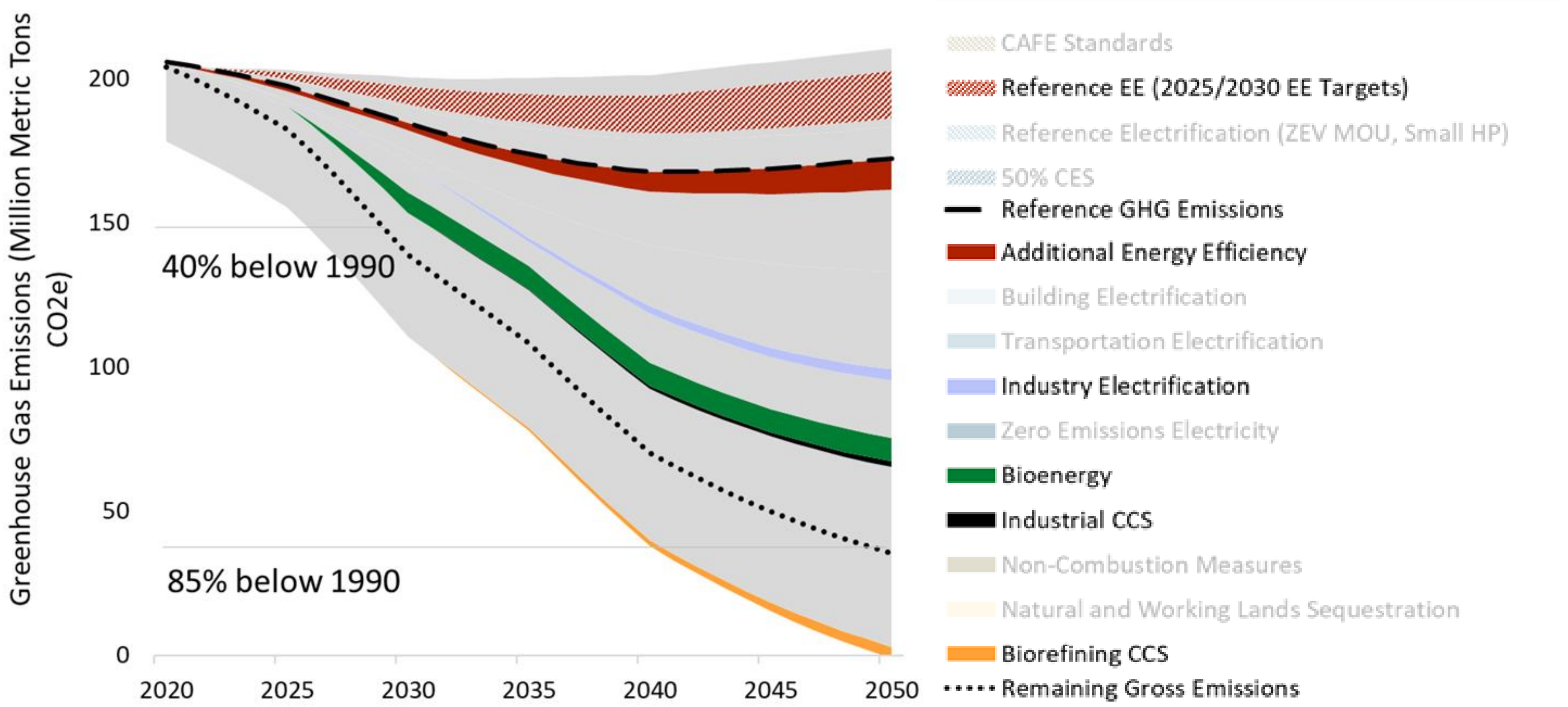
*** Range of values includes limited non-energy pathway*

