New York State Climate Action Council

Integration Analysis: Benefits and Costs

with Sensitivity Analysis

October 14, 2021

Updated November 18, 2021

NEW YORK STATE OF OPPORTUNITY. | Climate Action Council

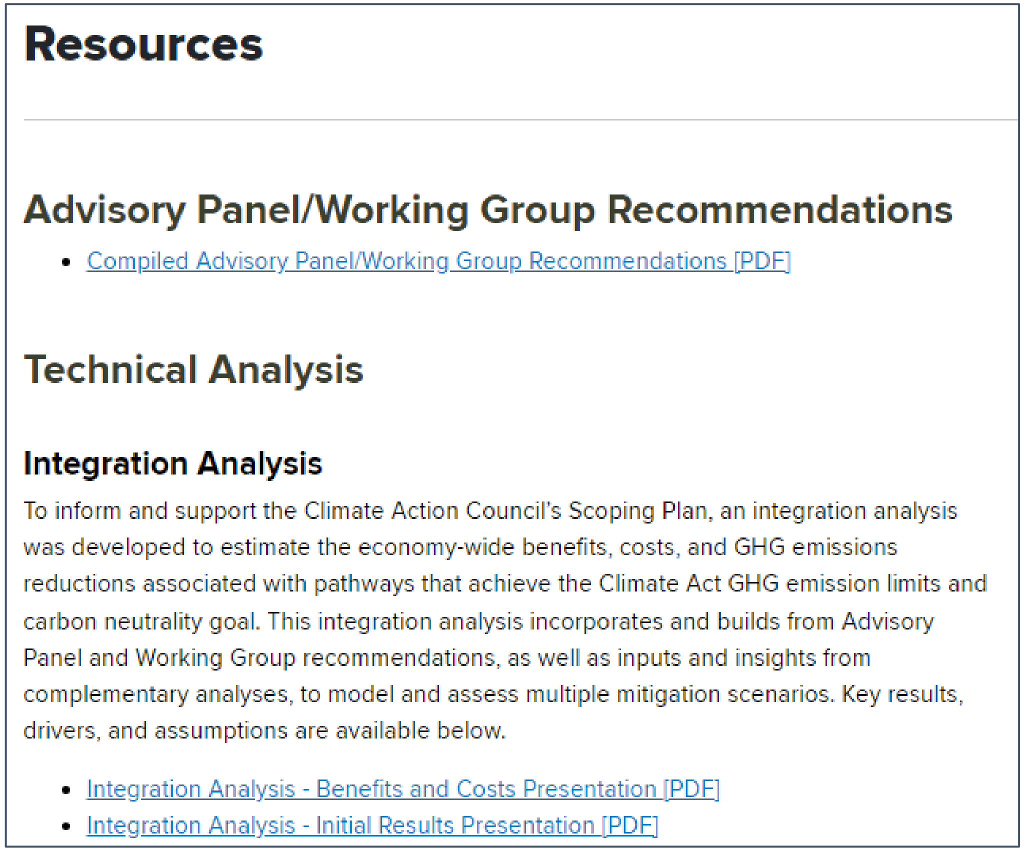
Contents

Revised November 18, 2021 with update to clarify reporting of wind and solar generation shares and include additional health effects detail

More Information

> For more information visit:

- https://climate.ny.gov/Climate-Resources
- https://climate.ny.gov/Climate-Action-Council/Meetings-and-Materials



Resources

Advisory Panel/Working Group Recommendations

- Compiled Advisory Panel/Working Group Recommendations [PDF]

Technical Analysis

Integration Analysis

To inform and support the Climate Action Council's Scoping Plan, an integration analysis was developed to estimate the economy-wide benefits, costs, and GHG emissions reductions associated with pathways that achieve the Climate Act GHG emission limits and carbon neutrality goal. This integration analysis incorporates and builds from Advisory Panel and Working Group recommendations, as well as inputs and insights from complementary analyses, to model and assess multiple mitigation scenarios. Key results, drivers, and assumptions are available below.

- Integration Analysis - Benefits and Costs Presentation [PDF]
- Integration Analysis - Initial Results Presentation [PDF]

NY CCSC New York Climate Change Science Clearinghouse

NEW YORK STATE CLIMATE IMPACTS ASSESSMENT

https://www.nyclimatescience.org/

https://nysclimateimpacts.org/

Overview of Scenarios and Recap of Sectoral Results

Scenario Overview

> Previous scenarios
- *Reference Case*
  - *Currently implemented policies*
- *Scenario 1: Advisory Panel Recommendations*
  - *Aggregate impacts of recommendations from Advisory Panels*

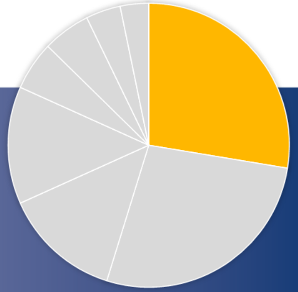
> Scenarios that meet or exceed GHG emission limits, achieve carbon neutrality by midcentury
- Foundational themes across **all** mitigation scenarios based on findings from Advisory Panels and supporting analysis
  - Zero emission power sector by 2040
  - Enhancement and expansion of transit & vehicle miles traveled reduction
  - More rapid and widespread end-use electrification & efficiency
  - Higher methane mitigation in agriculture and waste
  - End-use electric load flexibility reflective of high customer engagement and advanced techs
- **Scenario 2: Strategic Use of Low-Carbon Fuels**
  - Includes the use of bioenergy derived from biogenic waste, agriculture & forest residues, and limited purpose grown biomass, as well as green hydrogen, for difficult to electrify applications
- **Scenario 3: Accelerated Transition Away from Combustion**
  - Low-to-no bioenergy and hydrogen combustion; Accelerated electrification of buildings and transportation
- **Scenario 4: Beyond 85% Reduction**
  - Accelerated electrification + limited low-carbon fuels; Additional VMT reductions; Additional innovation in methane abatement; Avoids direct air capture of CO2

Level of Transformation by Mitigation Scenario

	Scenario 2: Strategic Use of Low-Carbon Fuels	Scenario 3: Accelerated Transition Away from Combustion
Efficiency and Electrification	High	Very High
Transit and Smart Growth	High	High
Zero-Emission Vehicles	High	Very High
Clean Electricity	High	High
Low-Carbon Fuels	High	Low
Emissions Mitigation in Agriculture & Waste	High	High
Carbon Sequestration in Lands and Forests	High	Very High
Negative Emissions Technologies	High	Medium

Buildings Sector

Scenario 2: Strategic Use of Low-Carbon Fuels



> Building emissions reductions are driven by rapid electrification, increased energy efficiency, and improved building shells

> Rapid adoption of electrified technologies that expands upon an ambitious interpretation of AP recommendations:

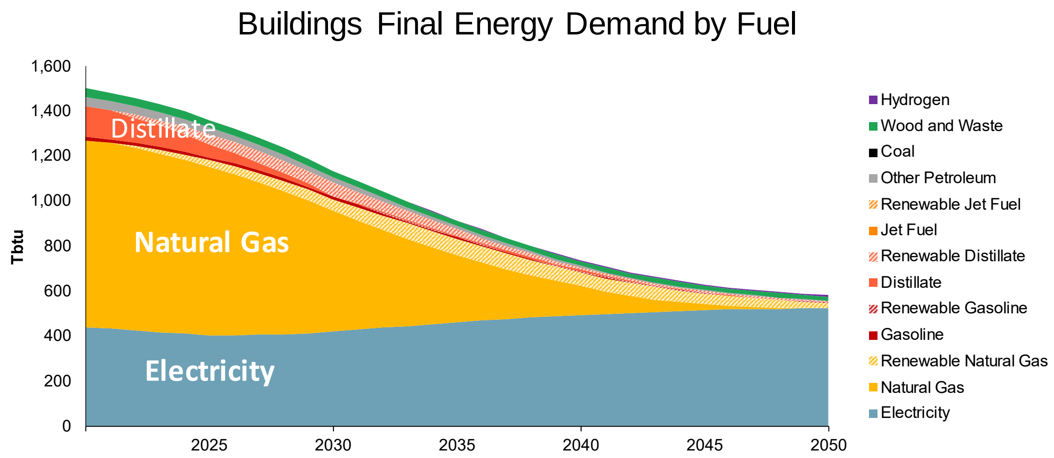
- 77% sales of HPs by 2029, 100% sales of HPs for all buildings by 2035
  - 41% of residential SH stocks are HPs by 2035, 92% by 2050
  - 47% of commercial SH stocks are HPs by 2035, 94% by 2050
  - 80% ASHP, 20% GSHP, with most ASHP using electric back-up
- 100% sales of electrified end uses for cooking and clothes drying by 2035
- NYC District Heat system converts 100% of natural gas use to hydrogen by 2050.

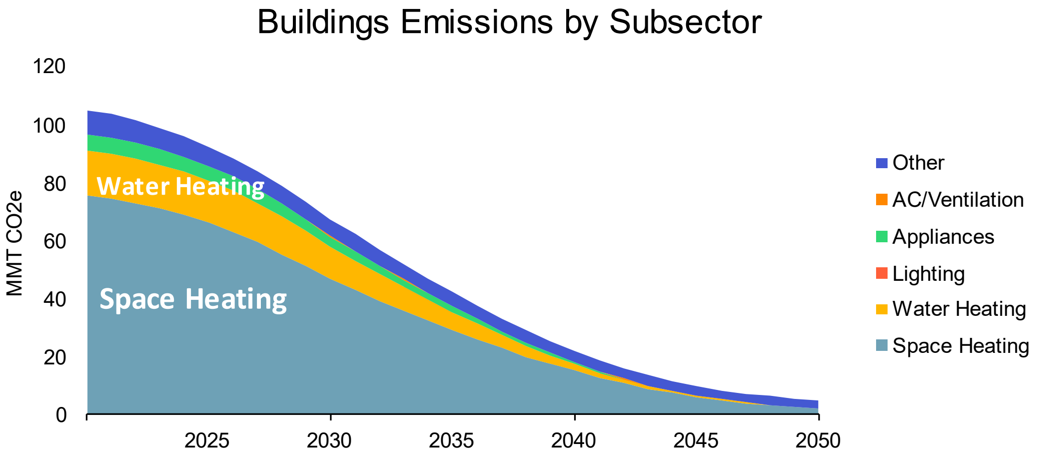
> Adoption of improved building shells for most new sales by 2035

- By 2035, 95% of new building shell installations (new and retrofits) implement a shell improvement or retrofit.
  - By 2050, around 92% of building stocks have improved shells

> Scenario 2 achieves significant emissions reductions relative to 1990:

- 2030: 36% reductions below 1990 levels
- 2050: 95% reductions below 1990 levels





2020 is a modelled year, reflecting historical trends

Underlying characterization of key technologies informed by Building Electrification Roadmap analysis

Buildings Sector

Scenario 3: Accelerated Transition Away from Combustion

> Building emissions reductions are driven by rapid electrification, increased energy efficiency, and improved building shells

> Rapid adoption of electrified technologies that expands upon an ambitious interpretation of AP recommendations:

- 80% sales of HPs by 2029, 100% sales of HPs for all buildings by 2035
  - Up to 10% early retirements of fossil stock for residential and commercial space heating by 2030
  - 41% of residential SH stocks are HPs by 2035, 92% by 2050
  - 51% of commercial SH stocks are HPs by 2035, 99% by 2050
  - All ASHP have electric backup, higher share of GSHP than scenario 2
- 100% sales of electrified end uses for cooking and clothes drying by 2035
- NYC District Heat system converts 100% of natural gas use to hydrogen by 2050.

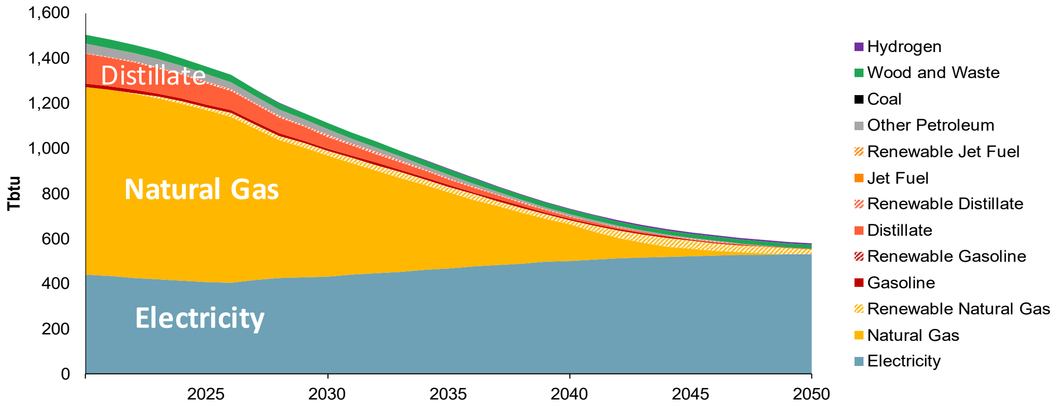
> Adoption of improved building shells for most new sales by 2035

- By 2035, 95% of new building shell installations (new and retrofits) implement a shell improvement or retrofit.
  - By 2050, around 92% of buildings stocks have improved shells

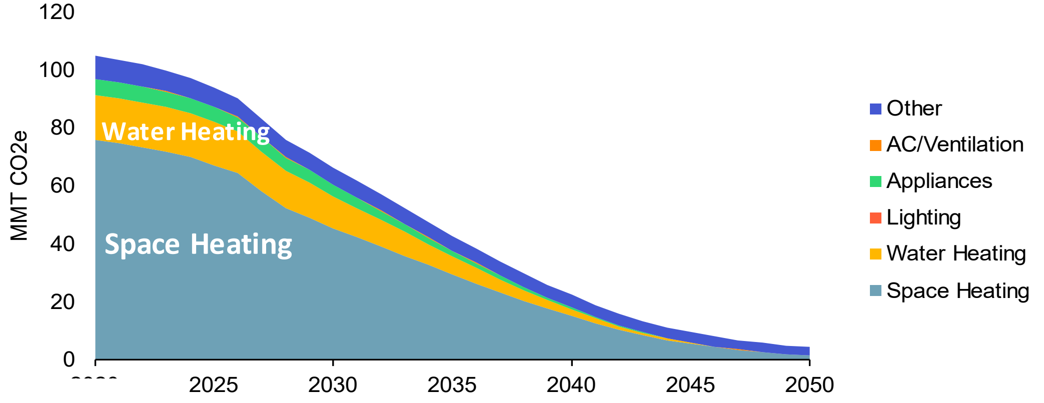
> Scenario 3 achieves significant emissions reductions relative to 1990:

- 2030: 37% reductions below 1990 levels
- 2050: 96% reductions below 1990 levels

Buildings Final Energy Demand by Fuel



Buildings Emissions by Subsector



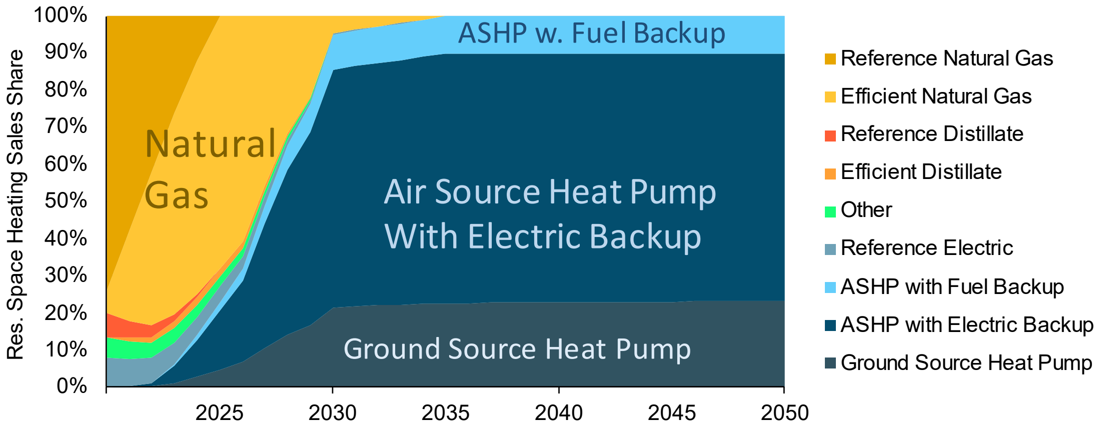
2020 is a modelled year, reflecting historical trends

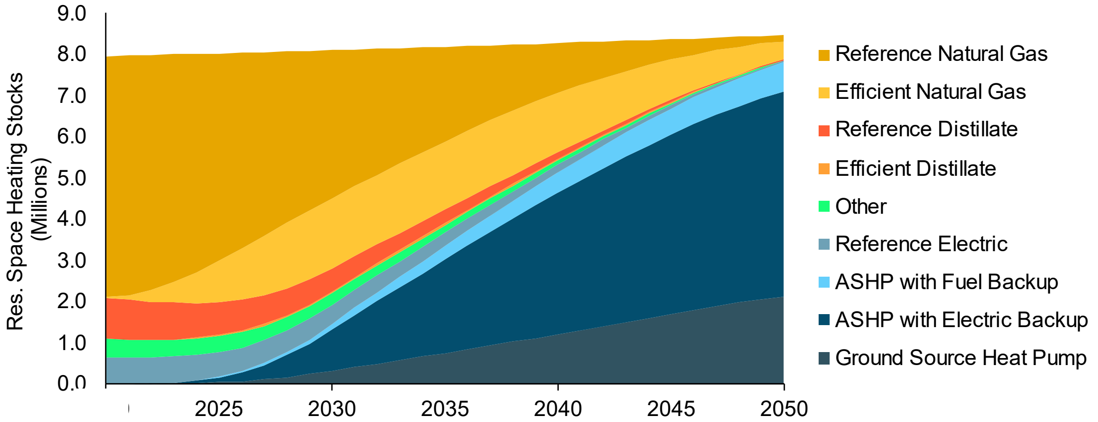
Underlying characterization of key technologies informed by Building Electrification Roadmap analysis

Key Technology Adoption in Buildings

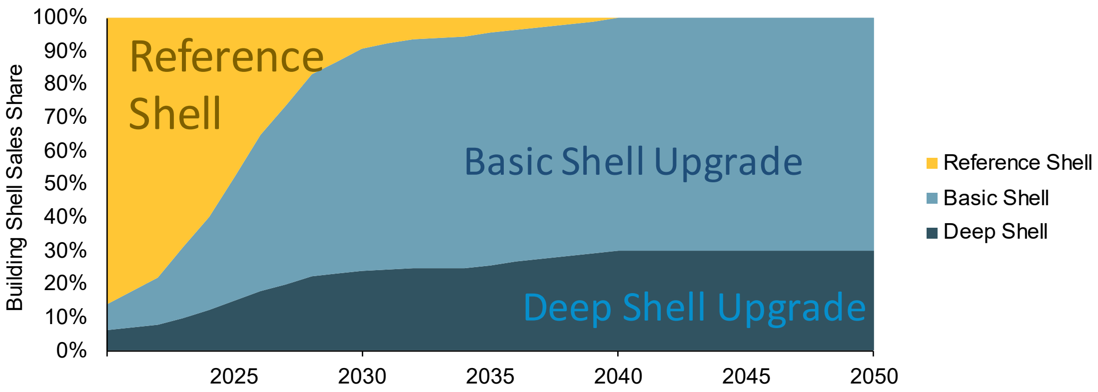
Scenario 2: Strategic Use of Low-Carbon Fuels

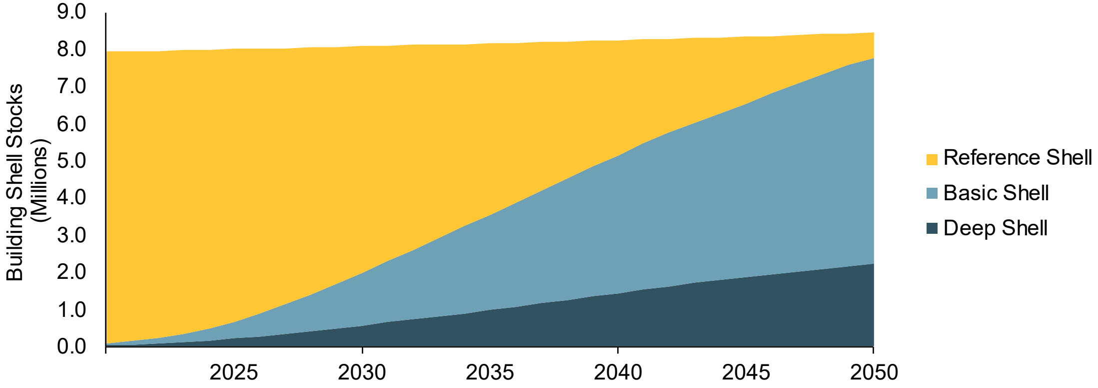
Residential Space Heating





Residential Building Shell





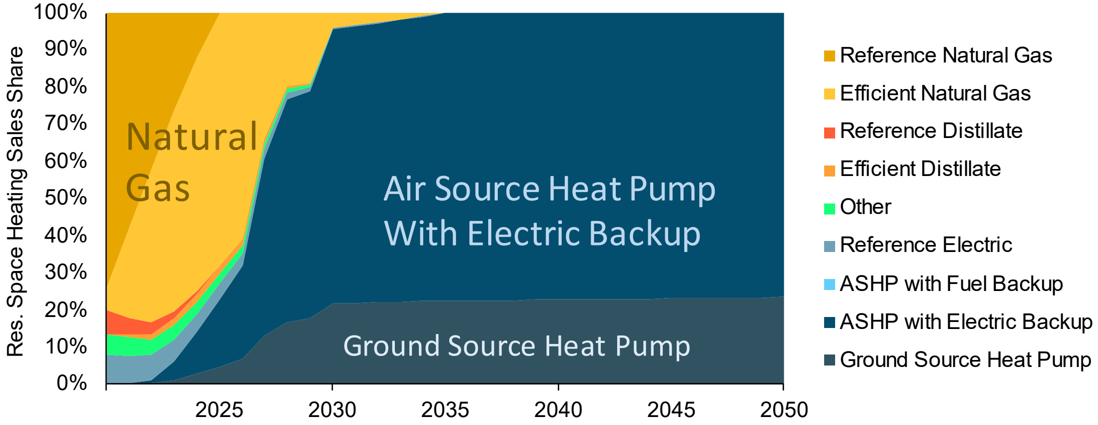
Basic Shell Definition: **27-44%** reduction in building space heating and **14-27%** AC demands
Deep Shell Definition: **57-90%** reduction in building space heating and **9-57%** AC demands

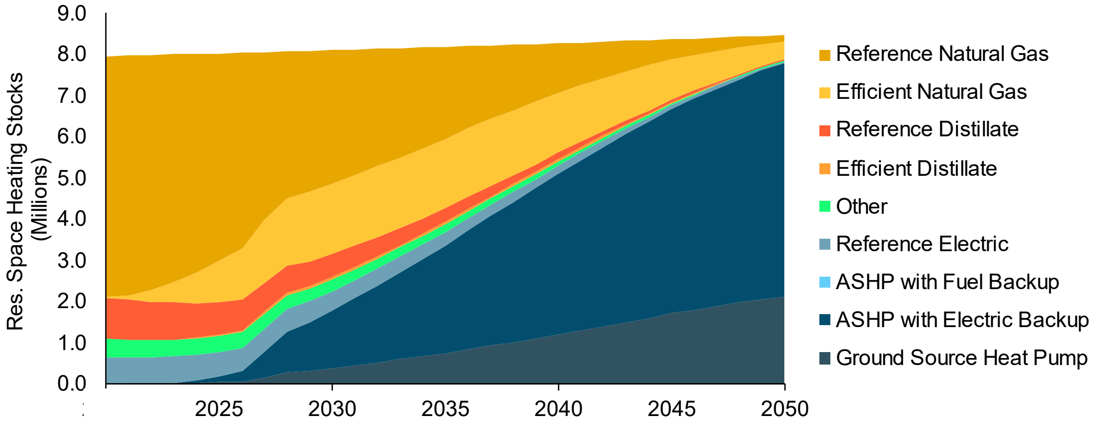
2020 is a modelled year, reflecting historical trends