Key Assumptions

Sector	Strategy	Expressed as	Reference	High Technology Availability	Limited Non-Energy
Industry	Efficiency	Efficiency increase relative to baseline projection	10% by 2030, 20% by 2050	10% by 2030, 45% by 2045	Same as HTA
	Fuel Switching	Share of natural gas and LPG use electrified	None	60% by 2045	Same as HTA
Zero Emissions Fuels	Bioenergy Availability	Feedstocks supply	Reference Projection (~70 TBtu)	In-state feedstocks (~150-200 TBtu)	Same as HTA
	Biofuels Blend	Share of conventional fuel use replaced with biofuels	8.4% biodiesel blend for heating oil in Downstate model segment by 2034 to account for areas with biodiesel mandates	40% renewable diesel by 2030, ~100% renewable diesel by 2050, 8% renewable gas in pipeline by 2050	40% renewable diesel by 2030, 100% renewable diesel by 2050, 18% renewable gas in pipeline by 2050
CCSU	Carbon Capture & Sequestration/Use	MMT CO2 captured and sequestered in 2050	None	Industry CCS: 2 MMT, BECCS: 4 MMT*	BECCS: 4 MMT*

* BECCS used only for bio-refining

Emissions Reductions by Measure
High Technology Availability Pathway

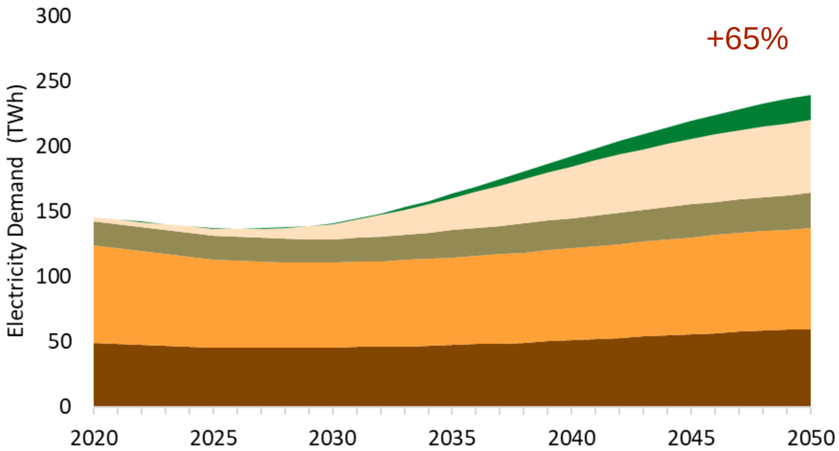


+ **Industrial measures such as energy efficiency, electrification, CCS, and low-carbon fuels are crucial to reach CLCPA goals**