Key Technology Adoption in Buildings

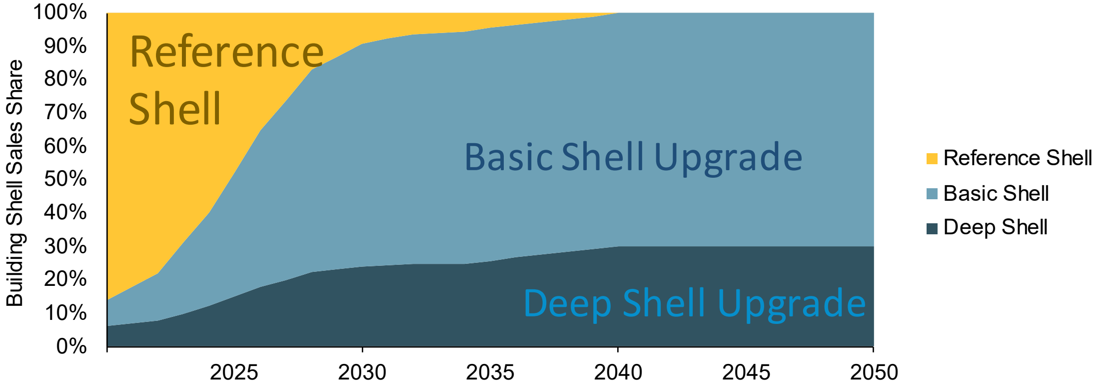
Scenario 3: Accelerated Transition Away from Combustion

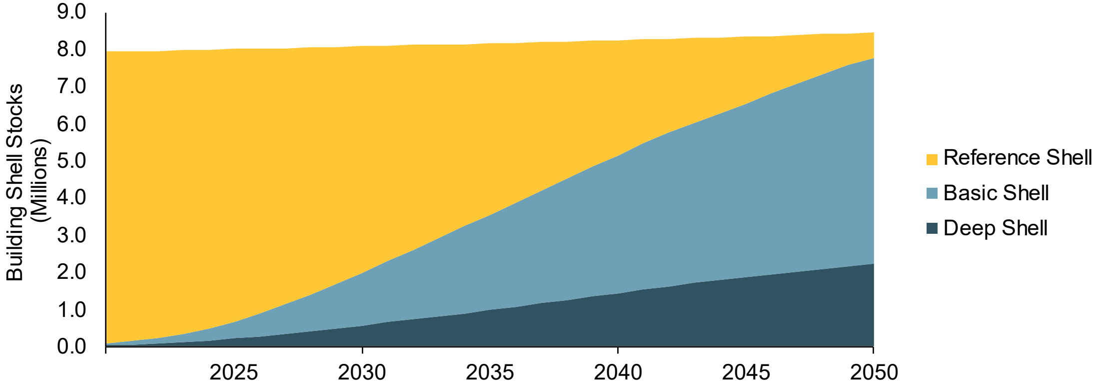
Residential Space Heating





Residential Building Shell





Basic Shell Definition: **27-44%** reduction in building space heating and **14-27%** AC demands
Deep Shell Definition: **57-90%** reduction in building space heating and **9-57%** AC demands

2020 is a modelled year, reflecting historical trends

Level of Transformation by Scenario: **Buildings**

	Scenario 2: Strategic Use of Low-Carbon Fuels	Scenario 3: Accelerated Transition Away from Combustion
Efficiency and Electrification	*High*	*Very High*
New Sales of Heat Pumps	77% by 2029, 100% by 2030/2035 (SF/MF+Com)	80% by 2029, 100% by 2030/2035 (SF/MF+Com), 10% early retirement by 2030
Mix of Heat Pump Technologies	70% ASHP, 10% ASHP + fuel backup, 20% GSHP	77% ASHP, 23% GSHP
Share of Electrified Buildings*	18% by 2030, 92% by 2050 1.5 Mil. Households by 2030, 7.8 Mil. by 2050 1.1 Bil. Com sqft by 2030, 5.3 Bil. By 2050	22% by 2030, 92% by 2050 1.8 Mil. Households by 2030, 7.8 Mil. by 2050 1.4 Bil. Com sqft by 2030, 5.6 Bil. By 2050
Share of Buildings with Efficient Shell	7% Deep Shell, 18% Basic Shell by 2030 26% Deep Shell, 66% Basic Shell by 2050	7% Deep Shell, 18% Basic Shell by 2030 26% Deep Shell, 66% Basic Shell by 2050
Air Conditioning Saturation	100% saturation by 2050 reflecting climate trends and HP adoption	100% saturation by 2050 reflecting climate trends and HP adoption
NYC District Heat System	3% annual efficiency improvement, 100% hydrogen conversion by 2050	3% annual efficiency improvement, 100% hydrogen conversion by 2050
Smart Devices and Conservation (AC, Space Heating)	10% reduction by 2030, 15% by 2050	10% reduction by 2030, 15% by 2050

**Electrified buildings include all homes with a heat pump (ASHP, ASHP with fuel backup, GSHP) but do not include homes with electric resistance heat, which are appx. 470,000 in 2030)*

Basic Shell Definition: **27-44%** reduction in building space heating and **14-27%** AC demands
Deep Shell Definition: **57-90%** reduction in building space heating and **9-57%** AC demands

Level of Transformation by Scenario: **Buildings Continued**

	Scenario 2: Strategic Use of Low-Carbon Fuels	Scenario 3: Accelerated Transition Away from Combustion
Low-Carbon Fuels	*High*	*Low*
Hydrogen (via electrolysis)	NYC district heat converted to hydrogen	NYC district heat converted to hydrogen
Biomass feedstock availability	In-state + regional feedstocks incl. energy crops	None
Bioenergy utilization	9% RNG, 75% renewable distillate by 2030 100% RNG and renewable distillate by 2050	4% RNG by 2030, 100% by 2050 (Limited volume from targeted methane abatement from landfills and wastewater only)
Climate-Friendly Refrigerants	*High*	*High*
Transition to ultra-low-GWP and natural refrigerant technologies	Max adoption for building, transportation, and industrial HVAC + refrigeration sectors	Max adoption for building, transportation, and industrial HVAC + refrigeration sectors
Service reclaim at end of life	90% recover rate	90% recover rate

Transportation Sector

Scenario 2: Strategic Use of Low-Carbon Fuels

> Light duty vehicles transition to battery electric technology

- 90% of new sales are ZEVs by 2030, 100% by 2035
- 21% of stocks are ZEVs by 2030, 95% by 2050

> Medium and heavy-duty vehicles are slower to transition, and rely on a combination of battery electric and hydrogen fuel cell technologies

- 40% of new sales are ZEVs by 2030, 100% by 2045
- 50/50 split BEV/FCEV for MDVs, 25/75 for HDVs
- 7% of stocks are ZEVs by 2030, 76% by 2050

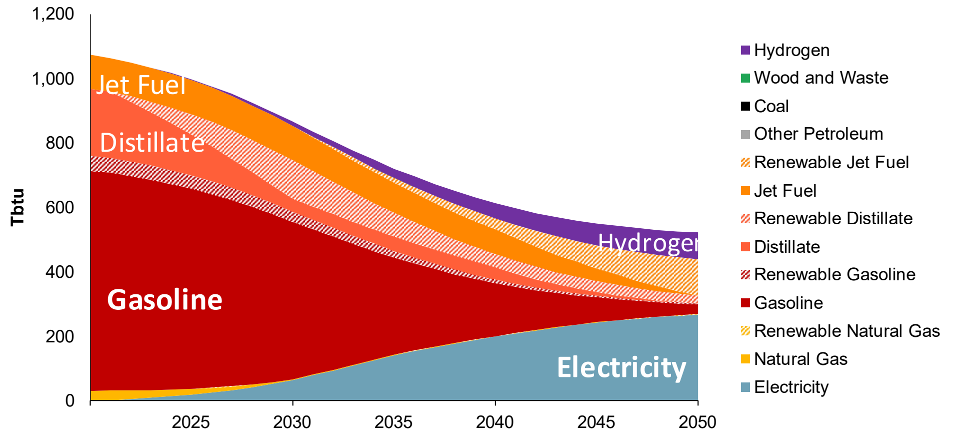
> Reduction in vehicle miles travelled due to transit, transportation demand management, telework, mixed-use development, and complete streets policies drives emission reductions

- 6% lower for LDV than the Reference in 2035 and 2050

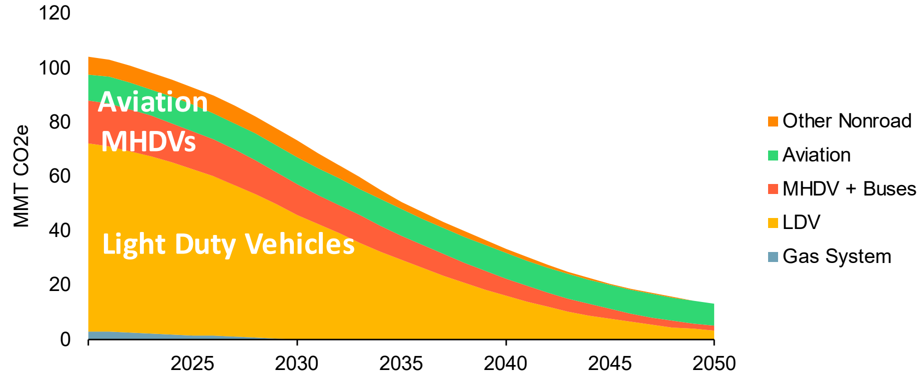
> Scenario 2 achieves significant emissions reductions relative to 1990:

- 2030: 27% reductions below 1990 levels
- 2050: 87% reductions below 1990 levels

Transportation Final Energy Demand by Fuel



Transportation Emissions by Subsector



2020 is a modelled year, reflecting historical trends

Key driver and underlying technology assumptions informed by Transportation Roadmap analysis

Transportation Sector

Scenario 3: Accelerated Transition Away from Combustion

> Light duty vehicles transition to battery electric technology

- 98% of new sales are ZEVs by 2030, 100% by 2035
  - 10% early retirements of fossil stock by 2030
  - 26% of stocks are ZEVs by 2030, 95% by 2050

> Medium and heavy-duty vehicles are slower to transition, and rely on a combination of battery electric and hydrogen fuel cell technologies

- 50% of new MDV sales are ZEVs by 2030, 100% by 2045
  - 75/25 for MDVs
- 40% of new HDV sales are ZEVs by 2030, 100% by 2045
  - 50/50 split BEV/FCEV for HDVs
- 9% of MHDV stocks are ZEVs by 2030, 85% by 2050

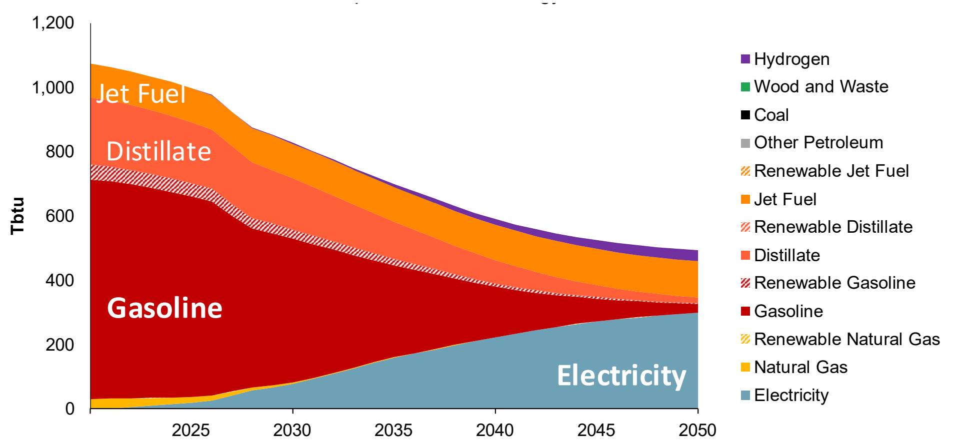
> Reduction in vehicle miles travelled due to transit, transportation demand management, telework, mixed-use development, and complete streets policies drives emission reductions

- 6% lower for LDV than the Reference in 2035 and 2050

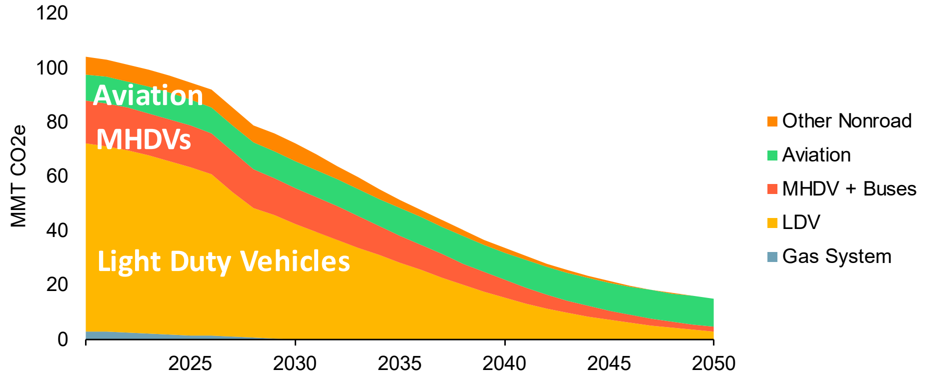
> Scenario 3 achieves significant emissions reductions relative to 1990:

- 2030: 28% reductions below 1990 levels
- 2050: 85% reductions below 1990 levels

Transportation Final Energy Demand by Fuel



Transportation Emissions by Subsector



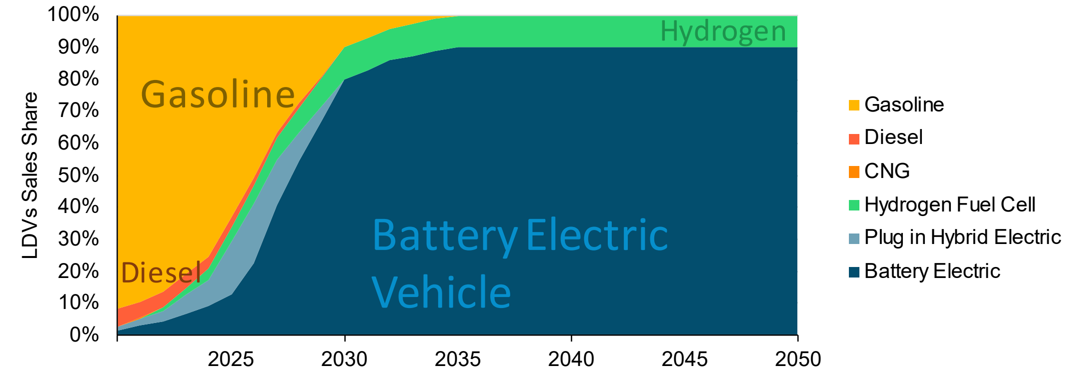
Key driver and underlying technology assumptions informed by Transportation Roadmap analysis

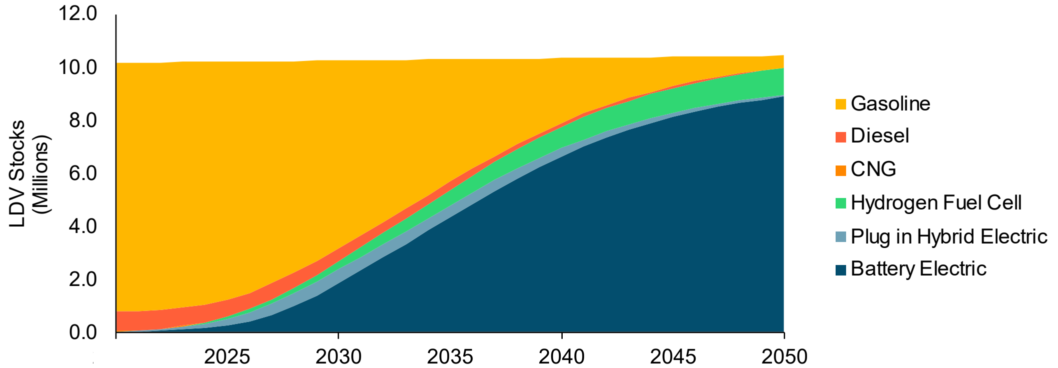
2020 is a modelled year, reflecting historical trends

Transportation Stock Rollover

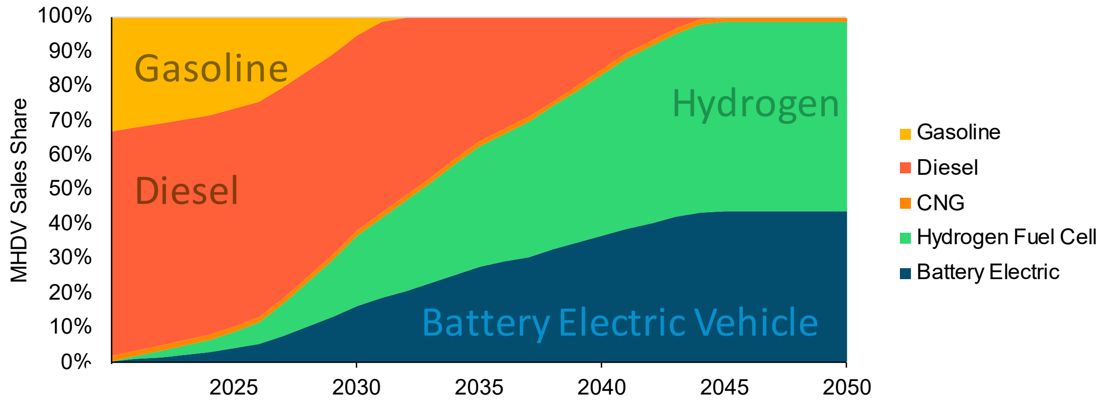
Scenario 2: Strategic use of Low-Carbon Fuels

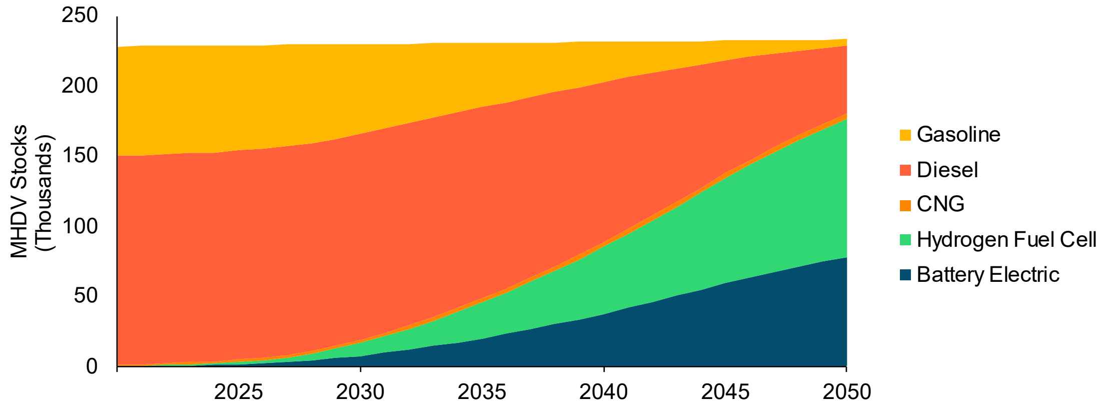
Light Duty Vehicles





Medium and Heavy Duty Vehicles



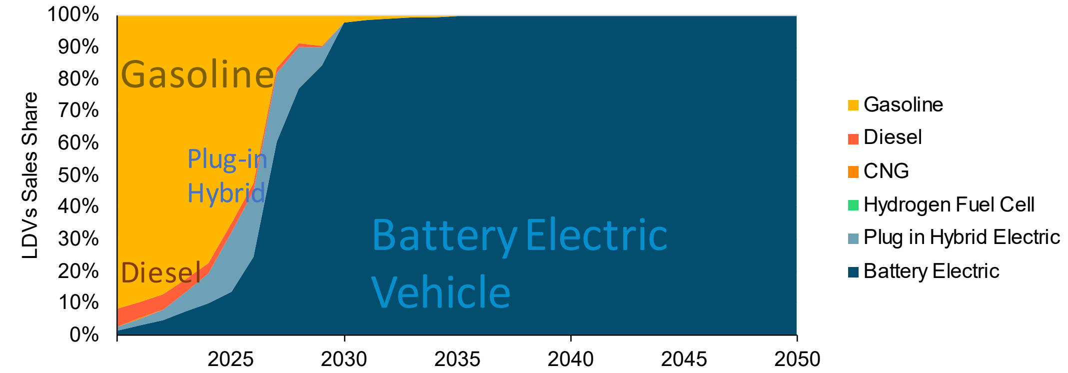


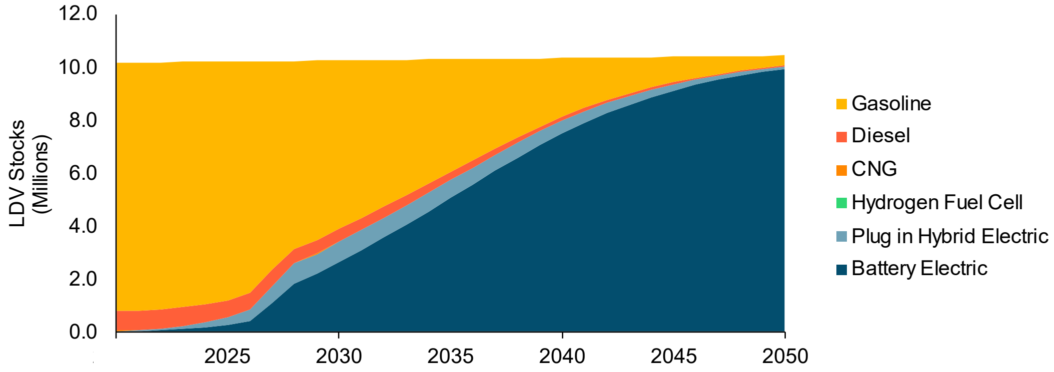
2020 is a modelled year, reflecting historical trends

Transportation Stock Rollover

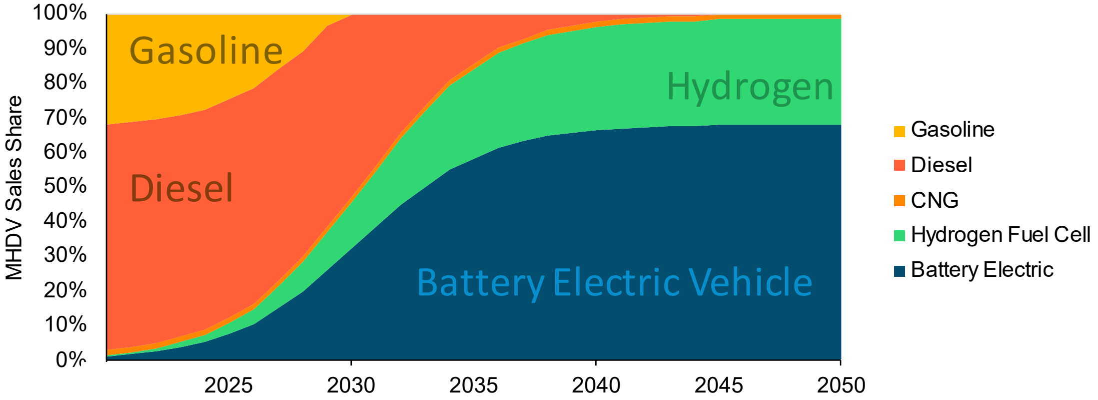
Scenario 3: Accelerated Transition Away from Combustion