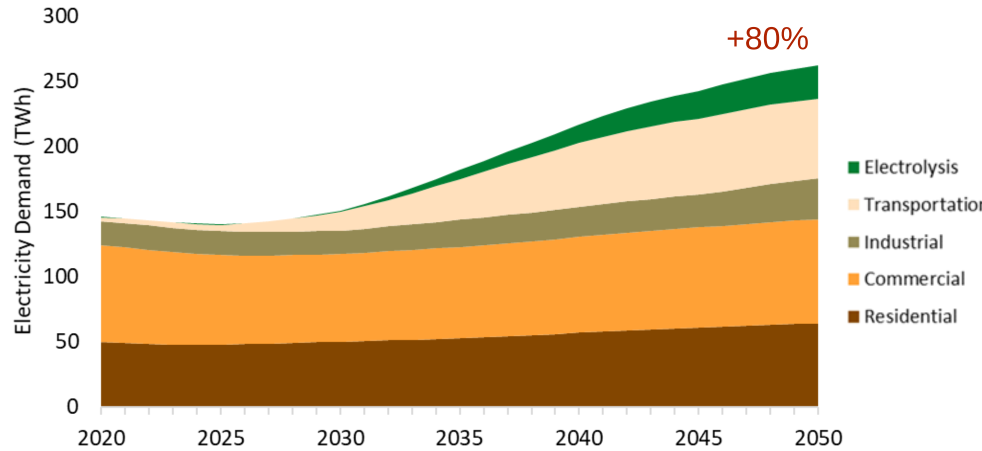
Annual Electricity Demand

+ 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

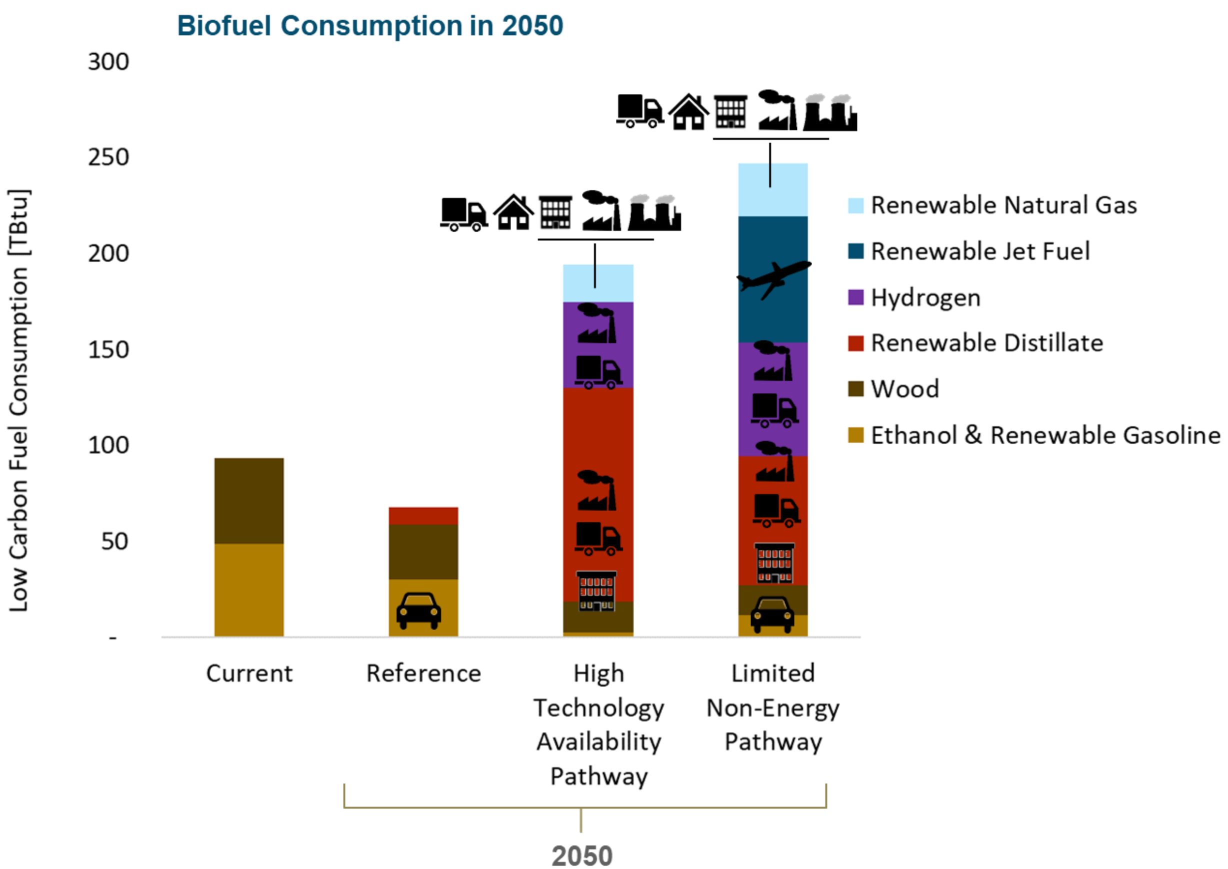


Limited Non-Energy Pathway
Electric Load by Sector



Low-Carbon Fuels

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



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

Key Takeaways for Industry

- Industrial emissions have decreased significantly since 1990, but additional effort is needed to ensure incremental reductions through 2030 and 2050
- Targeting economic and achievable energy efficiency measures has a significant role in reducing industrial emissions through 2030
- Achieving deep mid-century targets requires innovation in low-carbon fuel switching and electrification measures in addition to aggressive EE
- To reduce emissions in applications where electrification or low-carbon fuel-switching is infeasible, carbon capture utilization and storage is a potential measure

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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***
- ***Incorporation of Panel input into integrated, economy-wide pathways analysis***

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Questions?