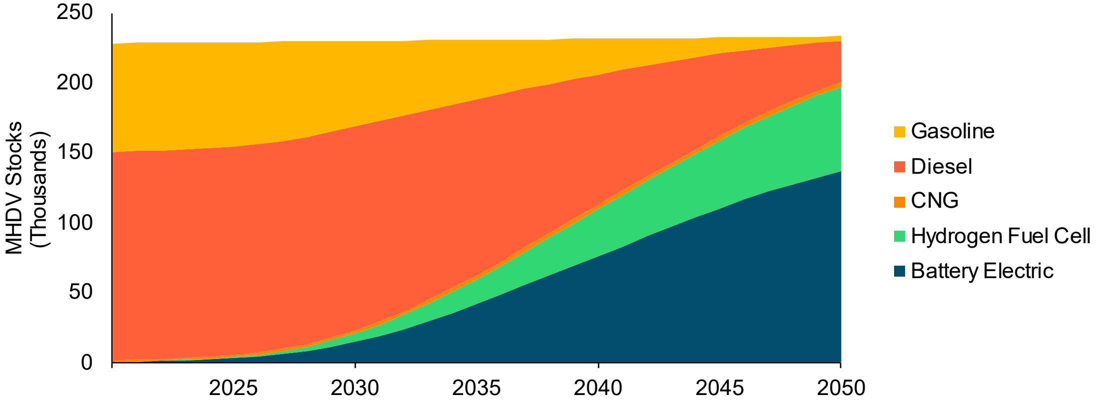
Light Duty Vehicles





Medium and Heavy Duty Vehicles





2020 is a modelled year, reflecting historical trends

Level of Transformation by Scenario: **Transportation**

	Scenario 2: Strategic Use of Low-Carbon Fuels	Scenario 3: Accelerated Transition Away from Combustion
Transit and Smart Growth	High	High
Bus Transit Service	Enhancement and expansion of bus transit, where service more than doubles in many areas of the state	Enhancement and expansion of bus transit, where service more than doubles in many areas of the state
Telework + TDM, Walking/Biking, Smart Growth, Rail	Expansion of telework + TDM programs, urban infrastructure, and smart growth	Expansion of telework + TDM programs, urban infrastructure, and smart growth
Zero-Emission Vehicles	High	Very High
New Sales of LDV ZEVs	90% by 2030, 100% by 2035, 90/10 BEV/FCEV	98% by 2030, 100% by 2035, 100% BEV 10% early retirement before 2030
New Sales of MDV ZEVs	40% by 2030, 100% by 2045, 50/50 BEV/FCEV	50% by 2030, 100% by 2045, 75/25 BEV/FCEV
New Sales of HDV ZEVs	40% by 2030, 100% by 2045, 25/75 BEV/FCEV	40% by 2030, 100% by 2045, 50/50 BEV, FCEV
New Sales of Bus ZEVs	100% by 2030	100% by 2030
LDV ZEVs on the Road	2.7 Million by 2030, 10 Million by 2050 26% of fleet by 2030, 95% of fleet by 2050	3.4 Million by 2030, 10.1 Million by 2050 33% of fleet by 2030, 96% of fleet by 2050
LDV BEV Charging Flexibility	25% of vehicles charge flexibly in 2030, 50% in 2050	25% of vehicles charge flexibly in 2030, 50% in 2050
MHDV ZEVs on the Road	19,000 by 2030, 180,000 by 2050 8% of fleet by 2030, 77% of fleet by 2050	23,000 by 2030, 200,000 by 2050 10% of fleet by 2030, 86% of fleet by 2050
Bus ZEVs on the Road	10,000 by 2030, 55,000 by 2050	10,000 by 2030, 55,000 by 2050

Level of Transformation by Scenario: **Transportation Continued**

	Scenario 2: Strategic Use of Low-Carbon Fuels	Scenario 3: Accelerated Transition Away from Combustion
Low-Carbon Fuels	*High*	*Low*
Hydrogen (via electrolysis)	Used for MHDVs and freight rail	Used for MHDVs and freight rail
Biomass feedstock availability	In-state + regional feedstocks incl. energy crops	None
Bioenergy utilization	75% renewable diesel by 2030, 100% by 2050 100% renewable jet kerosene by 2050	None
Non-Road Transportation	*Medium*	*Medium*
Aviation	Efficiency for new airplanes	Efficiency for new airplanes
Marine and Ports	75% renewable diesel in 2030, 100% electrification in 2050	100% electrification in 2050
Rail	90% electrification, 10% hydrogen use in 2050	90% electrification, 10% hydrogen use in 2050

Benefits and Costs Analysis

Approach

Integration Analysis Approach

Integration analysis will evaluate societal costs and benefits of GHG mitigation

- The pathways framework produces economy-wide **resource costs** for the various mitigation scenarios relative to a reference scenario
  - The framework is focused on annual societal costs and benefits and does not track internal transfers (e.g., incentives)
- Outputs are produced on an annual time scale for the state of New York, with granularity by sector
  - Annualized capital, operations, and maintenance cost for infrastructure (e.g., devices, equipment, generation assets, T&D)
  - Annual fuel expenses by sector and fuel (conventional or low-carbon fuels, depending on scenario definitions)
  - Does not natively produce detailed locational or customer class analysis
- Locational and customer class impact analyses would be developed through subsequent implementation processes

Integration Analysis Approach (cont'd)

Integration analysis will evaluate societal costs and benefits of GHG mitigation

- The pathways framework tracks annual greenhouse gas emissions by gas for the various mitigation scenarios and expresses changes in annual GHG emissions relative to a reference scenario
- **Value of avoided GHG emissions** calculated based on guidance developed by DEC


NEW YORK STATE | Department of Environmental Conservation

Establishing a Value of Carbon

GUIDELINES FOR USE BY STATE AGENCIES

Integration Analysis Approach (cont'd)

Integration analysis will evaluate societal costs and benefits of GHG mitigation

- Integration analysis included **health co-benefits** analysis to estimate and quantify health benefits of mitigation scenarios relative to a reference case
- County-level analysis using EPA's CO-Benefits Risk Assessment (COBRA) Health Impacts Screening and Mapping Tool customized with detailed inputs specific to NYS and the Pathways scenarios analyzed
  - Evaluates ambient air quality, based on SO_2, VOC, NO_x, and direct $PM_{2.5}$ emissions and the ensuing changes in annual $PM_{2.5}$ concentrations from 2020-2050
  - Results include 12 different health outcomes, such as premature mortality, heart attacks, hospitalizations, asthma exacerbation and emergency room visits, and lost workdays
- Public health benefits from increased physical activity due to increased use of active transportation modes (e.g., walking, cycling) and accounting for changes in traffic collisions estimated using the Integrated Transport Health Impacts Model (ITHIM)
- Values from published literature on the health and safety benefits of energy system changes and weatherization programs in homes used to estimate the potential benefits of energy efficiency interventions.
  - Applied to the low- and moderate-income homes expected to have upgraded systems and weatherization

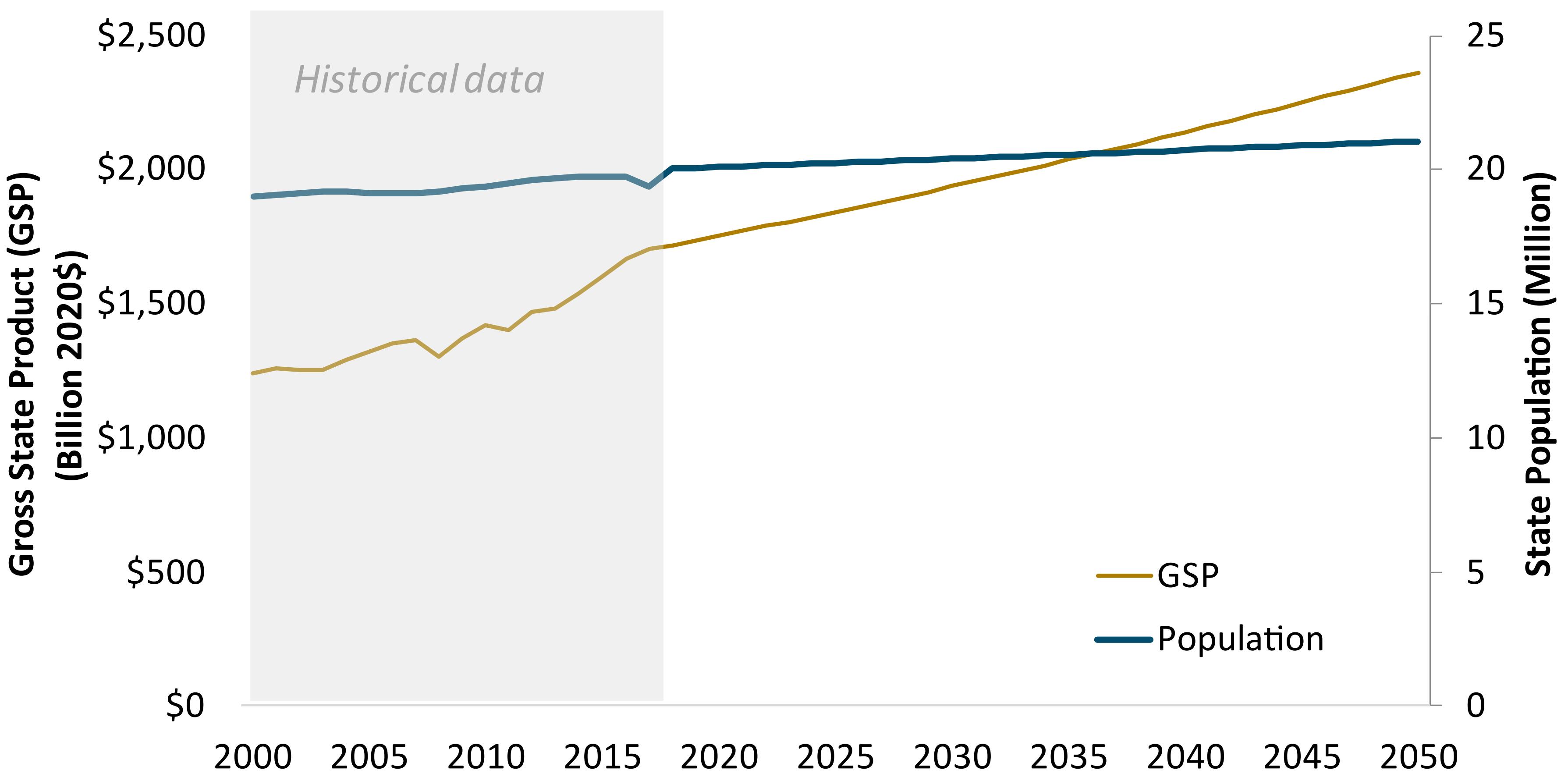
Integration Analysis Linkage with Jobs Study

Integration analysis will serve as key input to the Just Transition Working Group Jobs Study

> Linkage between integration analysis and jobs study will illustrate employment benefits of GHG mitigation

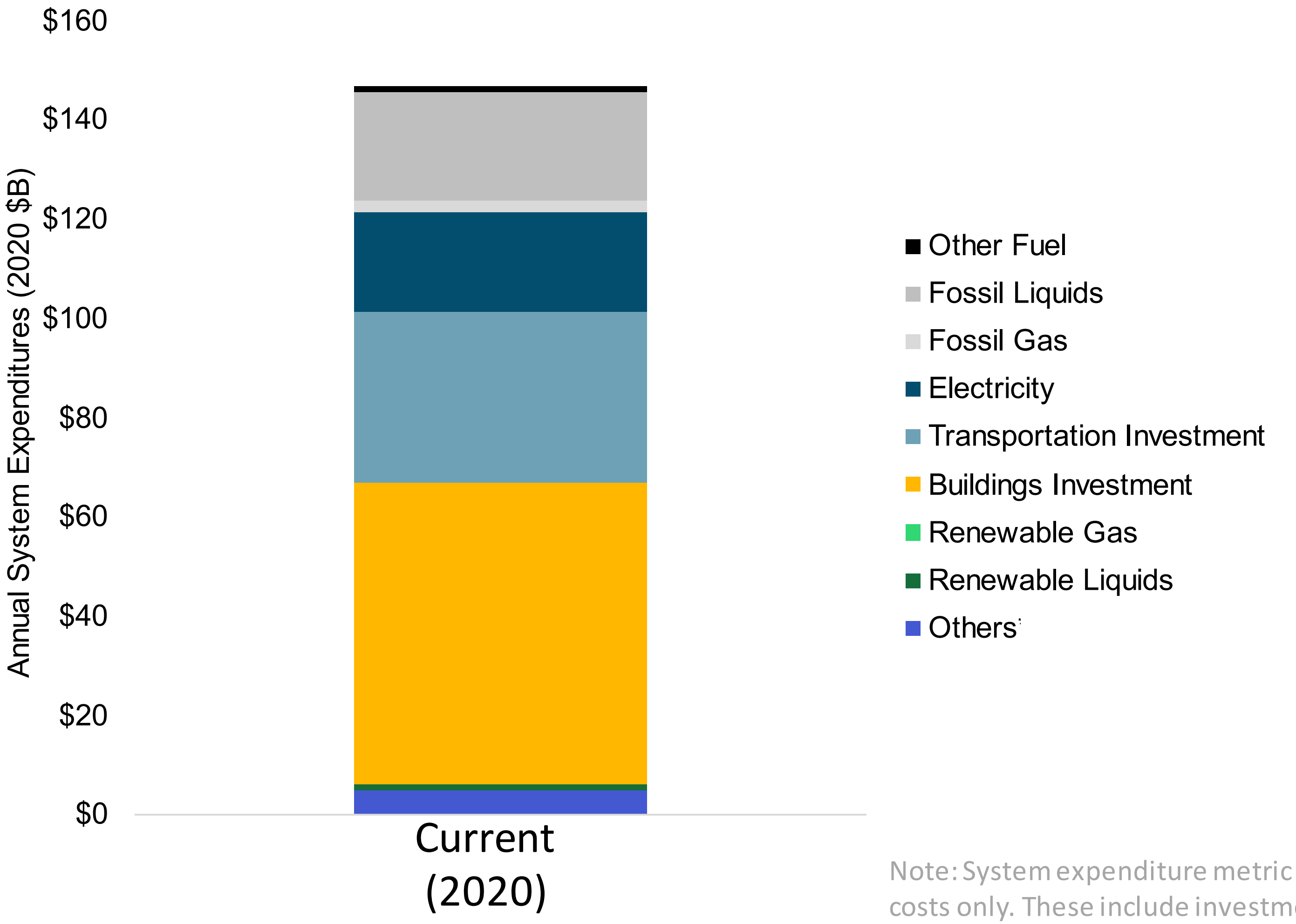
> ECL § 75-0103 (8)(g) [Jobs Study to report on]…“the number of jobs created to counter climate change, which shall include but not be limited to the energy sector, building sector, transportation sector, and working lands sector.”

Population and Gross State Product



Sources: NYSERDA Patterns and Trends, Federal Reserve Economic Data, Cornell Program on Applied Demographics

System Expenditure



> System expenditure is an estimate of the costs related to energy consumption: this includes capital investments for energy consuming devices, fuel costs associated with energy consumption within the state, and cost to generate electricity from in-state resources and imports

> While system expenditures are significant, these make up a small share of GSP

- 2020: 8.9%

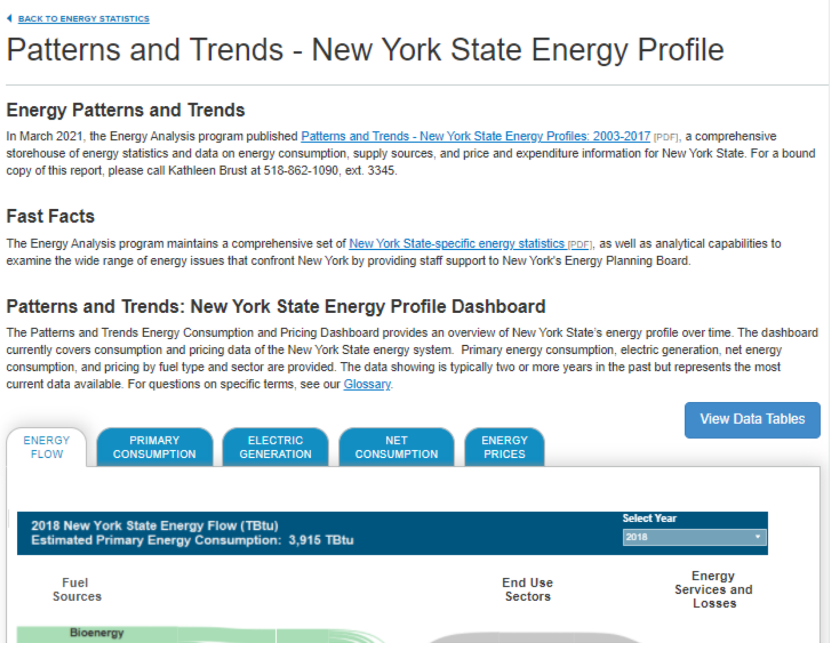
Note: System expenditure metric does not reflect direct costs in some sectors that are represented with incremental costs only. These include investments in industry, agriculture, waste, forestry, and non-road transportation

Energy Expenditures and Opportunity

> Total **annual** energy expenditures are approximately $50 billion

- Over half (almost $30 billion) is estimated to leave NYS
- Petroleum fuel expenditures are the largest single category at approximately $24 billion
- Buildings sector spends the most on energy services, followed by Transportation

> Opportunity for import-substitution through electrification, where a greater share of energy services are provided by in-state resources driving economic activity and job creation



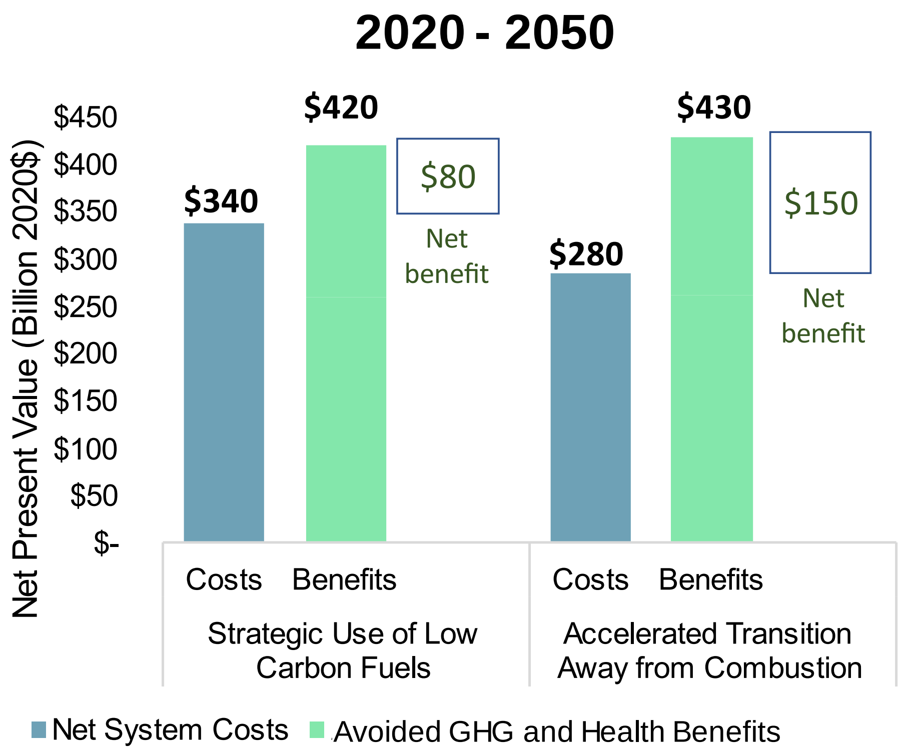
> For more information visit: https://www.nyserda.ny.gov/about/publications/ea-reports-and-studies/patterns-and-trends

Results

Key Benefit-Cost Findings

Cost of Inaction Exceeds the Cost of Action by more than $80 billion

There are significant required investments to achieve Climate Act GHG Emissions Limits, accompanied by even greater external benefits and the opportunity to create hundreds of thousands of jobs

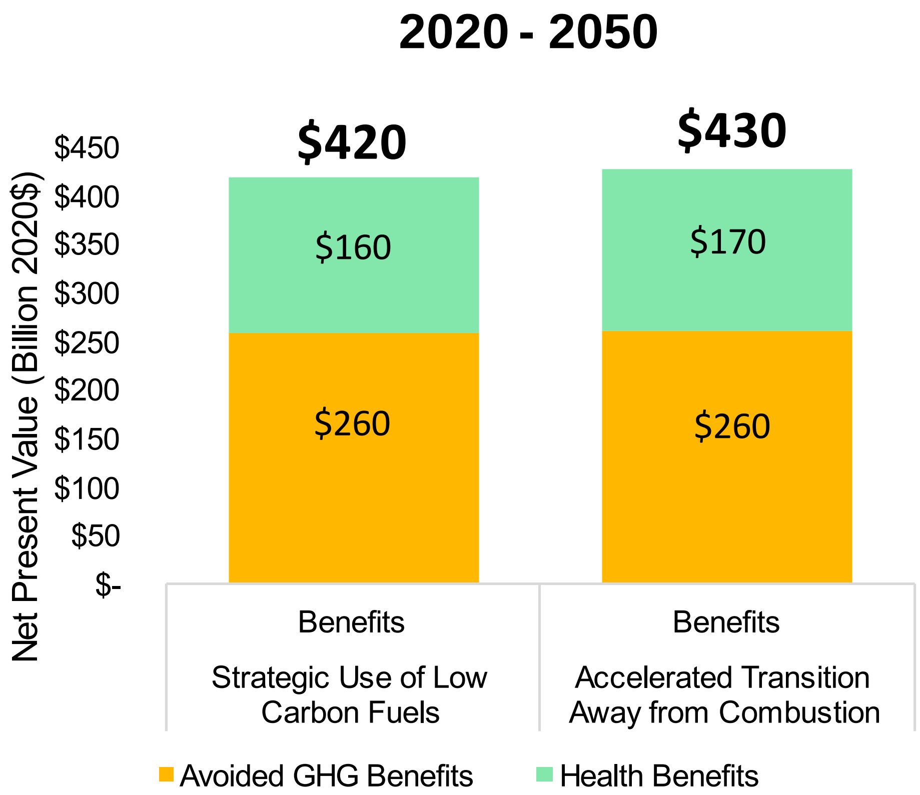


- **Net *benefits* range from $80-$150 billion**
- Costs are a small share of **New York's economy:** 0.5-0.6% of GSP in 2030 and 1.9-2.1% in 2050
- As a share of overall **system expenditures,** costs are moderate: 7.1-8.6% in 2030 and 24-27% in 2050

Key Benefit-Cost Findings cont'd

Cost of Inaction Exceeds the Cost of Action by more than $80 billion

There are significant required investments to achieve Climate Act GHG Emissions Limits, accompanied by even greater external benefits and the opportunity to create hundreds of thousands of jobs



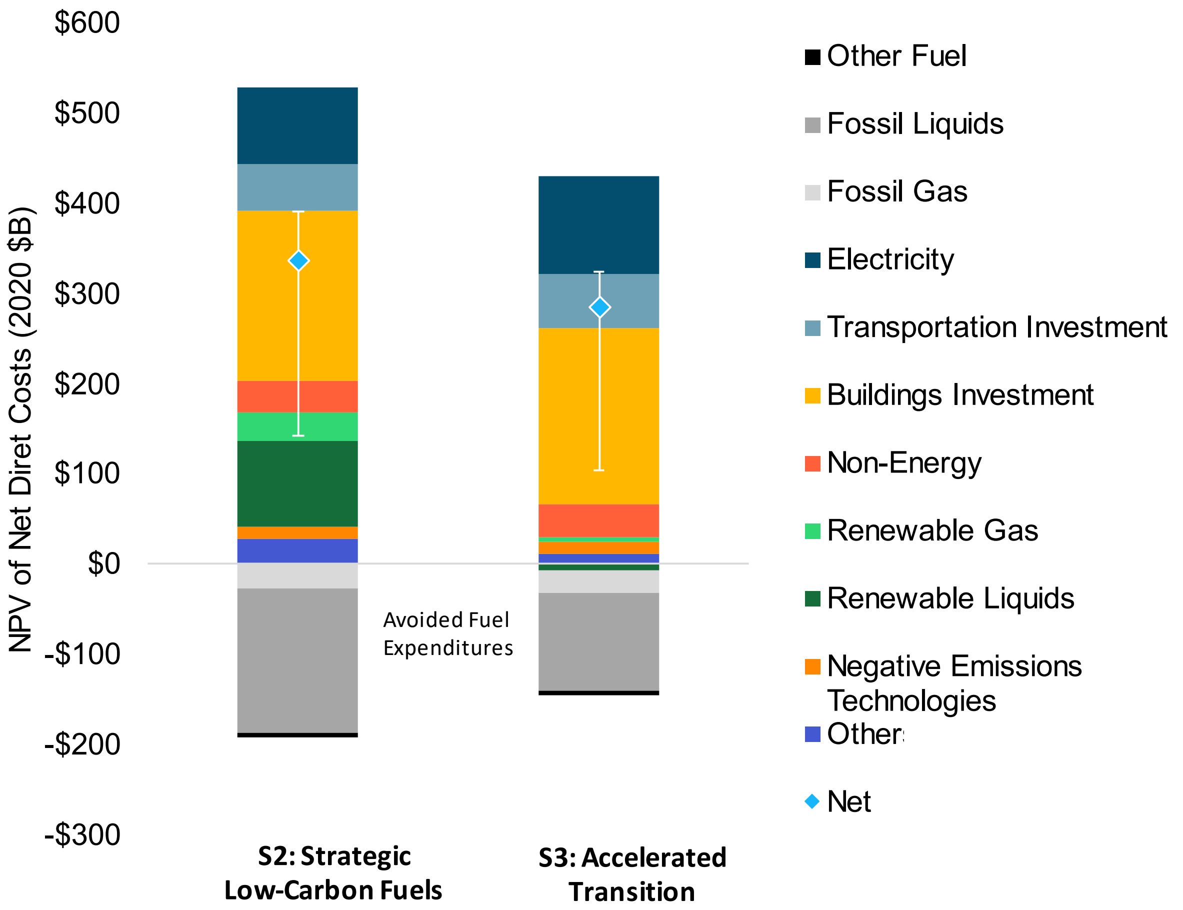
- Improvements in **air quality, increased active transportation, and energy efficiency interventions in low- and moderate-income homes** generates health benefits ranging from $160 - 170 billion
- Reduced GHG emissions **avoids economic impacts of damages caused by climate change** equaling approximately $260 billion

Cost Categorization

Cost Category	Description
Electricity System	Includes incremental capital and operating costs for electricity generation, transmission (including embedded system costs), distribution systems, and in-state hydrogen production costs.
Transportation Investment	Includes incremental capital and operating expenses in transportation (e.g. BEVs and EV chargers)
Building Investment	Includes incremental capital and operating expenses in buildings (e.g. HPs and building upgrades)
Non-Energy	Includes incremental mitigation costs for all non-energy categories, including agriculture, waste, and forestry
Renewable Gas	Includes incremental fuel costs for renewable natural gas and imported green hydrogen
Renewable Liquids	Includes incremental fuel costs for renewable diesel and renewable jet kerosene
Negative Emission Technologies (NETs)	Includes incremental costs for direct air capture of CO2 as a proxy for NETs
Other	Includes other incremental direct costs including industry sector costs, oil & gas system costs, HFC alternatives, and hydrogen storage
Fossil Gas	Includes incremental costs spent on fossil natural gas (shown as a negative for cases when Gas expenditures are avoided compared with the Reference Case)
Fossil Liquids	Includes incremental costs spent on liquid petroleum products (shown as a negative for cases when liquids expenditures are avoided compared with the Reference Case)
Other Fuel	Includes incremental costs spent on all other fossil fuels

Scenario Cost Assessment

Net Present Value of net direct costs relative to Reference (2020 – 2050)

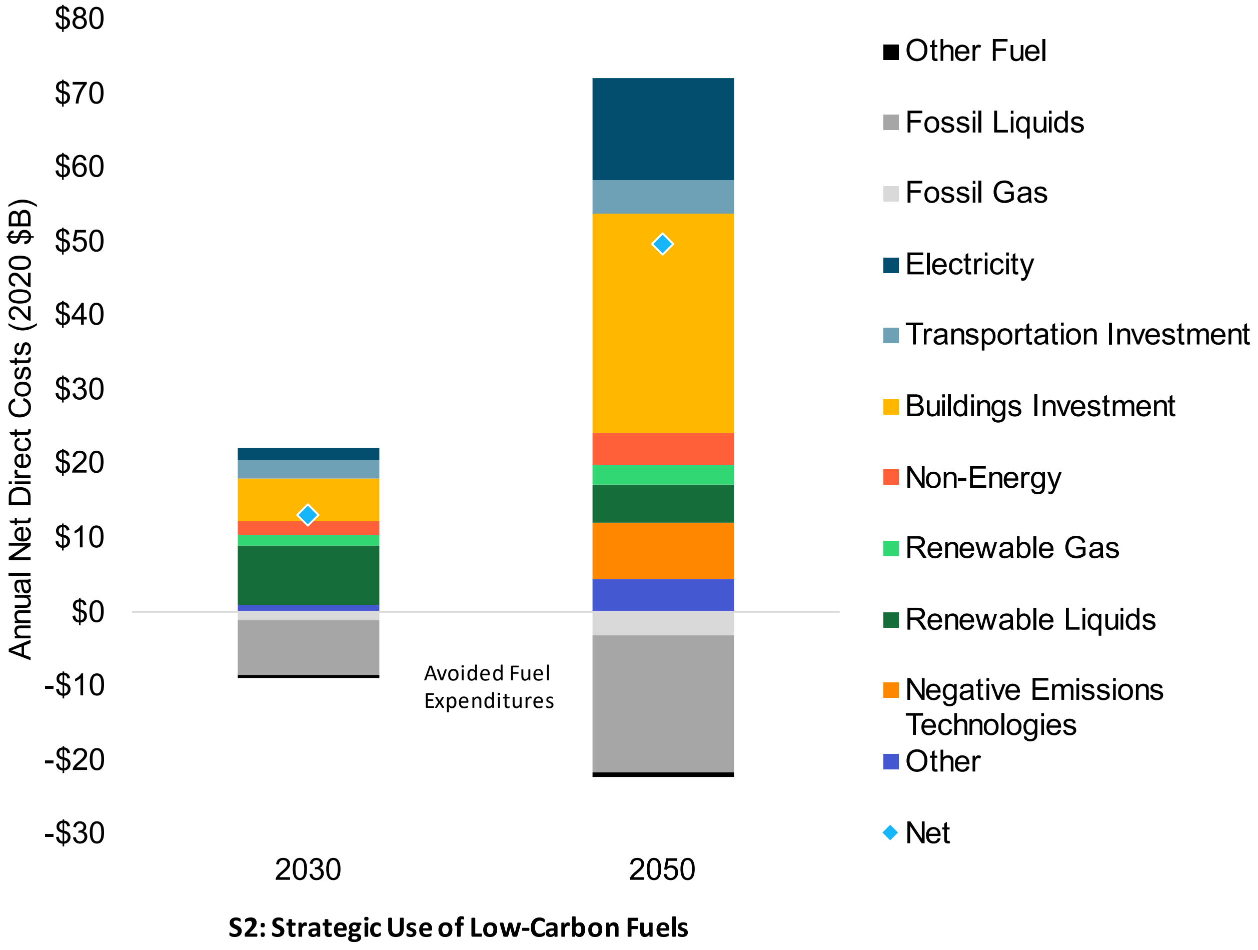


> Key findings:

- Net direct costs in both scenarios are in the **same range** given uncertainty, and are primarily driven by **investments in buildings and the electricity system**
- All scenarios show avoided fossil fuel expenditures due to efficiency and fuel-switching relative to the Reference Case (shown in the chart as negative costs)
- Scenario 2: Strategic Use of Low-Carbon Fuels includes significant investment in renewable diesel, renewable jet kerosene, and renewable natural gas
- Scenario 3: Accelerated Transition Away From Combustion meets emissions limits with greater levels of electrification, which results in greater investments in building electrification, zero-emission vehicles, and the electricity system

Scenario 2 Costs

Annual net direct costs relative to Reference



> Net direct costs:

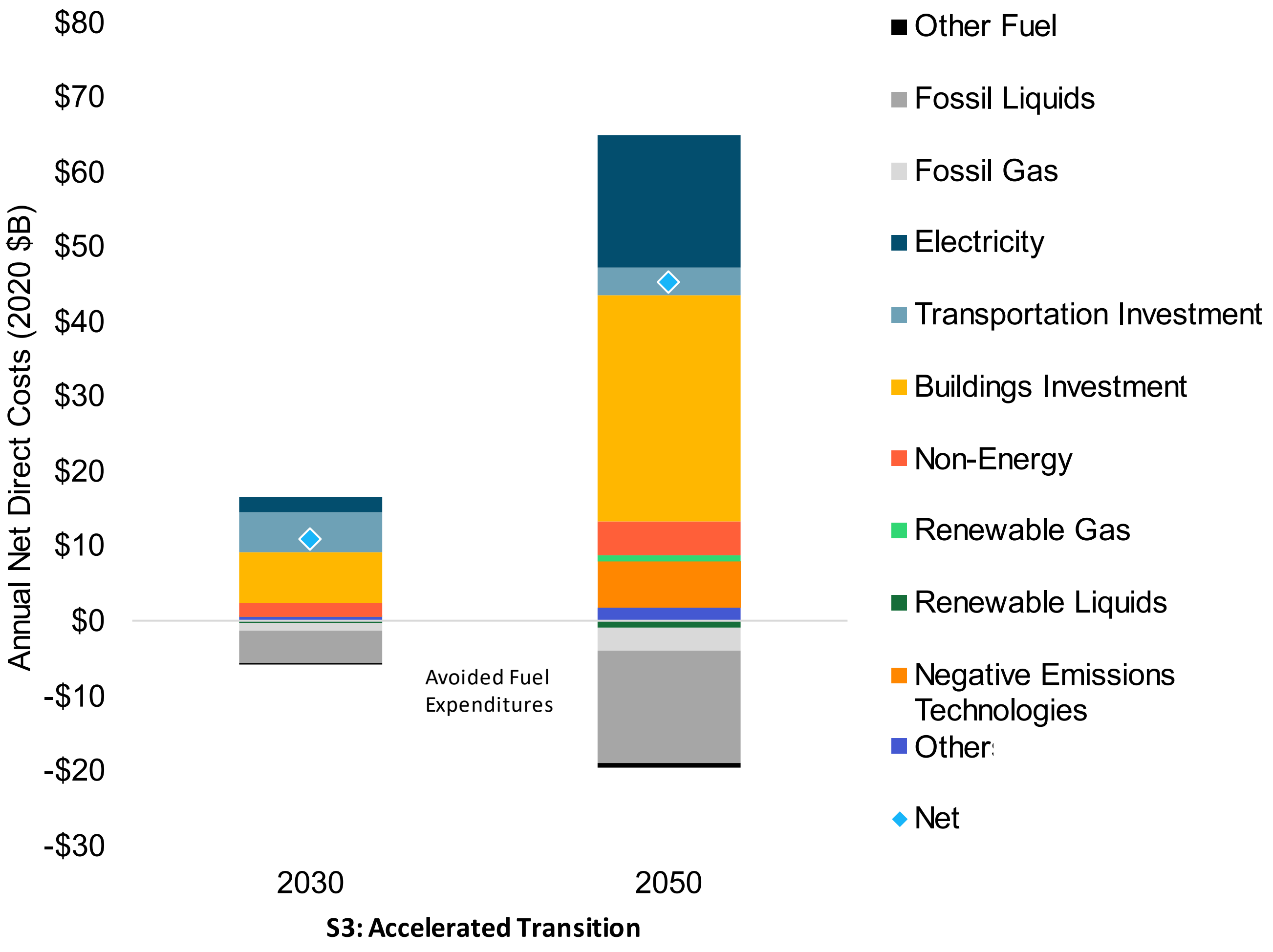
- In the early years on the order of $10 billion per year, equivalent to 0.6% of GSP in 2030
- In the later years on the order of $50 billion per year, equivalent to 2.0% of GSP in 2050

> Key findings:

- Incremental costs in all scenarios are primarily driven by investments in buildings and the electricity system
- All scenarios have avoided fossil fuel expenditures due to efficiency and fuel-switching relative to the Reference Case (shown in the chart as negative costs)
- Significant investment in renewable diesel, renewable jet kerosene, and renewable natural gas starting in the mid-2020s
- Investment in Negative Emissions Technologies (NETs) is needed to achieve net zero by 2050

Scenario 3 Costs

Annual net direct costs relative to Reference



> Net direct costs:

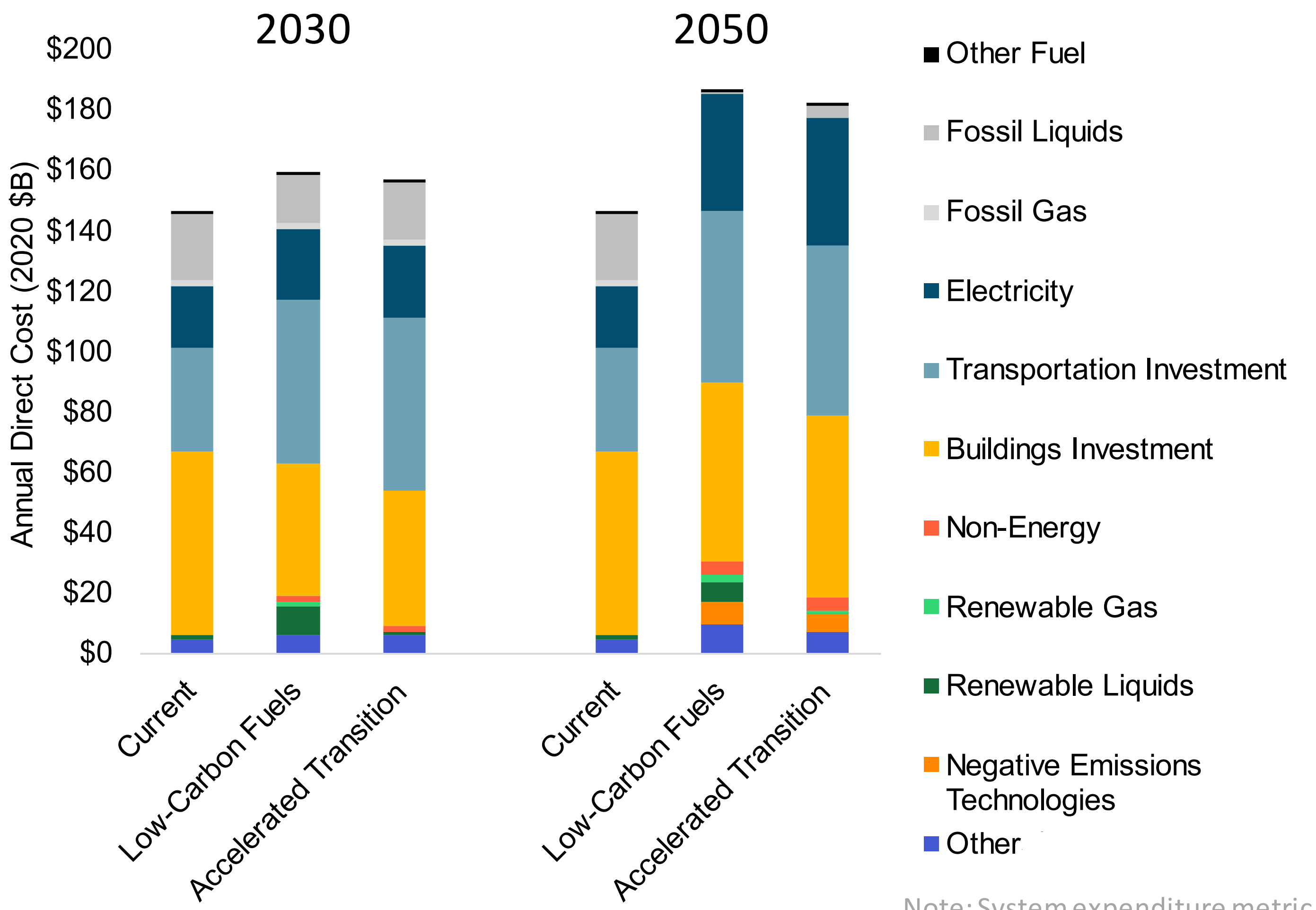
- In the early years on the order of $10 billion per year, equivalent to 0.7% of GSP in 2030
- In the later years on the order of $50 billion per year, equivalent to 2.0% of GSP in 2050

> Key findings:

- Incremental costs in all scenarios are dominated by investments in buildings and the electricity system
- All scenarios have avoided fossil fuel expenditures due to efficiency and fuel-switching relative to the Reference Case (shown in the chart as negative costs)
- Scenario 3 includes greater levels of electrification compared to Scenario 2, which results in greater investments in building retrofits, zero-emission vehicles, and the electricity system
- Investment in Negative Emissions Technologies (NETs) is needed to achieve net zero by 2050

System Expenditure

Annual direct costs



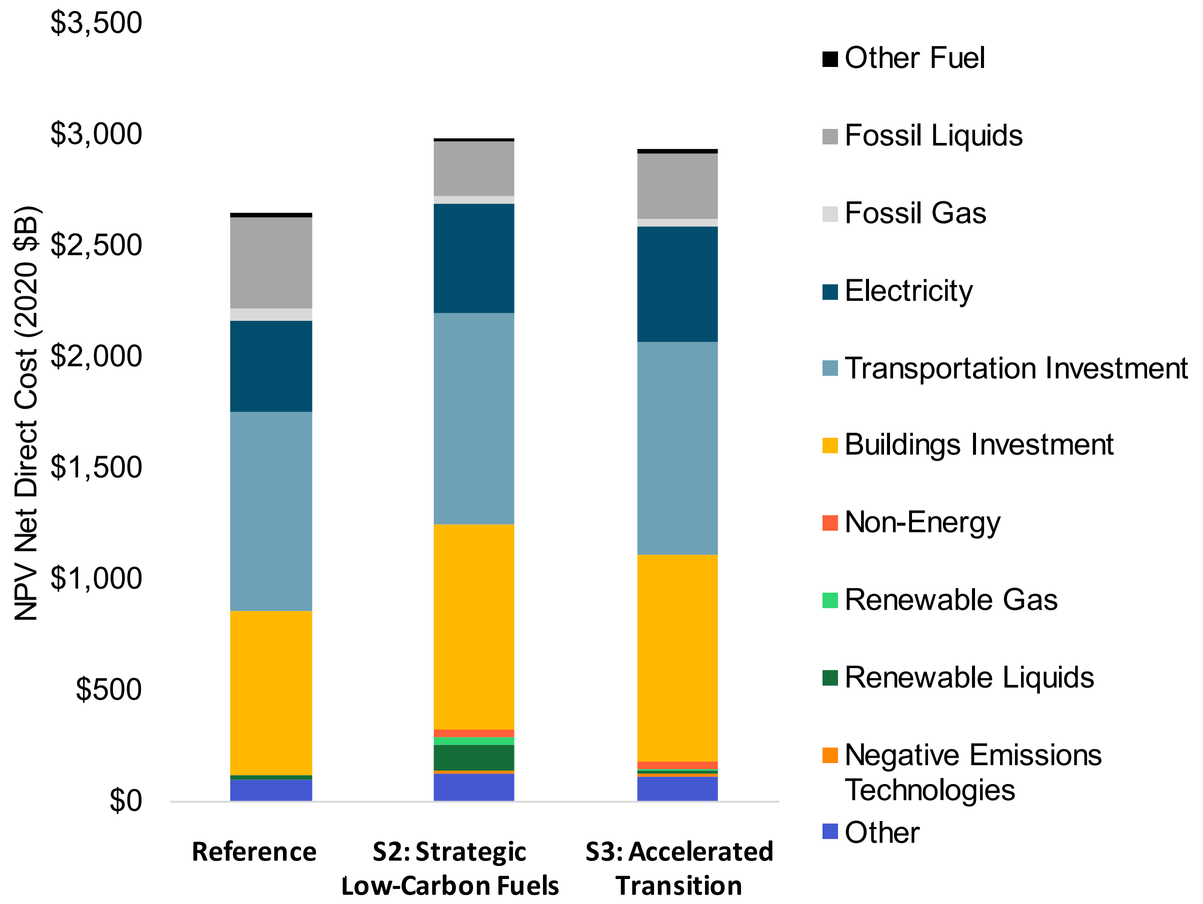
> Change in direct costs over time is moderate relative to total system expenditure in 2030 and 2050:

- 2030: 7.1 - 8.6% of system expenditure
- 2050: 24 – 27% of system expenditure

Note: System expenditure metric does not reflect direct costs in some sectors that are represented with incremental costs only. These include investments in industry, agriculture, waste, forestry, and non-road transportation

System Expenditure

Net Present Value of direct costs (2020 – 2050)



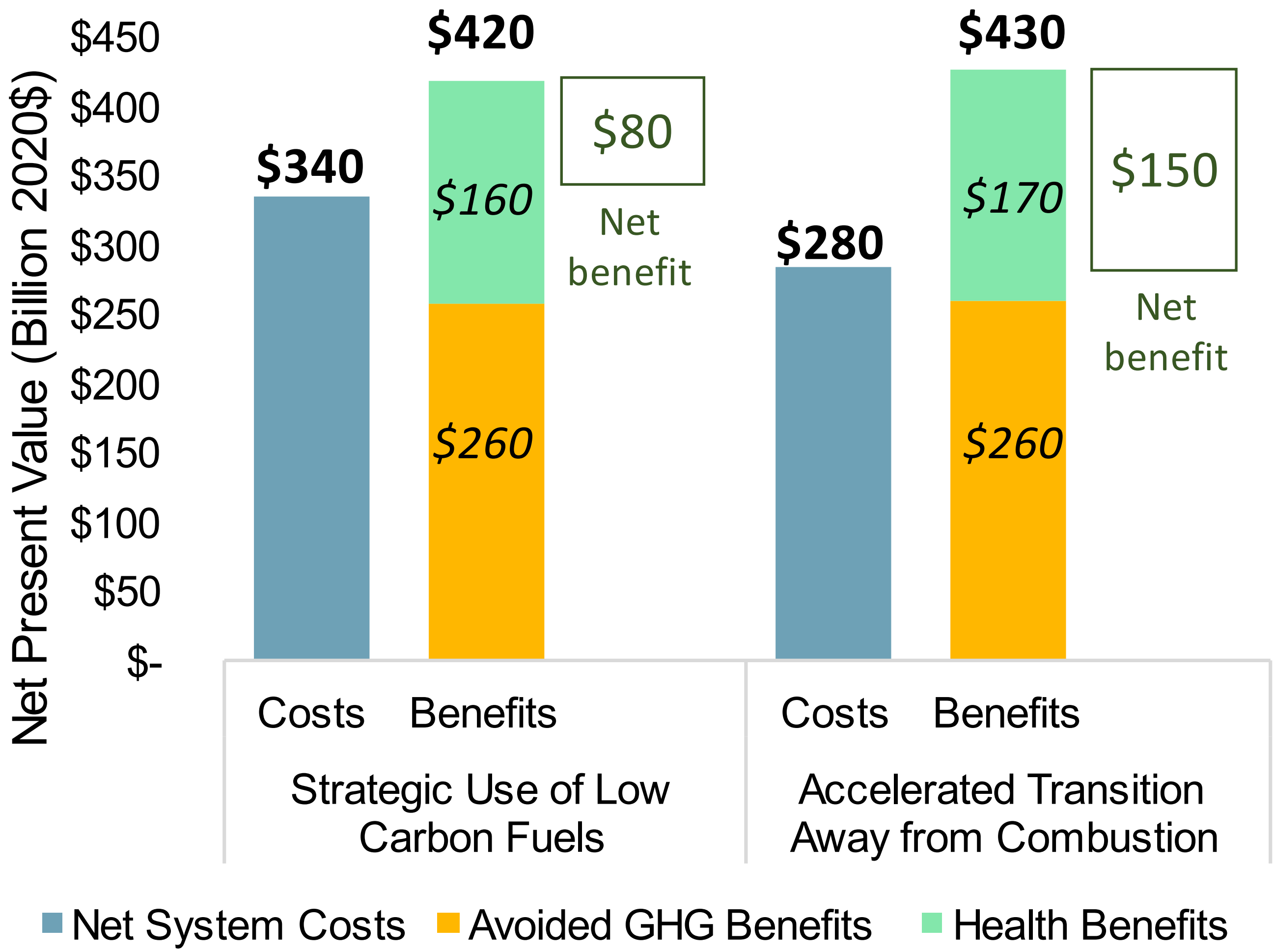
> The NPV of Reference Case system expenditure: $2.7 trillion