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Appendix

Industry Key Drivers

+ Key drivers of industrial demand include nationwide population, regional population, and regional GDP growth

- Agriculture and mining forecast to grow with US population growth (average 0.6%/year through 2050)
- Construction assumed to grow with statewide population (average 0.19%/year through 2050 statewide, higher downstate)
- Manufacturing key driver is GDP growth, which we forecast by correlating US GDP growth to population with NYS population forecast (resulting in 0.6%/year manufacturing demand growth rate through 2050)

+ Energy demand calculations were performed for upstate and downstate regions

- Variety of data sources, including BLS data on jobs and NYSERDA data on industrial load by utility, used to perform this geographic allocation

Subsector	Geographic downscaling variable	Growth rate key driver
Agriculture	100% upstate	United States population growth rate 2017-2050
Mining	100% upstate	United States population growth rate 2017-2050
Construction	26% upstate (align with BLS data on construction jobs)	New York State population growth rate 2017-2050
Manufacturing Subsectors	90% upstate (align with NYSERDA industrial electricity use in upstate region, since key geographic downscale was initially to focus on implications on electricity)	0.6% (proxy for manufacturing related economic growth calculated by downscaling AEO US GDP growth by ratio of population growth rate for NYS/US)
Non-combustion and non-energy emissions	Relative population of upstate/downstate region used to downscale statewide non-combustion and non-energy emissions	NYSERDA provided forecast

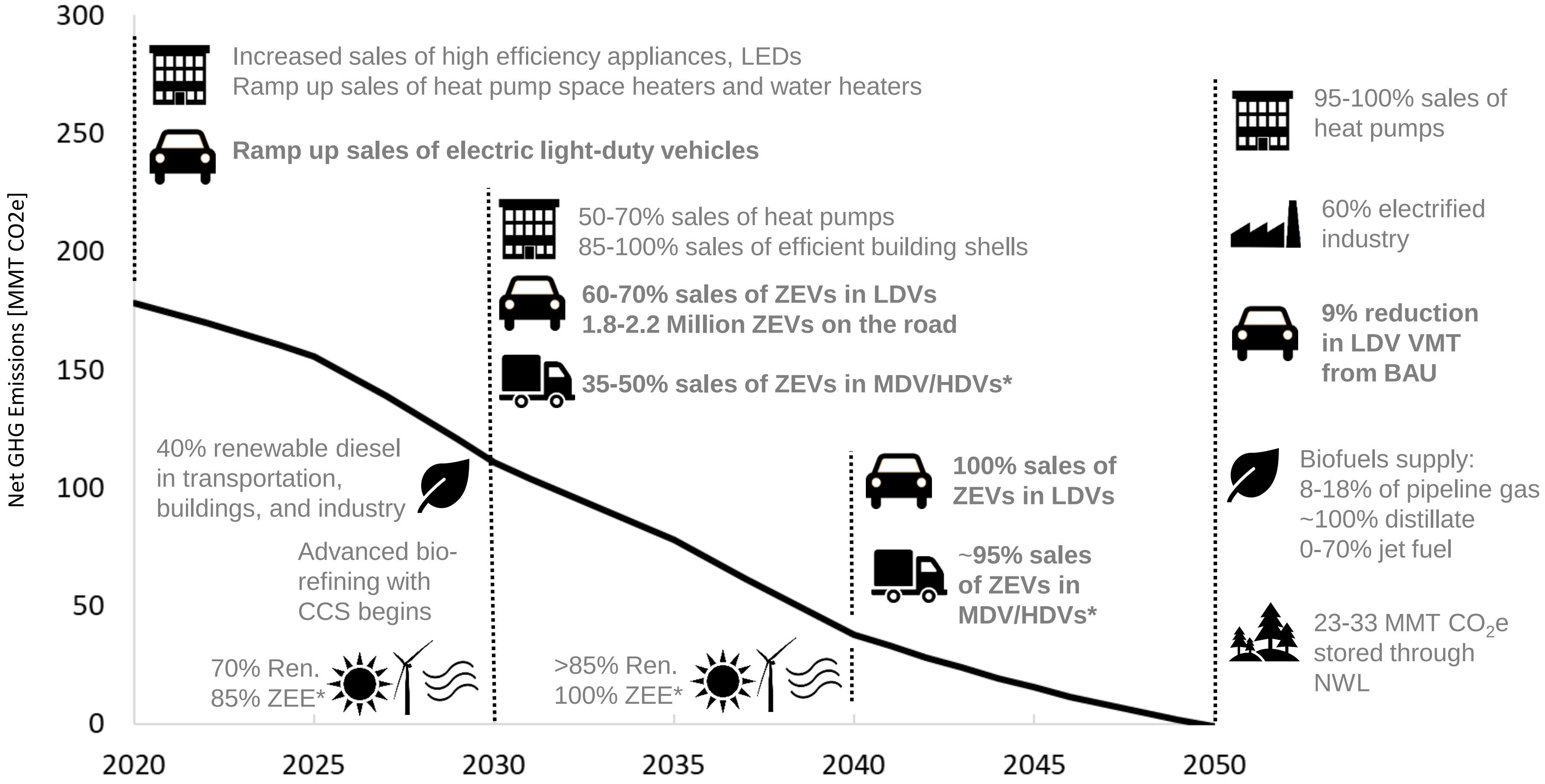
Notes: US population growth rate obtained from EIA AEO 2019
New York State population growth rate sourced from Cornell population forecast