> When calculated on an NPV basis, the net direct costs are moderate: 10-12% higher than the Reference case

Note: System expenditure metric does not reflect direct costs in some sectors that are represented with incremental costs only. These include investments in industry, agriculture, waste, forestry, and non-road transportation

Benefit-Cost Assessment

Net Present Value of benefits and costs relative to Reference, including net direct costs, GHG benefits, and health benefits (2020 – 2050)



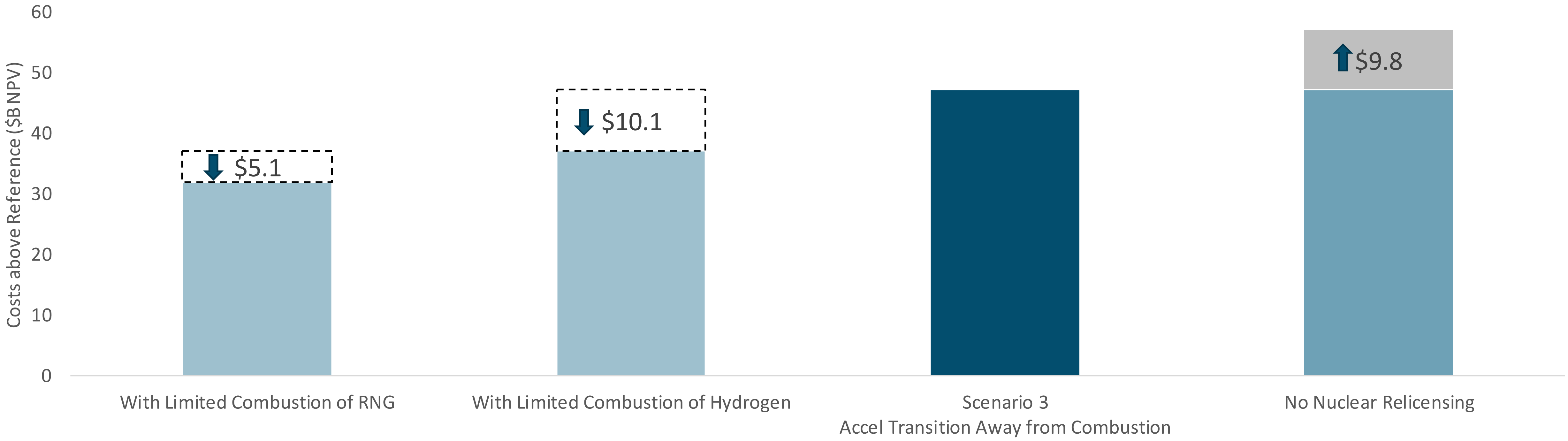
Mitigation cases show **positive net benefits ($80-$150 billion)** when considering the value of avoided greenhouse gas emissions and health co-benefits, in addition to cost savings from reduced fuel use

Electricity System Sensitivities

Electricity System Cost Impacts

Scenario 3 Sensitivities

- Costs are measured against a Reference Case **controlling for electrification loads**
- Limiting available technologies places upward pressure on costs



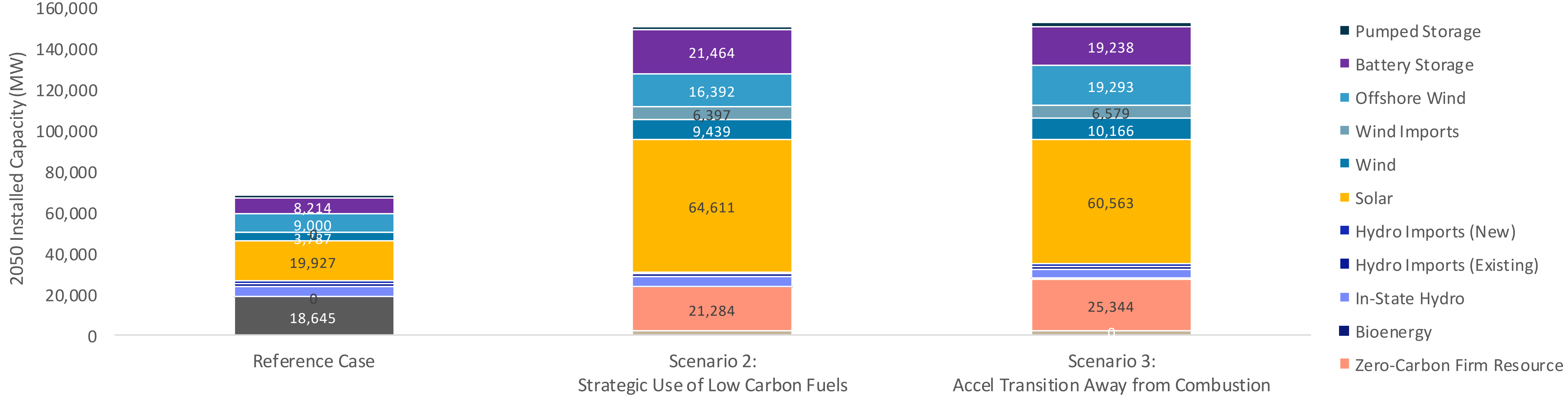
Note: In Scenario 3, existing fossil fuel resources are retired by 2040 and no new combustion-based (CCGT or CT) capacity is permitted. New firm capacity is provided by a combustion-free resource (e.g. hydrogen fuel cells).

Electricity Generation

Comparison of 2050 Installed Capacity

> In these Scenarios, firm capacity is provided by hydrogen resources to meet multi-day reliability needs, ranging from 21-25 GW

> Significant expansion of foundational resources (wind, solar, and storage) is needed across scenarios
- Offshore wind: 16-19 GW
- Land based wind: 16-17 GW
- Solar: 61-65 GW
- Storage: 19-21 GW

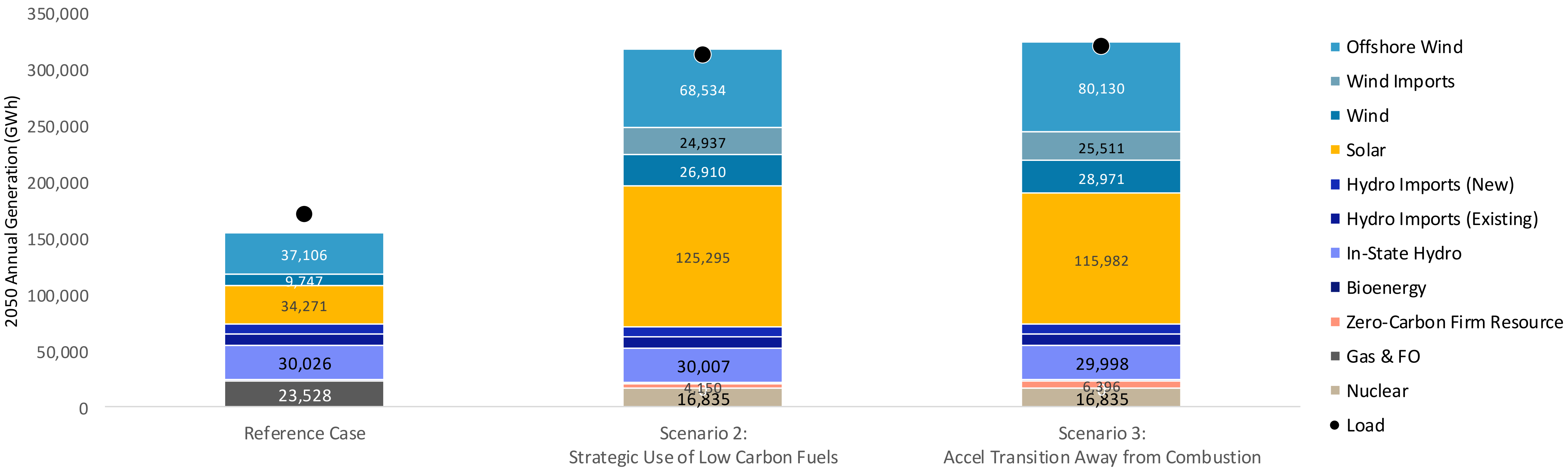


Note: In Scenario 3, existing fossil fuel resources are retired by 2040 and no new combustion-based (CCGT or CT) capacity is permitted. New firm capacity is provided by a combustion-free resource (e.g. hydrogen fuel cells).

Electricity Generation

Comparison of 2050 Annual Generation

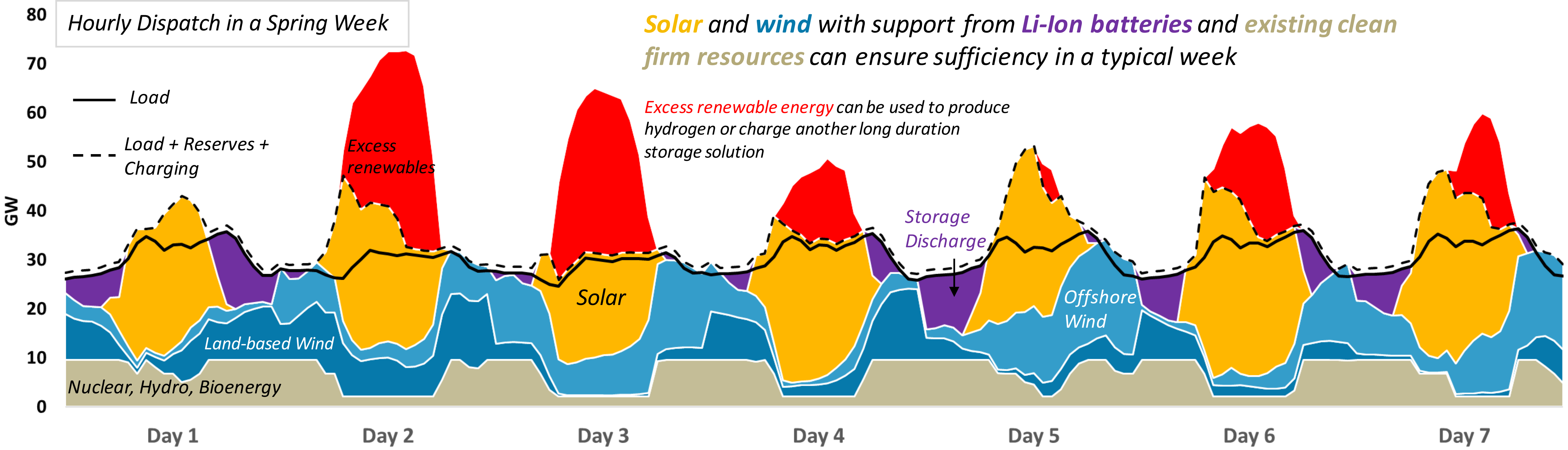
> Share of annual generation across mitigation scenarios:
- Solar: 36-40%
- Wind: 39-42%
- Zero-carbon firm resource: 1-2%

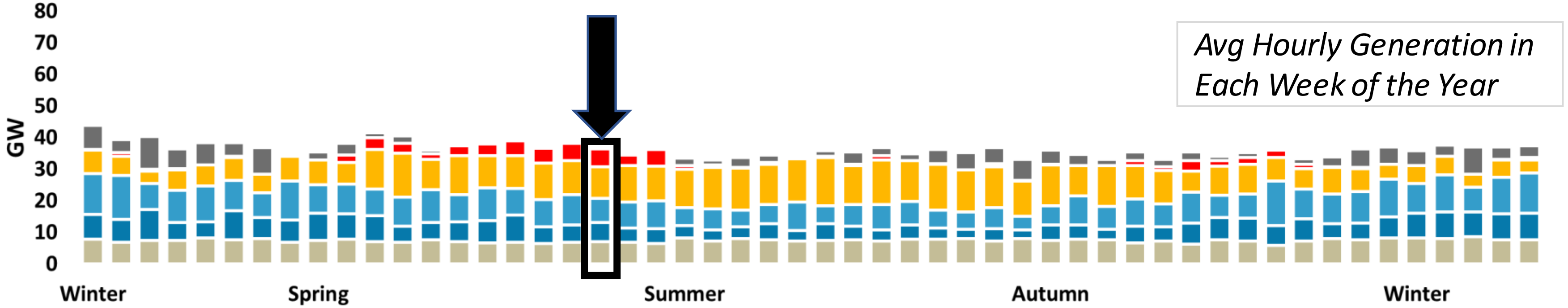


Typical Spring Week in 2050

Scenario 3

Solar and *wind* with support from *Li-Ion batteries* and *existing clean firm resources* can ensure sufficiency in a typical week

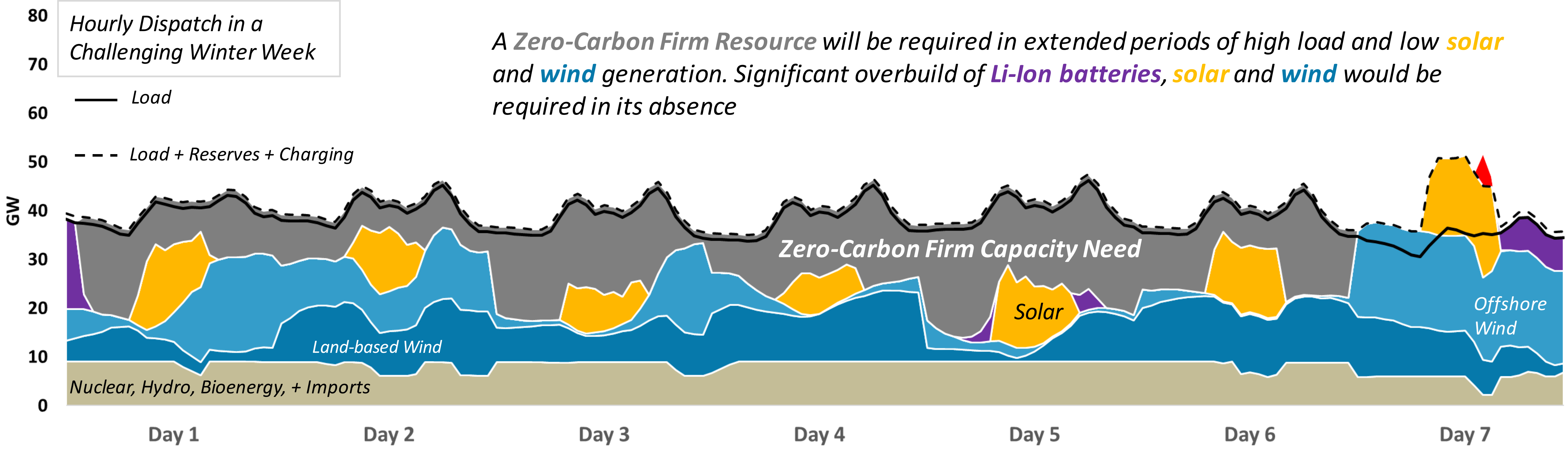


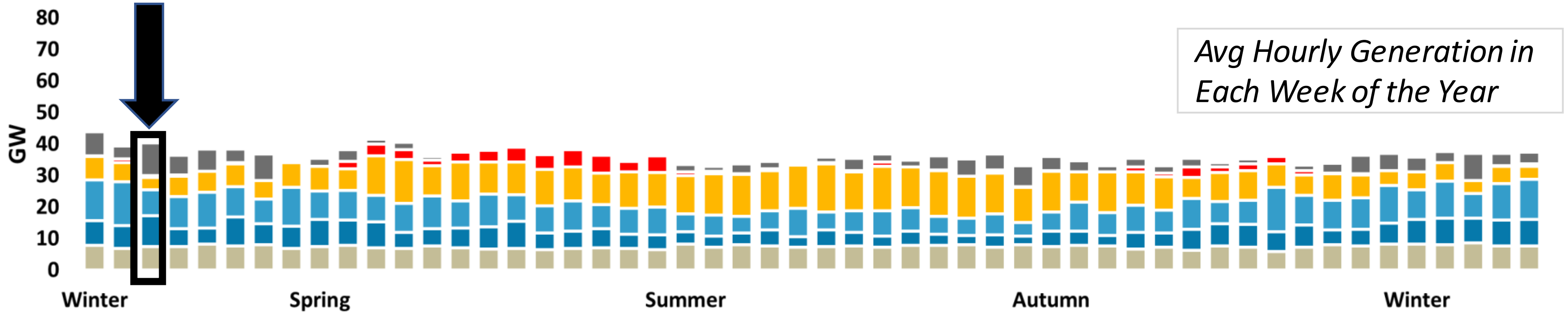


Multi-Day Reliability Needs in 2050

Scenario 3

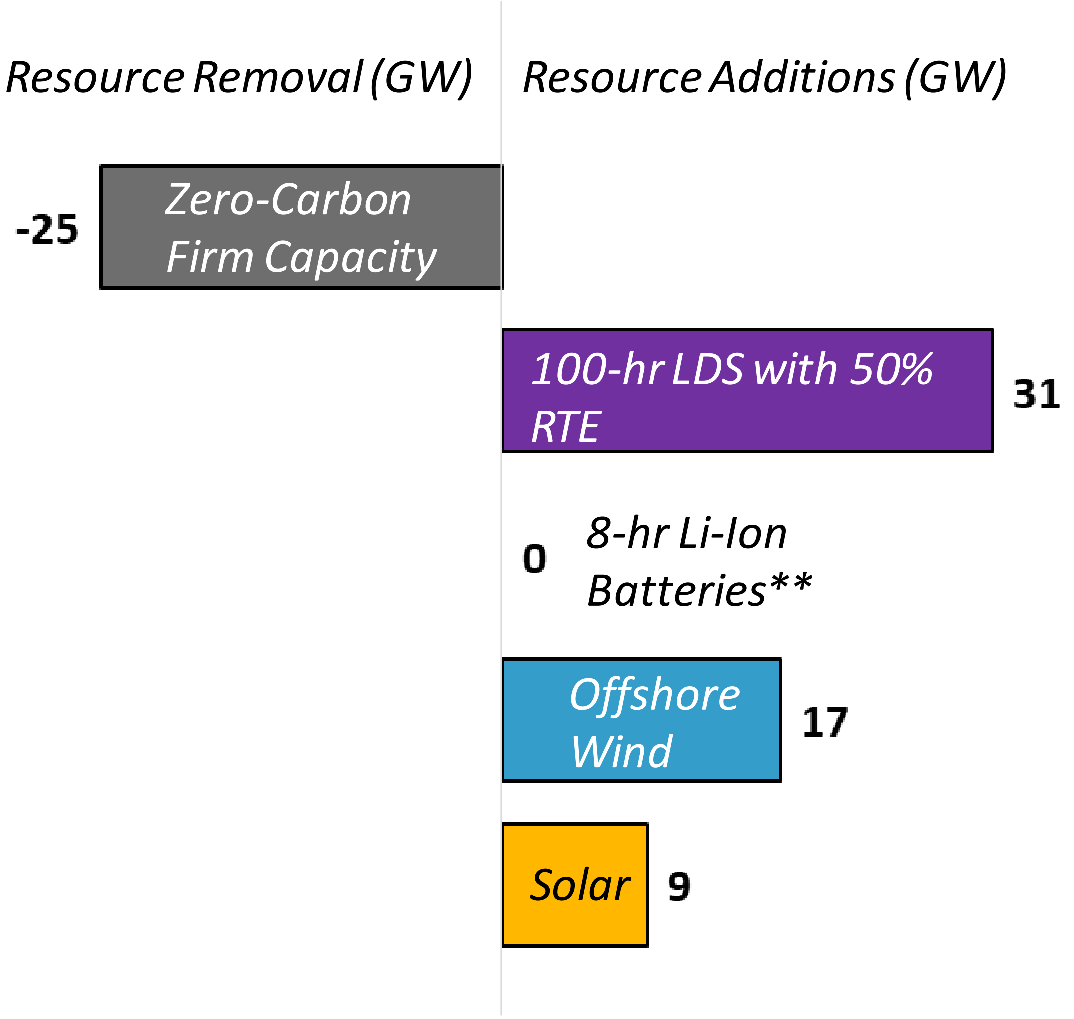
*A **Zero-Carbon Firm Resource** will be required in extended periods of high load and low **solar** and **wind** generation. Significant overbuild of **Li-Ion batteries**, **solar** and **wind** would be required in its absence*





Replacing Zero-Carbon Firm Capacity with Long Duration Storage and Additional Renewables

Scenario 3



> Starting point: Scenario 3 loads and resources (without in-state electrolysis)

> 25 GW of zero-carbon firm capacity removed from system

> Analyzed cost-effective strategies to maintain statewide reliability with a mix of additional storage and renewables

> Options for replacement included*:

- 100-hr long duration storage (LDS) with 50% round-trip efficiency (RTE)
- 8-hr Li-Ion battery storage
- New solar and offshore wind

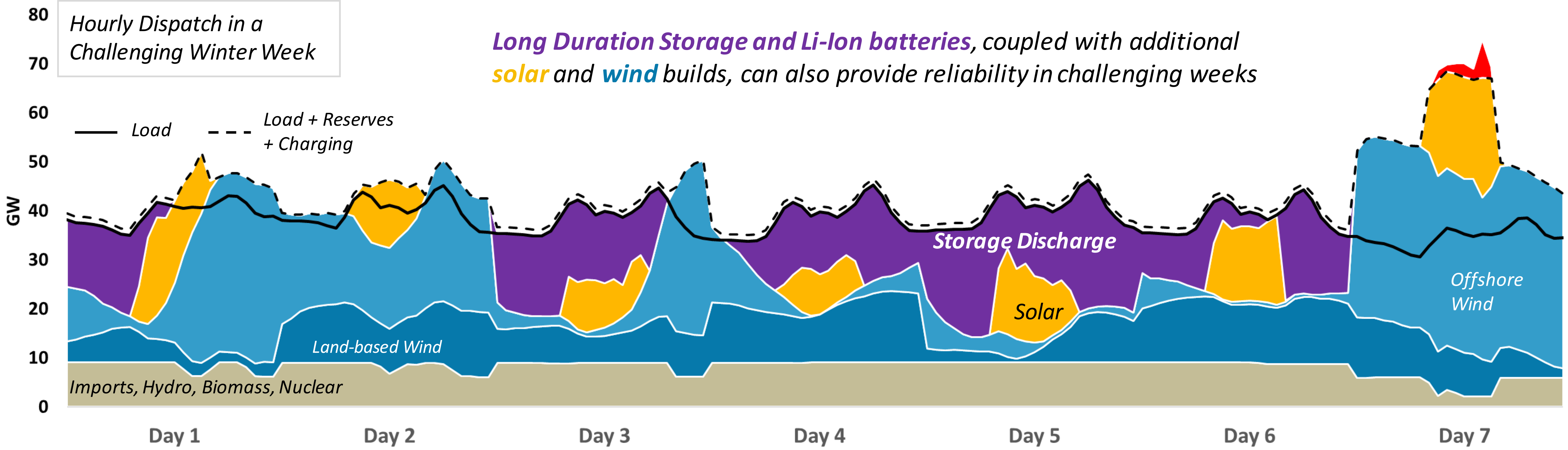
> 31 GW of **LDS** + 26 GW of additional **renewables** required to replace 25 GW of **firm capacity**

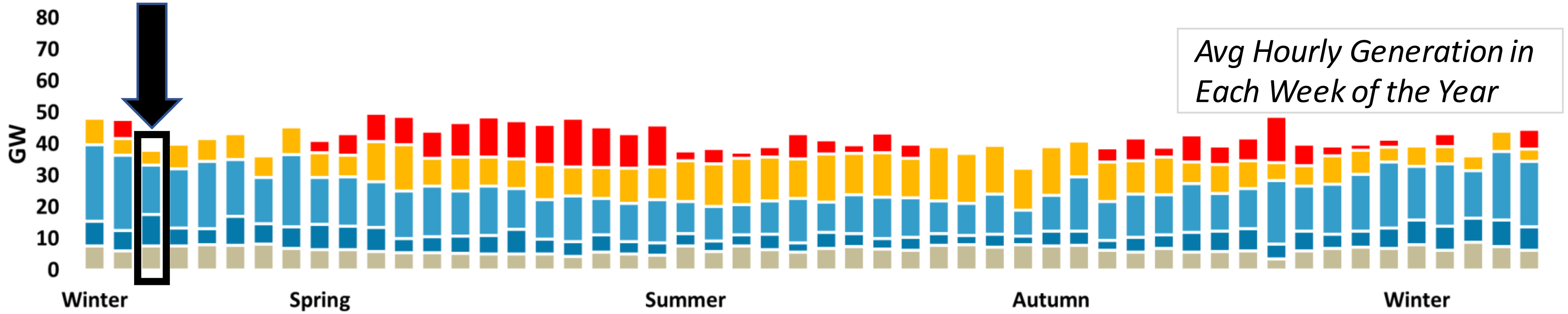
- *Additional onshore wind beyond the amount already built in the Scenario 3 portfolio was not considered here due to potential resource constraints.*

** *The starting portfolio already contains 7 GW of 8-hr Li-Ion batteries; reliability value of incremental 8-hr storage is limited due to long loss of load periods.*

Meeting Multi-Day Reliability Needs in 2050 with LDS

Scenario 3





Health Effects

Overview of the Analyses

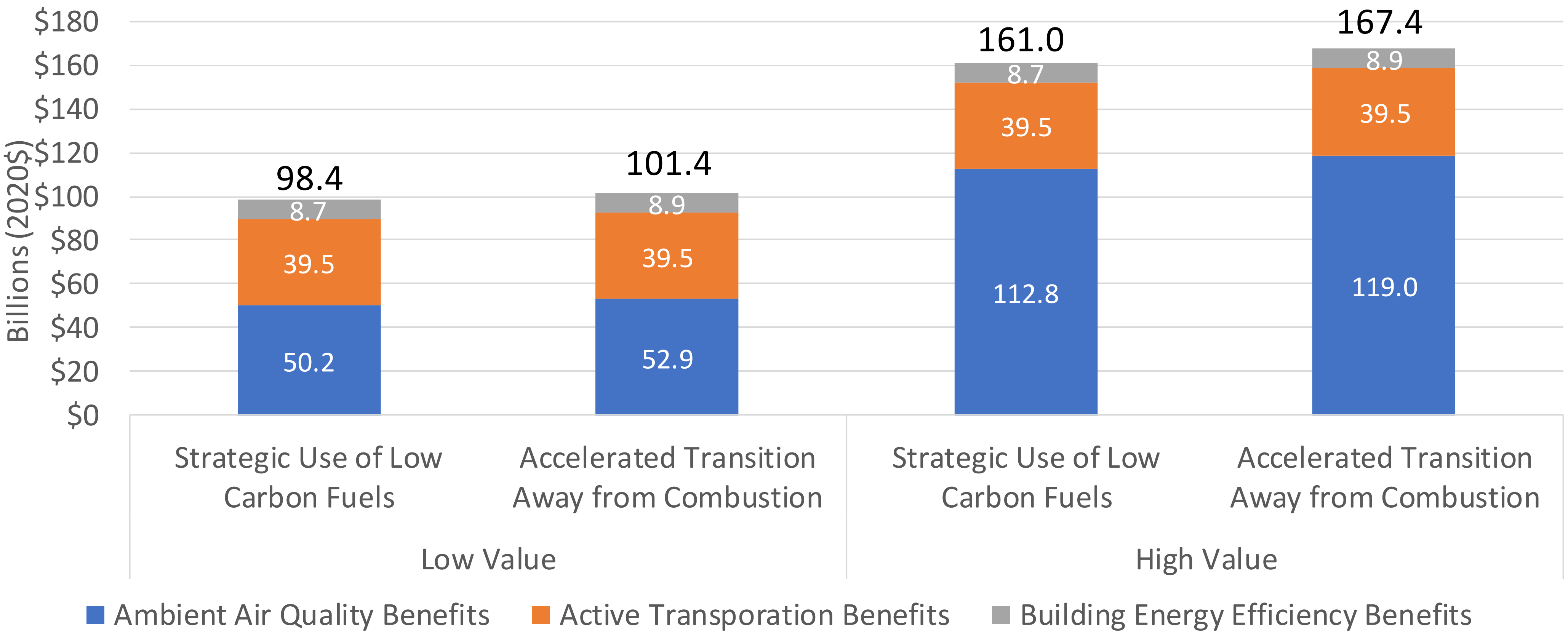
The public health benefits analysis includes three components:

1. Improvements in **ambient air quality** from reduced fuel combustion
   - Using EPA's Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA), NYS quantified **air quality and health benefits** resulting from the pathways analyzed from 2020 to 2050
2. Health improvements from increased **active transportation** (e.g., walking and cycling)
   - The potential for public health benefits from increased activity while accounting for changes in traffic collisions were estimated using the *Integrated Transport Health Impacts Model* (ITHIM)
3. Health benefits associated with **energy efficiency interventions** in low- and moderate-income homes
   - This analysis applies the average values from published literature on the health and safety benefits of energy efficiency and weatherization programs to estimate the benefits of such programs in NYS

Key Findings

- Decarbonization of New York can result in a substantial health benefit from improved air quality, on the order of **$50 - $120 billion** from 2020-2050 (based on reduced mortality and other health outcomes)
  - Benefits would be experienced **throughout the state** and downwind of the state in neighboring states.
  - Benefits of reduced fossil fuel combustion are **higher in urban areas** due to both higher emissions and larger impacted population.
  - Benefits of reduced wood combustion are **higher in upstate areas**.
  - Annual benefits **grow over time** as pollution rates decrease.
- In addition, we estimate other related potential health benefits:
  - **$40 billion** associated with the health benefits of increased **active transportation** (e.g., walking, cycling)
  - **$9 billion** associated with energy **efficiency interventions** in **low- and moderate-income homes** (additional benefits, not quantified, may occur in other buildings as well)

Total Health Benefits



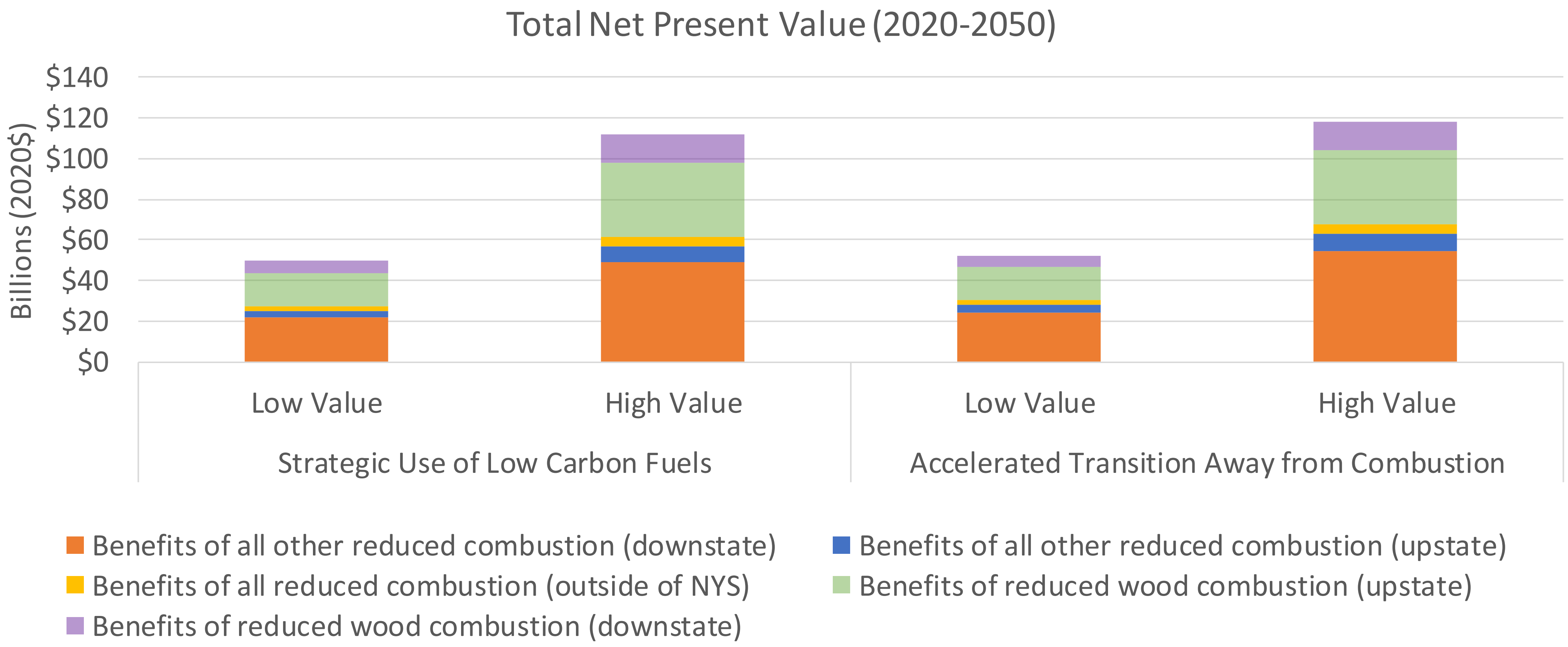
Ambient Air Quality and Health Effects

Ambient Air Quality Health Benefits

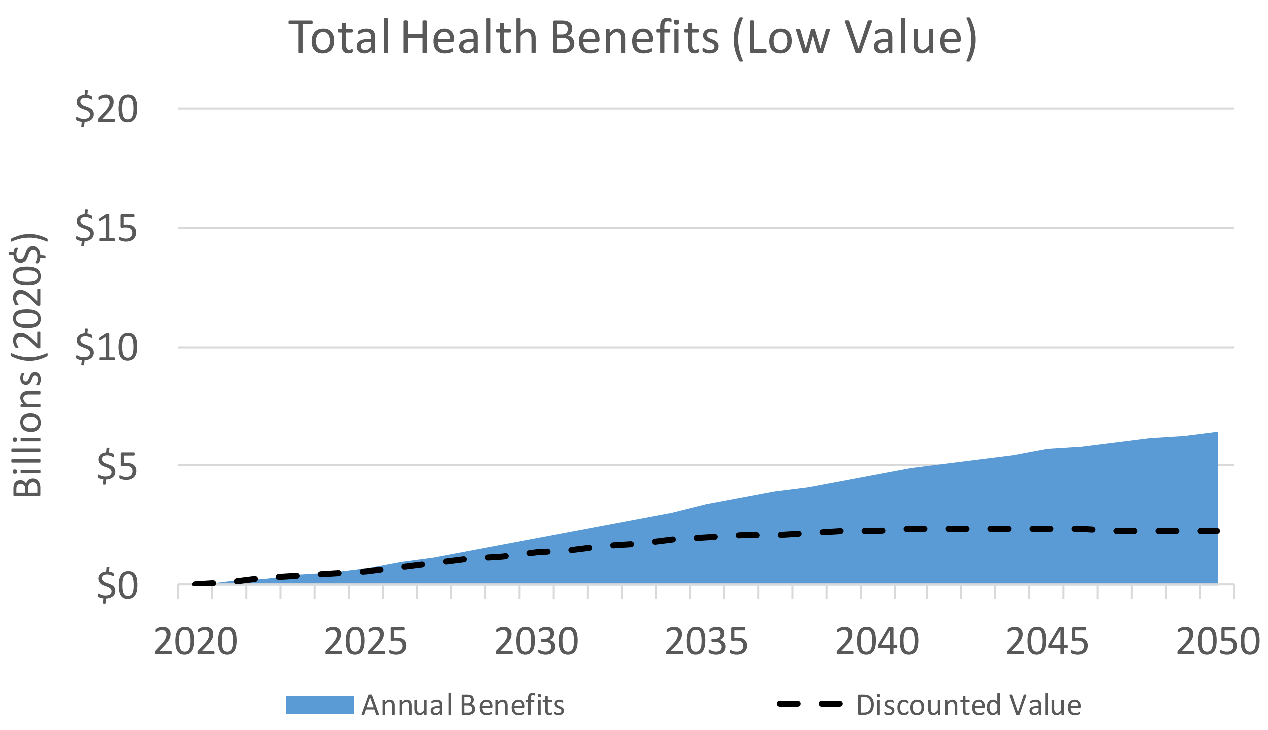
Air quality improvements can **avoid:**

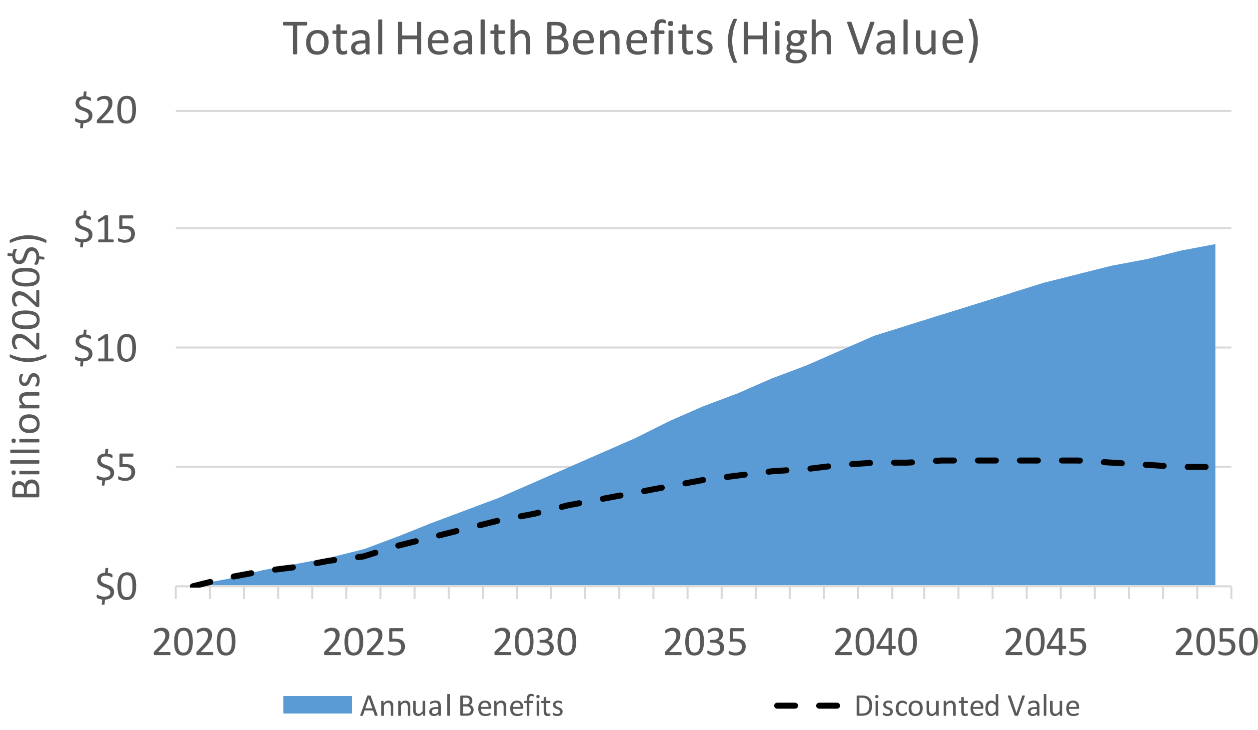
- **Tens of thousands** premature **deaths**
- **Thousands** of non-fatal **heart attacks**
- **Thousands** of other **hospitalizations**
- **Thousands** of **asthma**-related **emergency room visits**
- **Hundreds of thousands** lost **workdays**

Ambient Air Quality Health Benefits (cont'd)



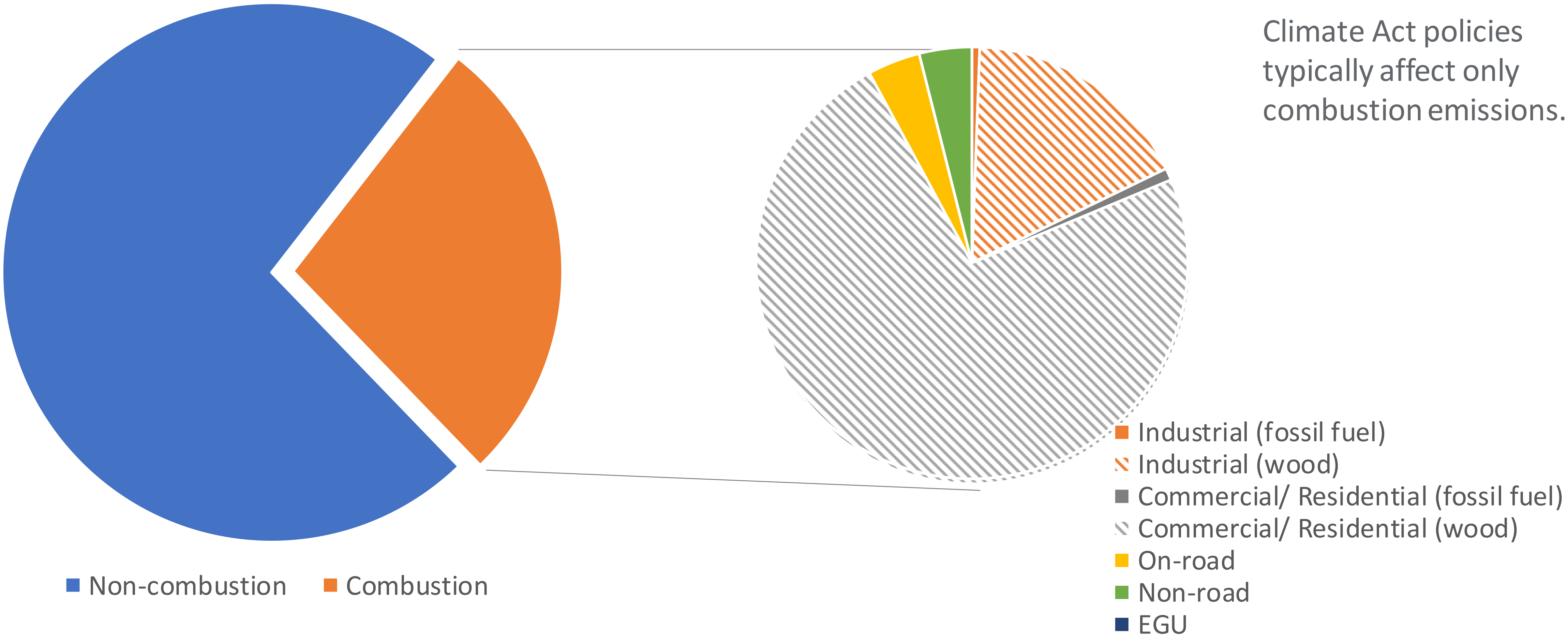
Annual Health Benefits
Strategic Use of Low Carbon Fuels





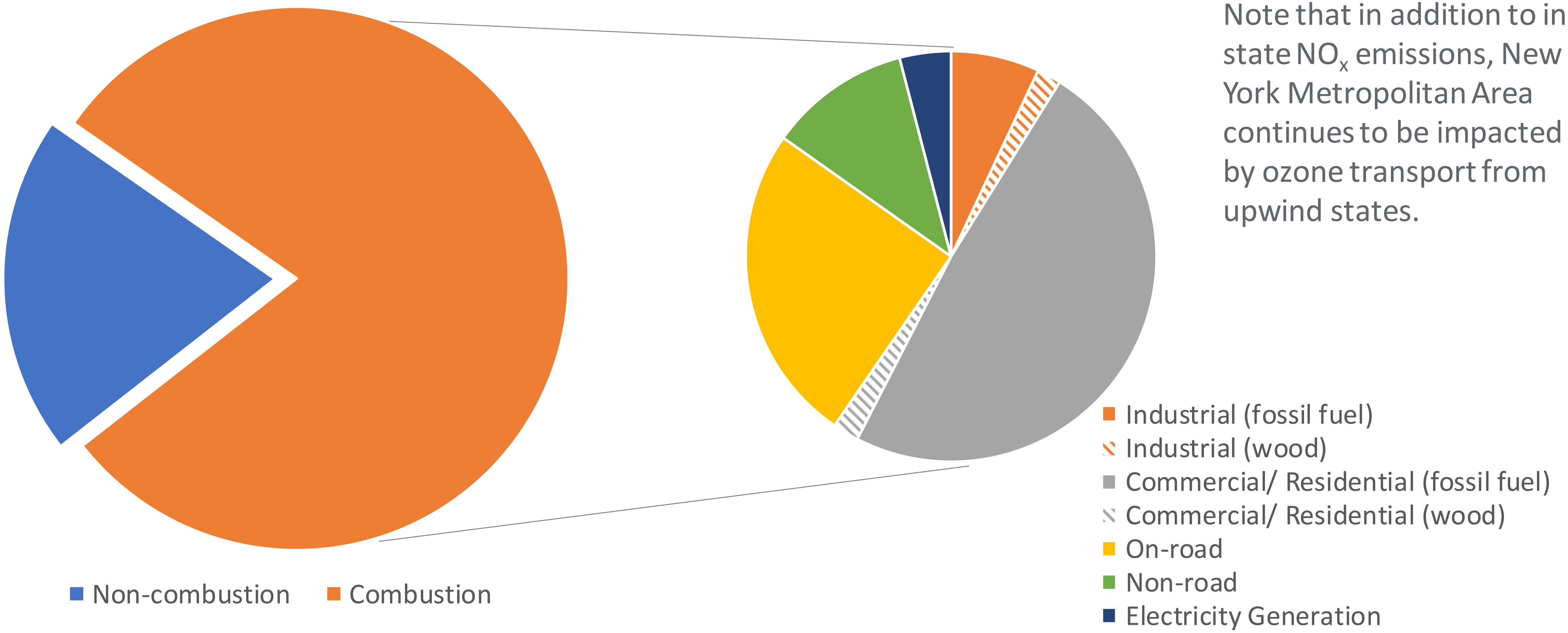
Sector-level Analysis

Sectoral-level $PM_{2.5}$ Emissions (2025 Reference Case)



Climate Act policies typically affect only combustion emissions.

Sectoral-level NO_x Emissions (2025 Reference Case)

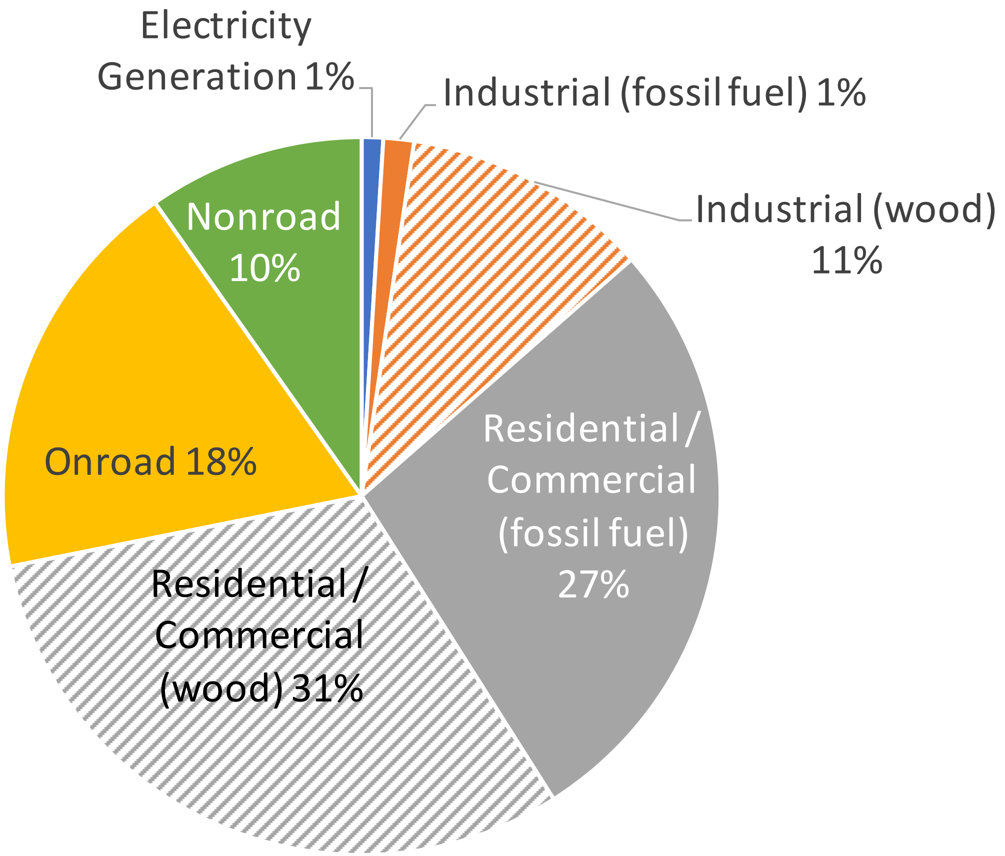


Note that in addition to in-state NO_x emissions, New York Metropolitan Area continues to be impacted by ozone transport from upwind states.