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**

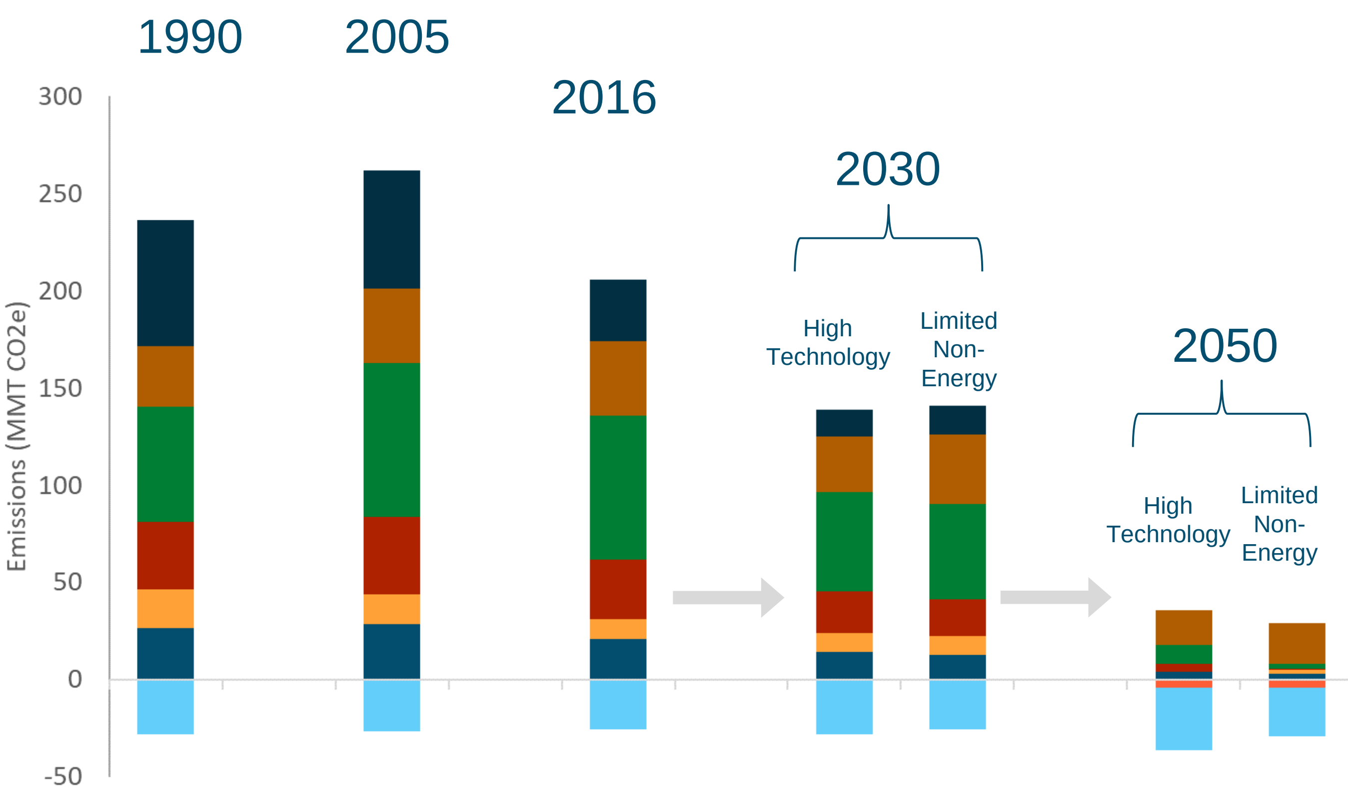


*Zero-Emissions Electricity (ZEE) includes wind, solar, large hydro, nuclear, CCS, and bioenergy; MDV includes buses

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



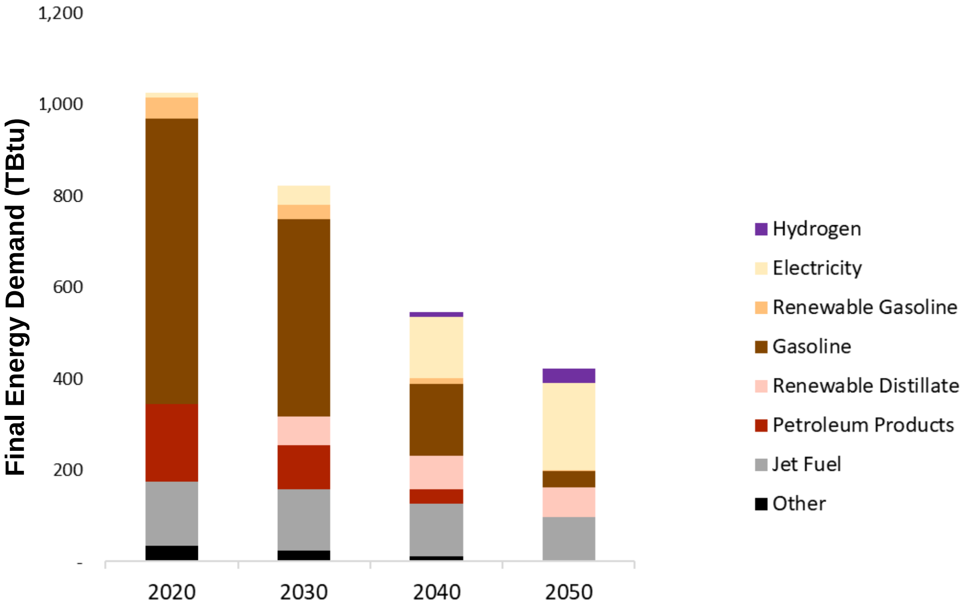
Percent reduction from 2016:

	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		

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%

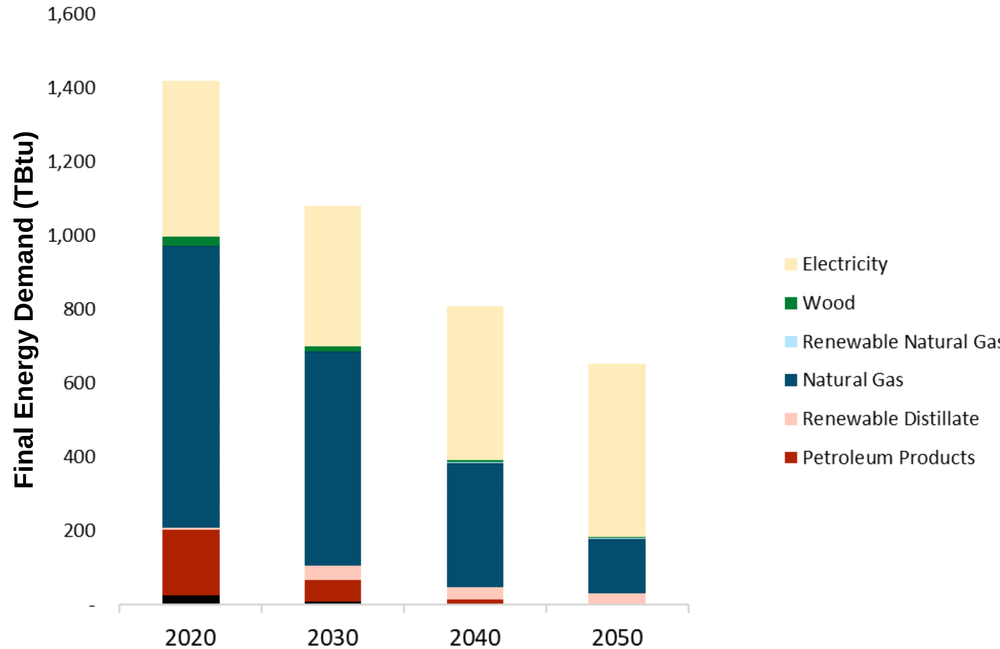
** Relative to 2016*

*** 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



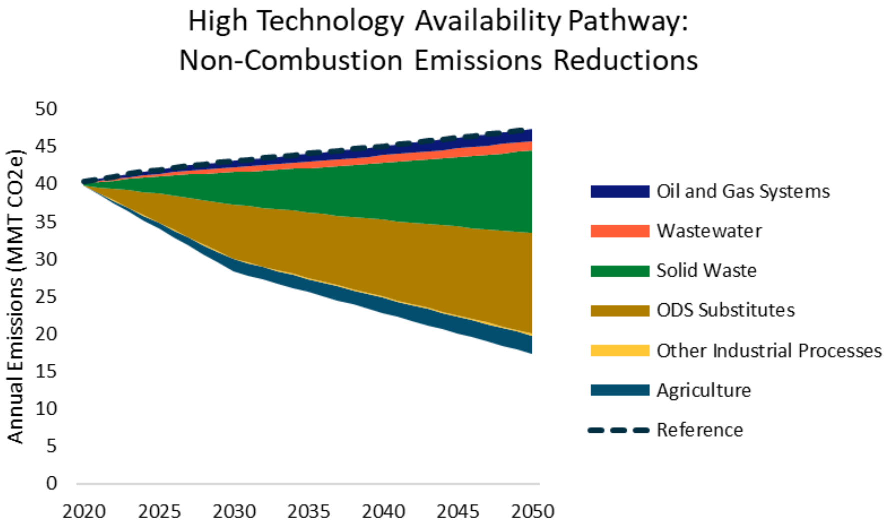
Metric	2030**	2050**
Percent GHG emissions reduction*	31%-39%	85%-93%
Percent reduction in final energy demand*	26%-31%	55%-59%

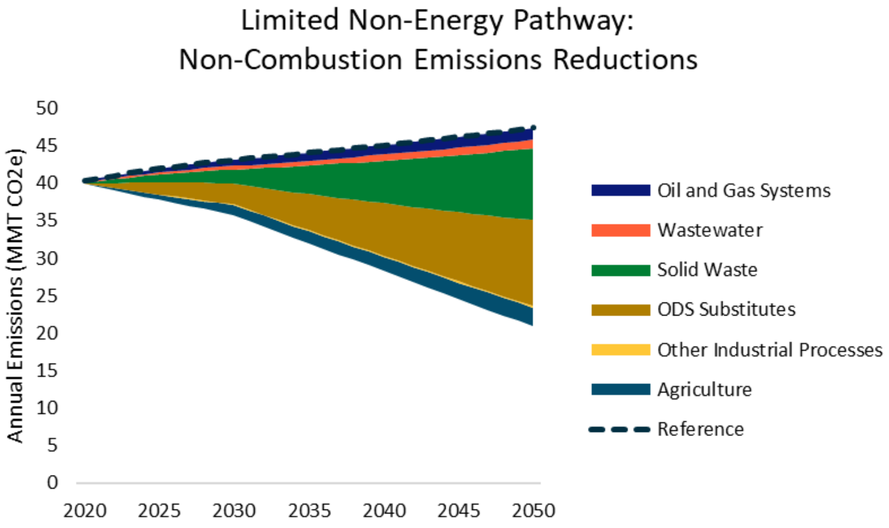
** Relative to 2016*

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

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.





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.