Health Benefits by Sector

Accelerated Transition Away From Combustion

2020-2050



The Strategic Use of Low Carbon Fuels scenario has similar proportions of health benefits by sector

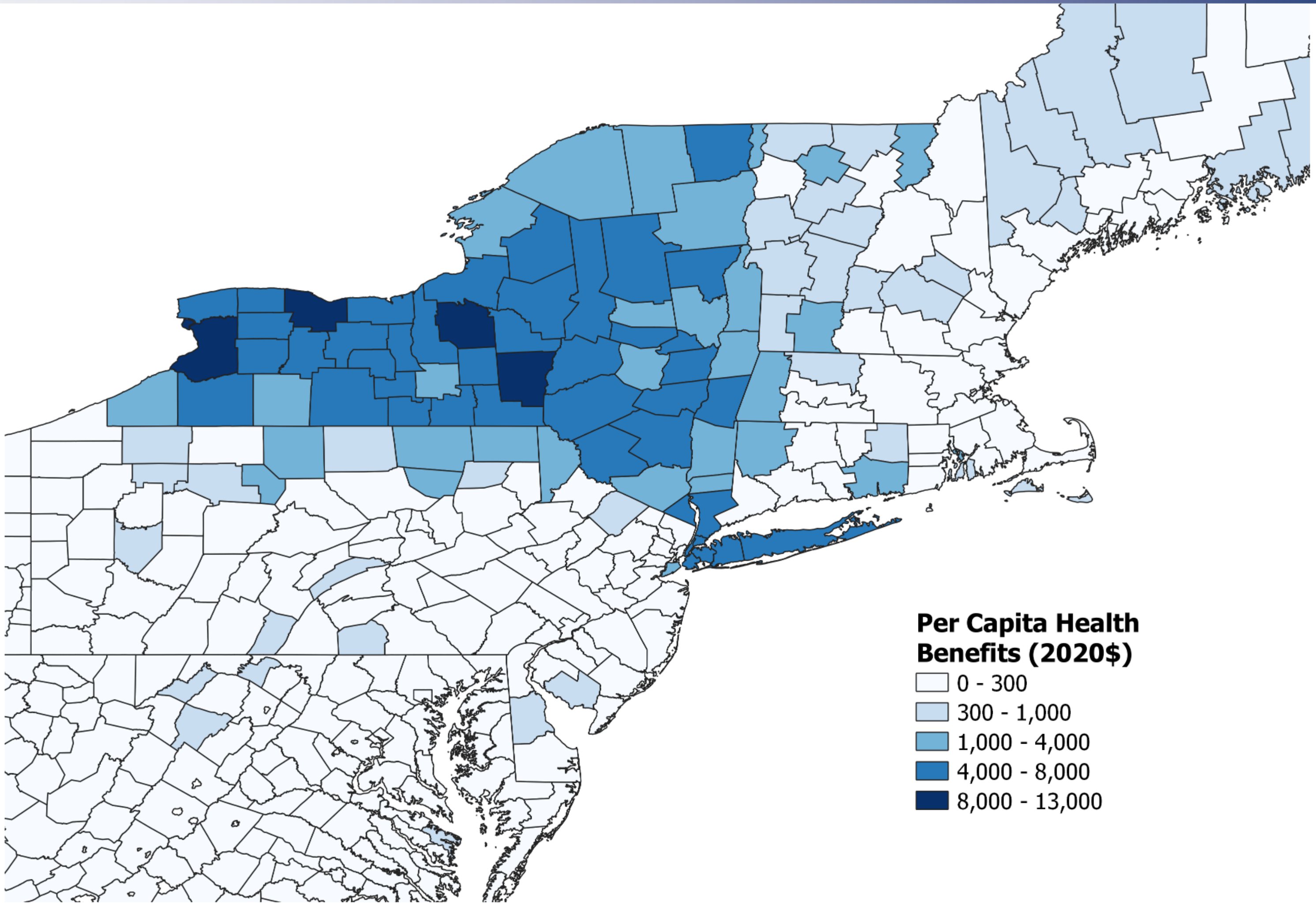
County-level Results

Per Capita Health Benefits

Strategic Use of Low Carbon Fuels

2020-2050

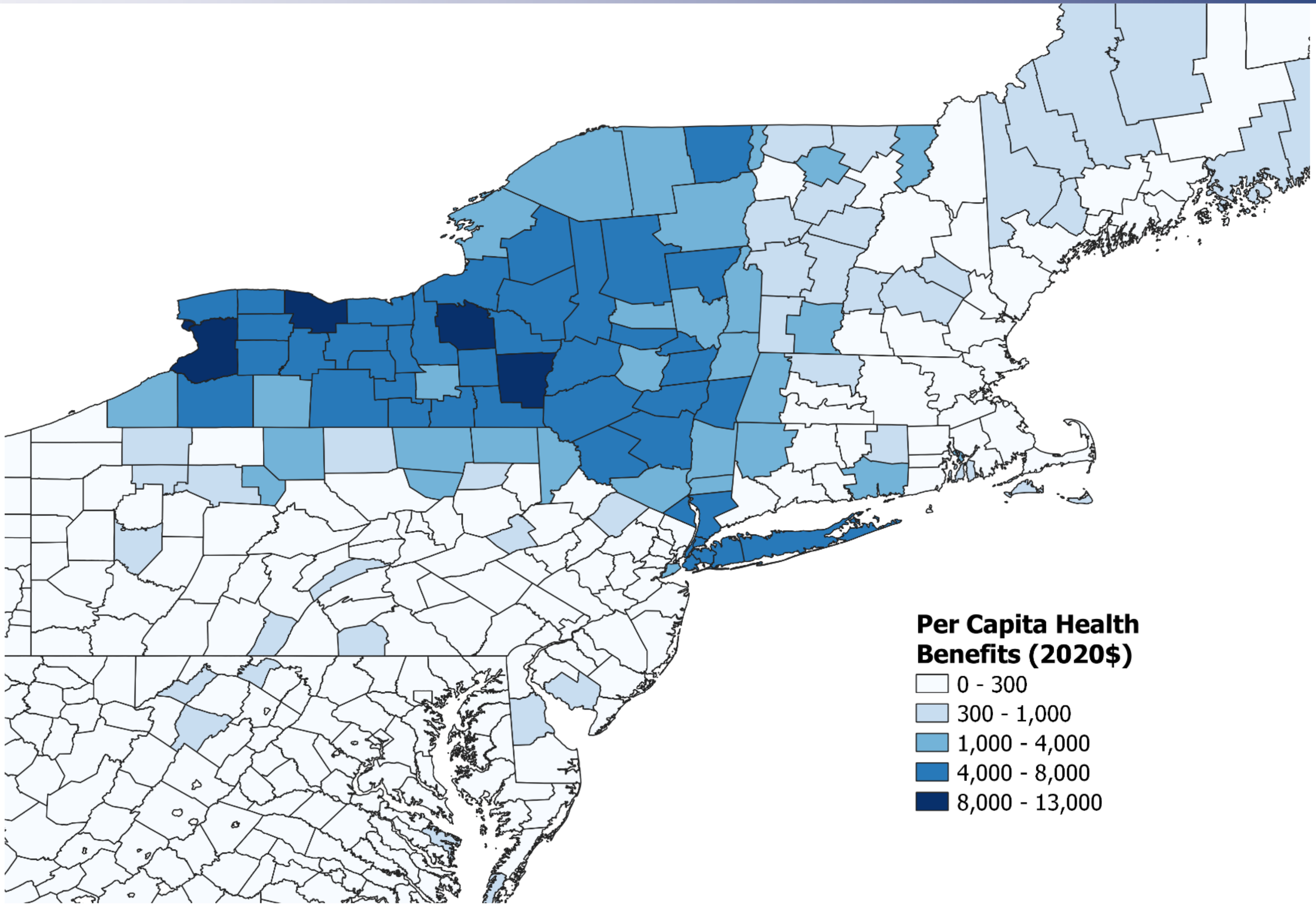
Per-capita benefits of emission reductions with wood combustion are higher upstate.



Per Capita Health Benefits

Accelerated Transition Away from Combustion

2020-2050



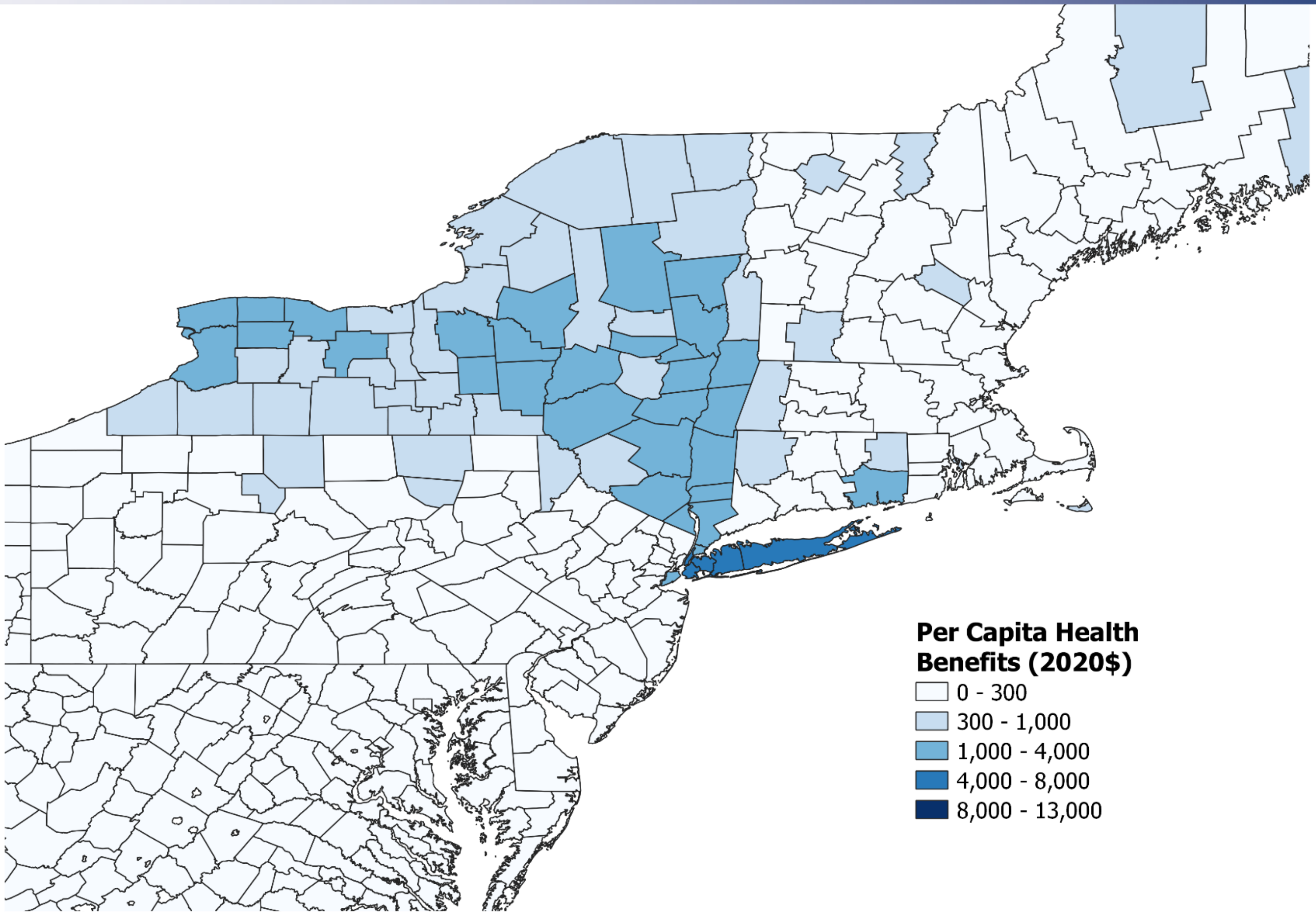
Per Capita Health Benefits

Strategic Use of Low Carbon Fuels

(excluding benefits of avoided wood combustion)

2020-2050

Benefits of emission reductions without wood combustion are concentrated downstate.

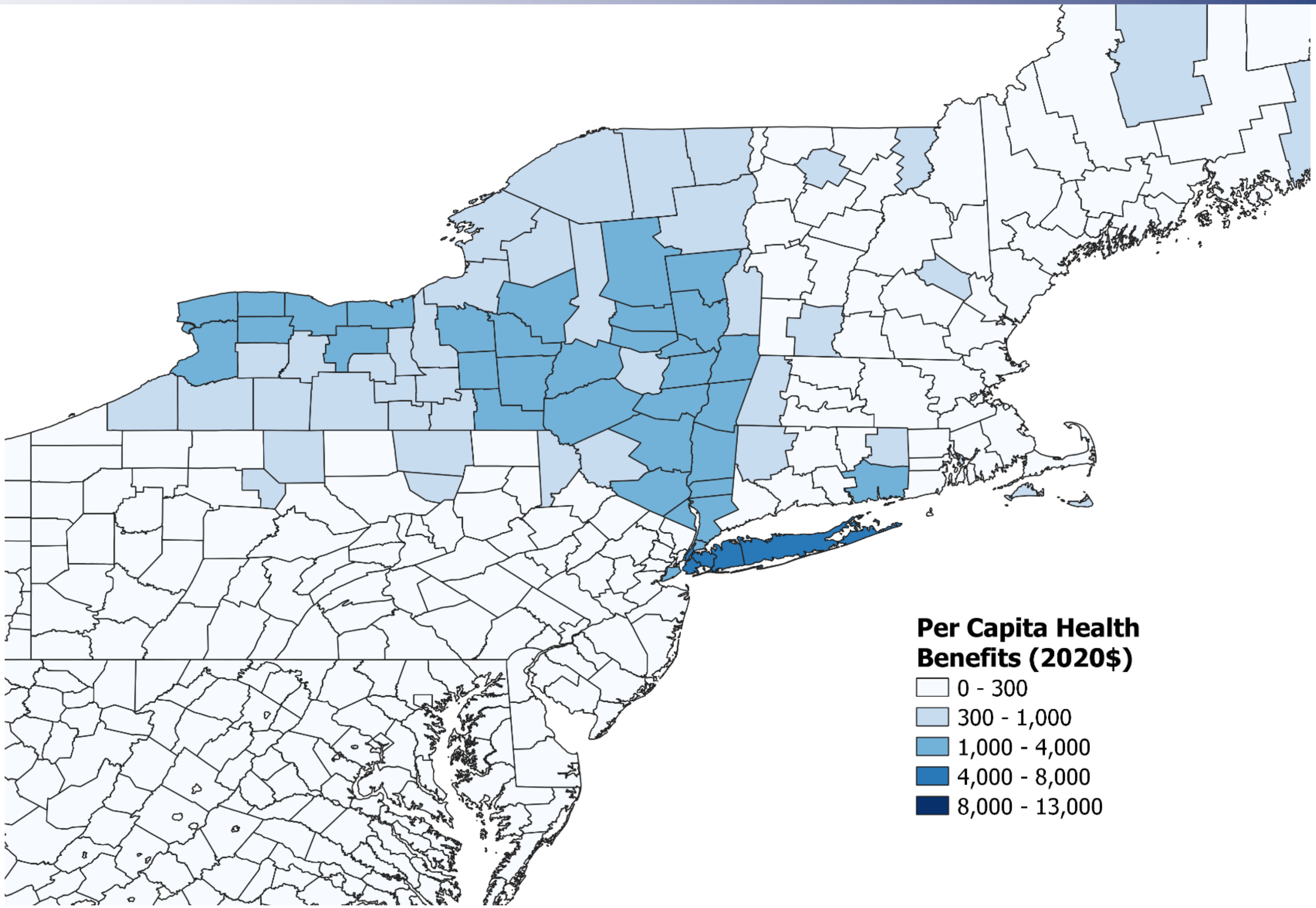


Per Capita Health Benefits

Accelerated Transition Away from Combustion

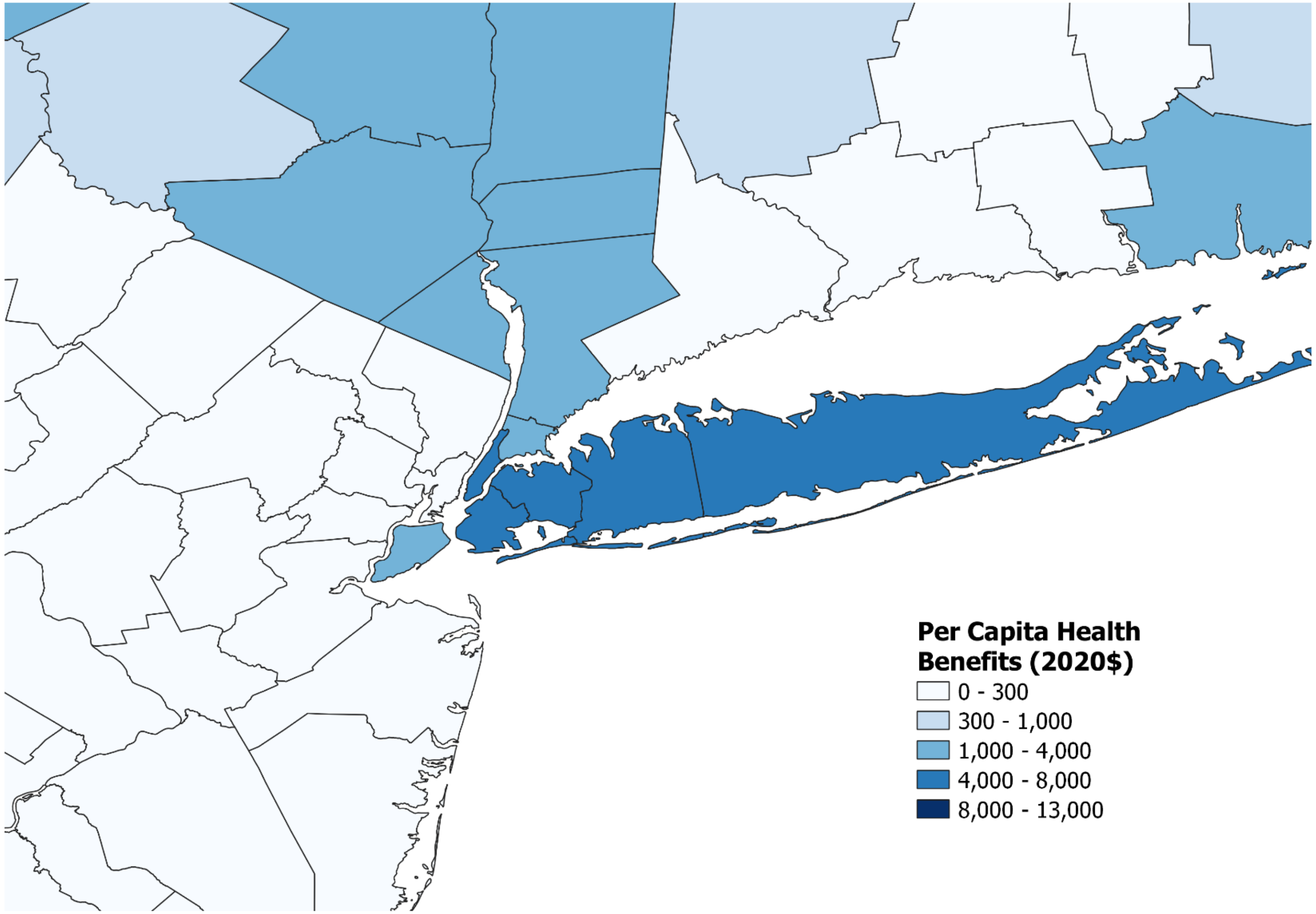
(excluding benefits of avoided wood combustion)

2020-2050



Per Capita Health Benefits

Borough	Per Capita Health Benefits (2020-2050)	
	Strategic Use of Low Carbon Fuels	Accelerated Transition Away from Combustion
Bronx	$3,273	$3,643
Brooklyn	$4,160	$4,526
Manhattan	$4,749	$5,135
Queens	$5,173	$5,646
Staten Island	$2,840	$3,072

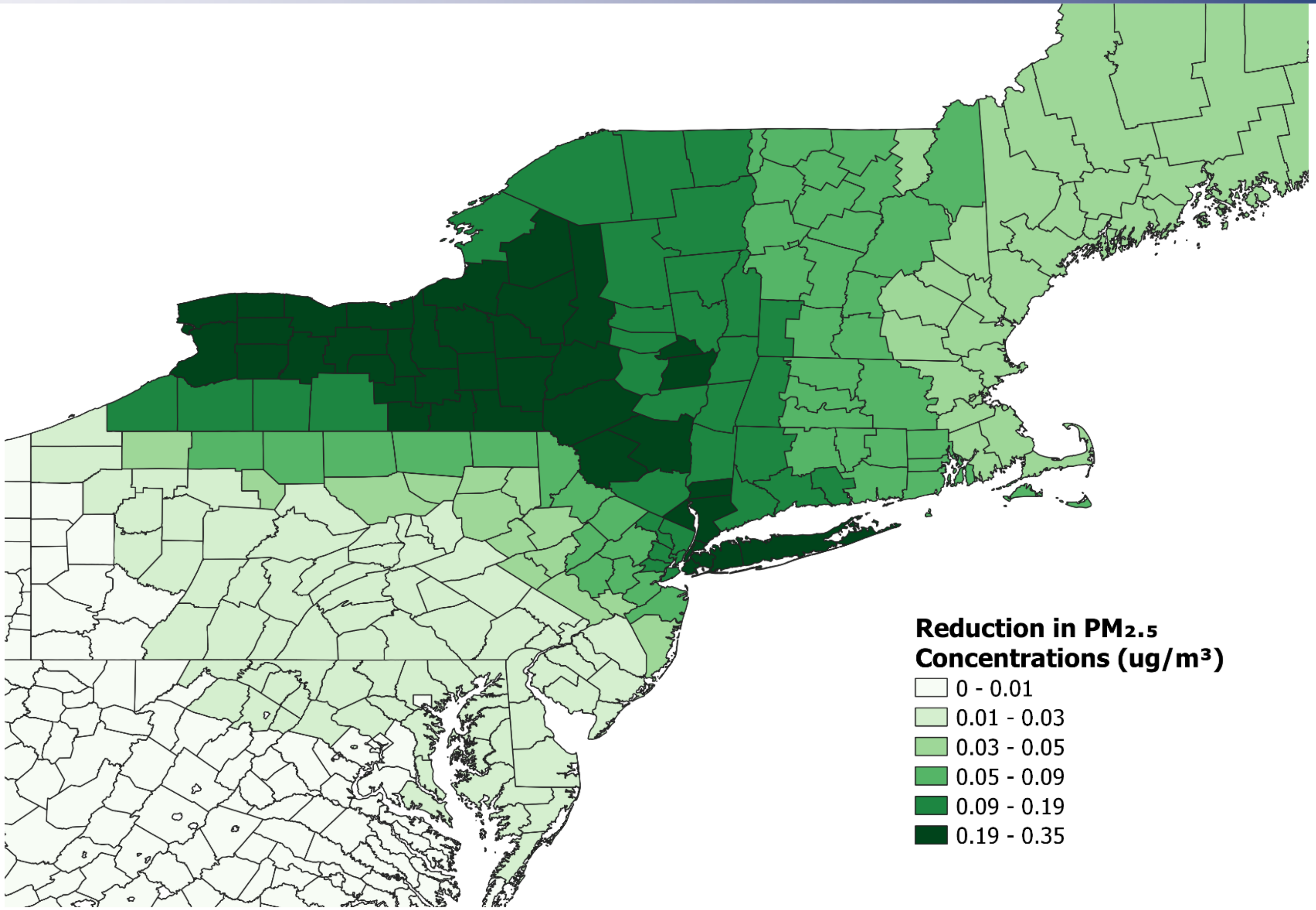


County-level Reductions in $PM_{2.5}$ Concentrations

Reduction in $PM_{2.5}$ Annual Average Concentrations

Strategic Use of Low Carbon Fuels

2050

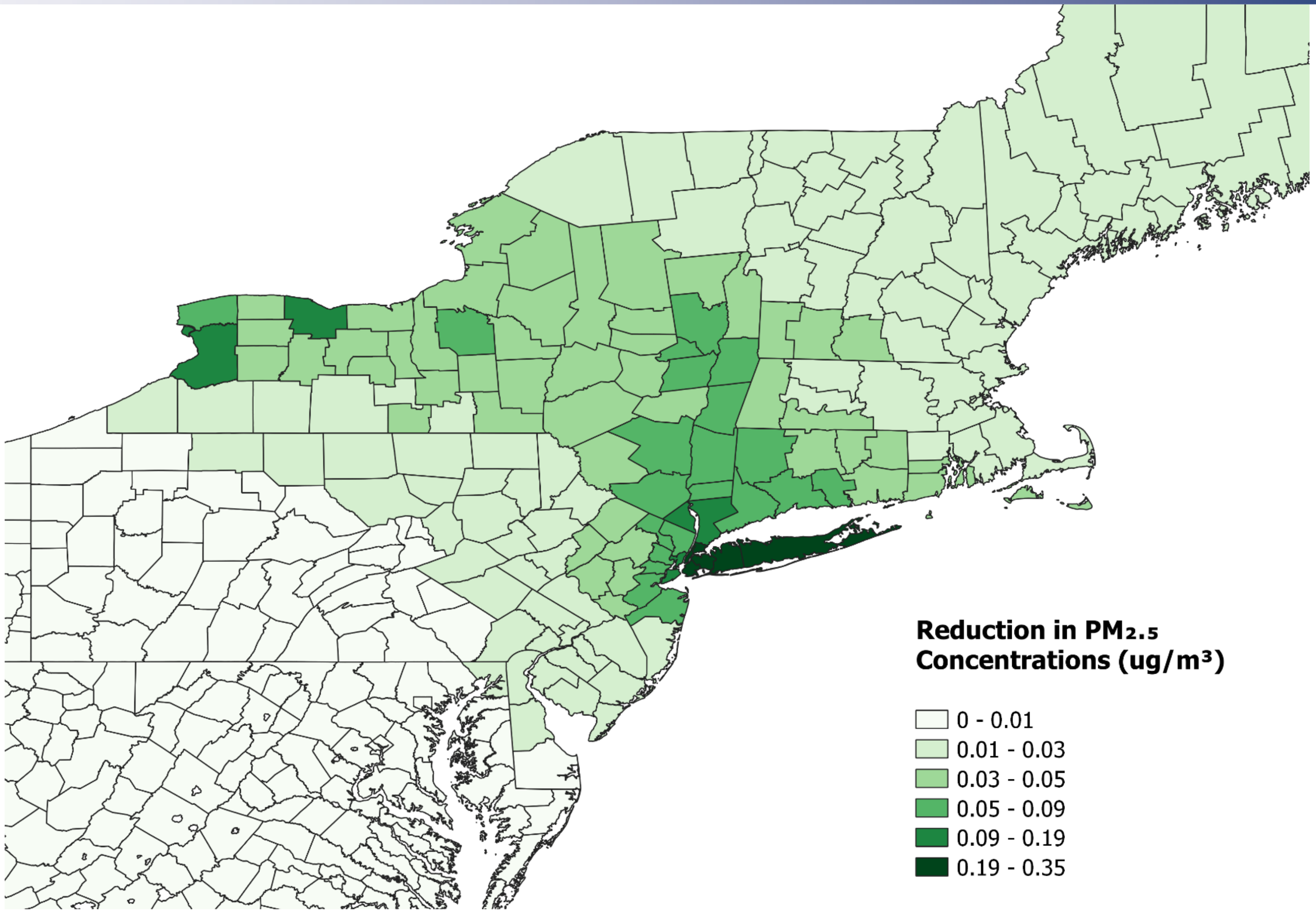


Reduction in $PM_{2.5}$ Annual Average Concentrations

Strategic Use of Low Carbon Fuels

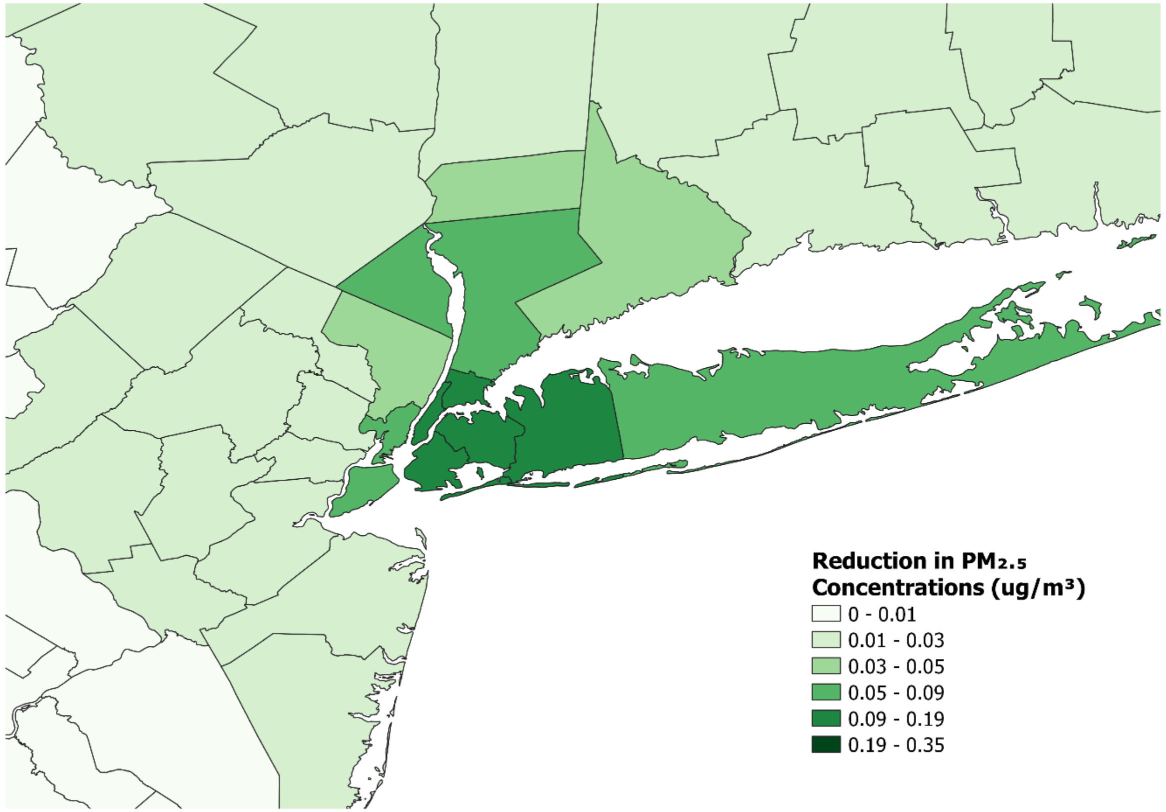
(excluding benefits of avoided wood combustion)

2050

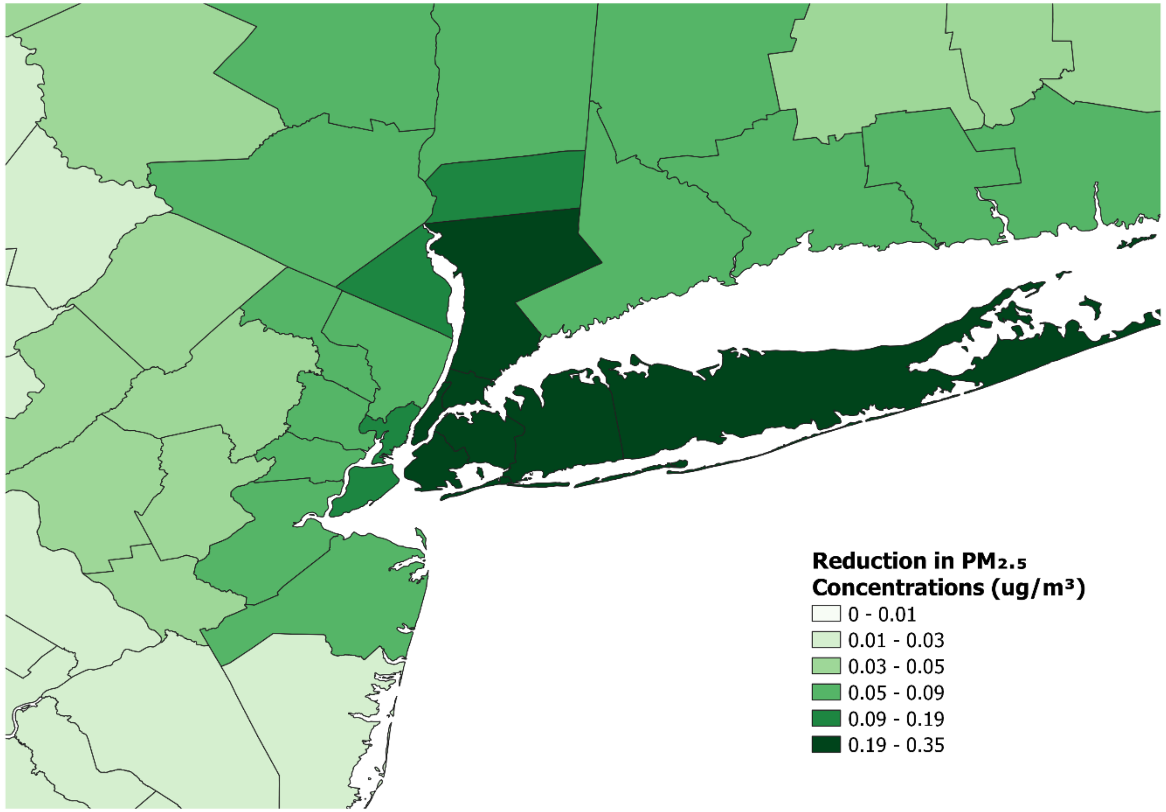


Reduction in $PM_{2.5}$ Annual Average Concentrations

2030



2050



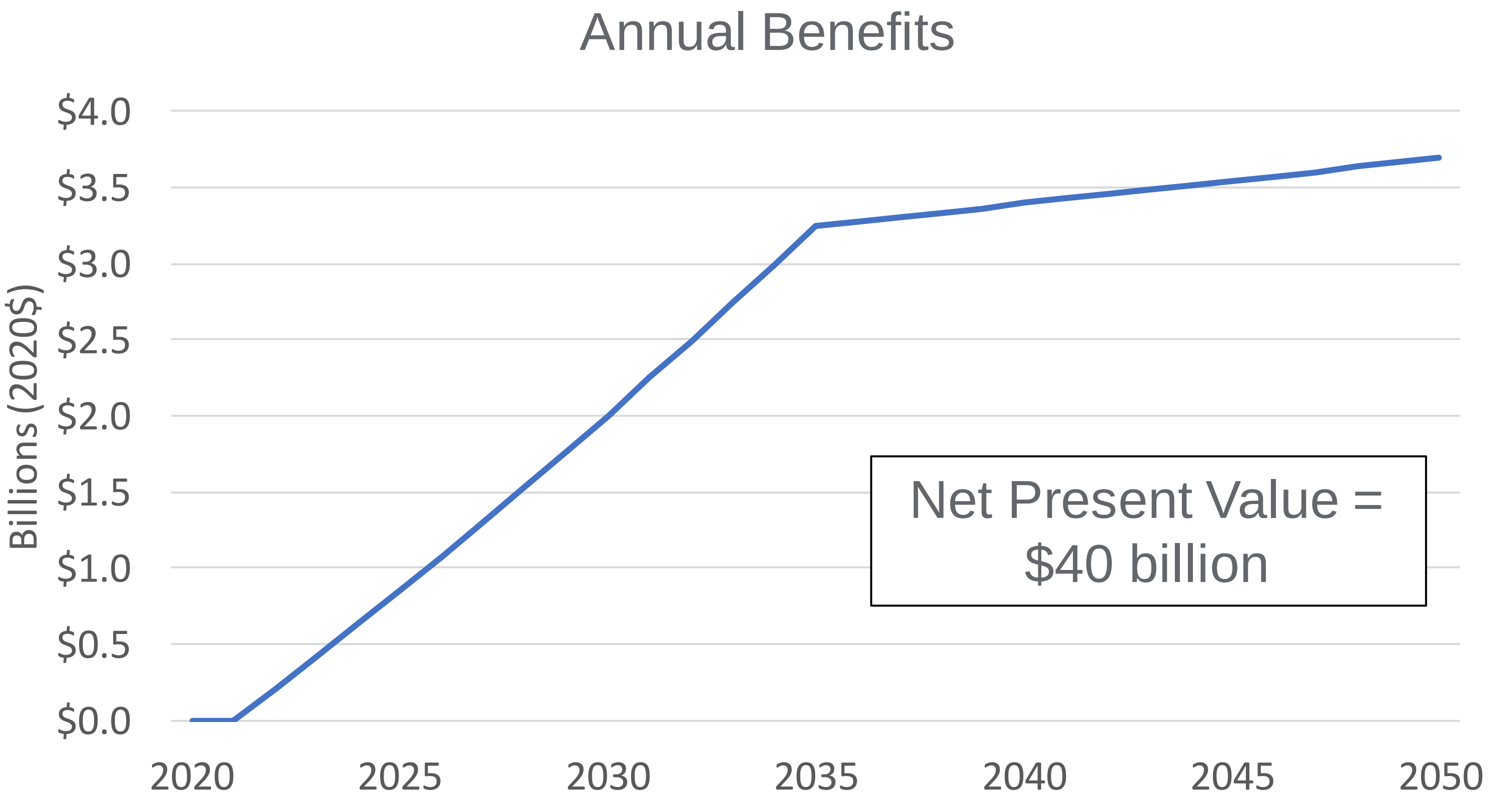
Note: The maps are the same for Low Carbon Fuels and Accelerated Transition Scenarios. These results exclude benefits of avoided wood combustion.

Active Transportation Health Effects

Active Transportation Benefits: Methods

- The analysis uses the ***Integrated Transport Health Impacts Model*** **(ITHIM)**
  - Scenario modeling of increases in active modes of transportation (e.g., cycling and walking) in 2050 and their health effects associated with physical activity and traffic collisions, based on VMT reductions.
  - ITHIM uses U.S.-level data from the *Global Burden of Disease* study and other published literature for estimates of health impacts of physical activity
  - We have customized it to apply NYS-specific data on population, walking, and cycling rates, baseline mortality rates, and VMT
- The output is the net change in the number of deaths, including the decrease in deaths from increase physical activity and the increase in deaths from traffic collisions
  - Note that in our initial results, the decrease in deaths from physical activity far outweighs the increase in deaths from traffic collisions.

Active Transportation Benefits: Results



Active transportation benefits are the same for the Low Carbon Fuels and Accelerated Transition scenarios

Energy Efficiency Health Effects

Energy Efficiency Benefits: Methods

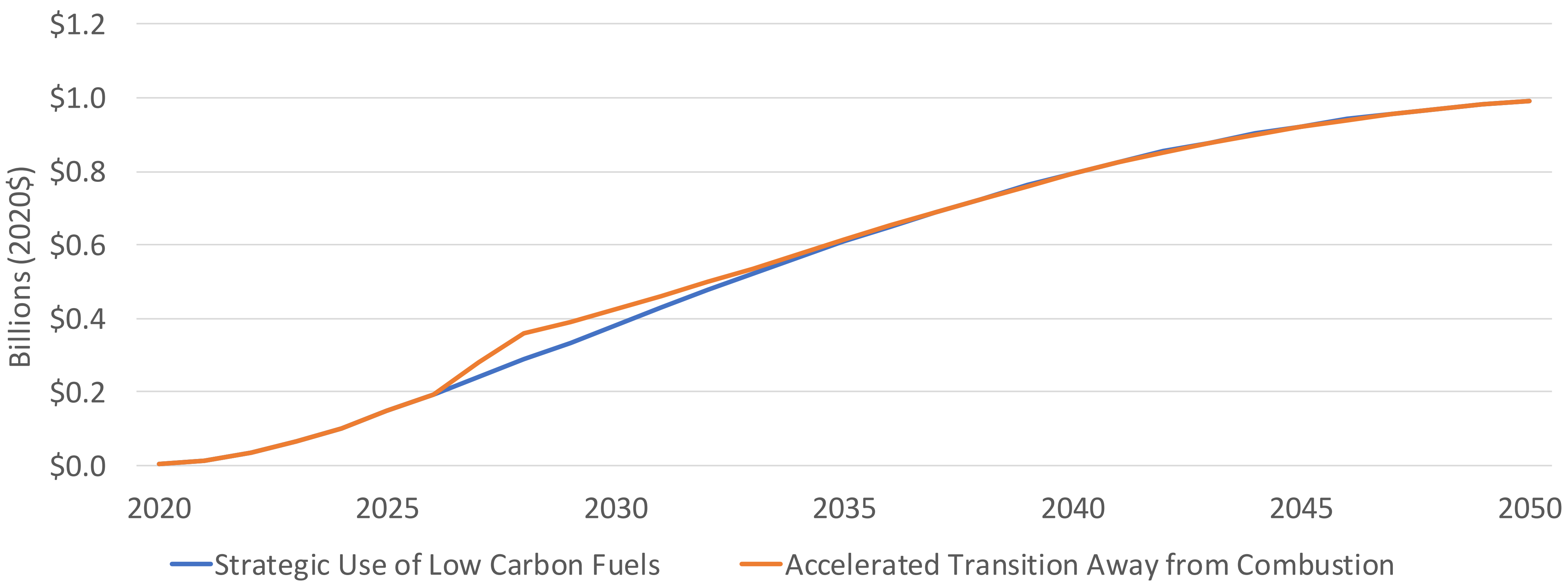
- This analysis used values from published literature on the health and safety benefits of energy efficiency and weatherization programs to estimate the benefits of such programs in NYS.
- Three key studies include estimates of a variety of potential benefits:
  - Evaluation of the Department of Energy's *Weatherization Assistance Program* conducted by ORNL (2014)
  - Literature review, ACEEE (2020)
  - Analysis of benefits in multifamily homes, ORNL (2021)
- Benefits are estimated for low- and moderate-income (LMI) homes.
  - LMI definition is less than or equal to 80% of median income; approximately 40% of homes in NYS.
  - The literature has estimated the benefits of EE programs that target LMI homes.
  - There are likely also benefits for higher income homes, but we do not have data to estimate them.
- We apply average benefits to the number of LMI homes projected to undergo weatherization and/or system changes to estimate a total value of benefits.

Energy Efficiency Benefits: Results (2020-2050)

Strategic Use of Low Carbon Fuels

Health-related measure	LMI single family (billion $)	LMI multi-family (billion $)	Total (billion $)
Reduced asthma-related incidents or reduced asthma symptoms	$3.0	na	$3.0
Reduced trip or fall injuries	$1.4	$0.5	$1.9
Reduced thermal stress - cold	$0.4	$0.9	$1.2
Reduced thermal stress - heat	$0.6	$1.5	$2.2
Reduced CO poisonings	$0.5	na	$0.5
Total	**$5.8**	**$2.9**	**$8.7**

Energy Efficiency Annual Benefits



Integration Analysis: Scenario Results Appendix

Appendix Contents

- Energy efficiency health benefits methodology details and additional results
- Cost metric definitions
- Range of fuel costs and technology costs
- Uncertainty range in annual net direct costs
- Range of upstream emissions from natural gas, including high upper bound

Energy Efficiency Benefits: Methods

The analysis includes the following benefits:

Health-related measure	Causes for Each Benefit	Low income single family	Low income multi-family
Reduced thermal stress – heat and cold	Building envelope tightening, appliance replacements	X	X
Reduced asthma-related incidents or reduced asthma symptoms	Improved ventilation	X	*
Reduced trip or fall injuries	Removal of trip hazards, roofing improvements	X	X
Reduced CO poisonings	Appliance replacements, CO monitors	X	

** Studied but no significant difference detected.*

Energy Efficiency Benefits: Results (2020-2050)

Accelerated Transition Away from Combustion

Health-related measure	**Low income single family (billion $)**	**Low income multi-family (billion $)**	**Total (billion $)**
Reduced asthma-related incidents or reduced asthma symptoms	$3.0	na	$3.1
Reduced trip or fall injuries	$1.4	$0.5	$1.9
Reduced thermal stress - cold	$0.4	$0.9	$1.3
Reduced thermal stress - heat	$0.6	$1.6	$2.2
Reduced CO poisonings	$0.5	na	$0.5
Total	**$6.0**	**$3.0**	**$8.9**

Discounted at 3.6%

Cost Metric Definitions

> Annual Net Direct Costs

- Net Direct Costs are levelized costs in a given scenario incremental to the Reference Case for a single year.
- Includes direct capital investment, operating expenses, and fuel expenditures

> NPV of Net Direct Costs

- NPV of levelized costs in a given scenario incremental to the Reference Case from 2020-2050
- Includes direct capital investment, operating expenses, and fuel expenditures
- Assumes discount rate of 3.6%

> System Expenditure

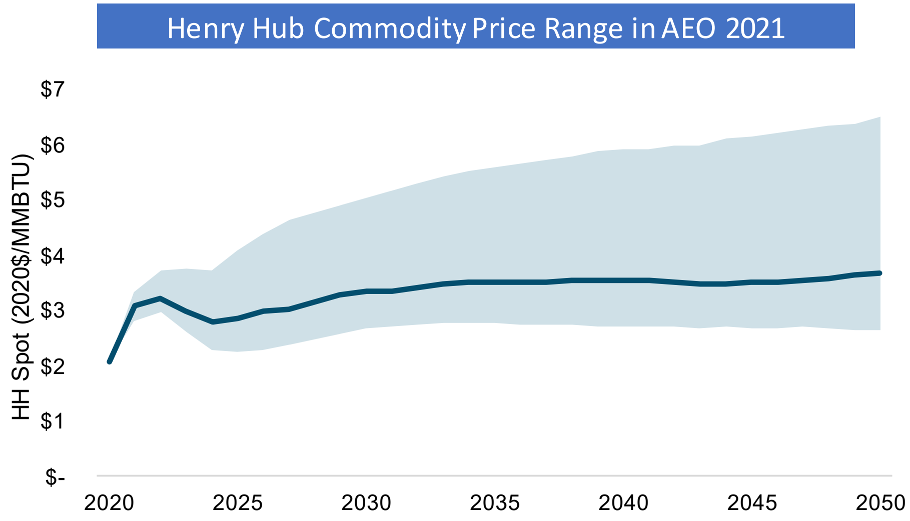
- System expenditure is an estimate of absolute direct costs (not relative to Reference Case)
- Does not reflect direct costs in some sectors that are represented with incremental costs only. These include investments in industry, agriculture, waste, forestry, and non-road transportation

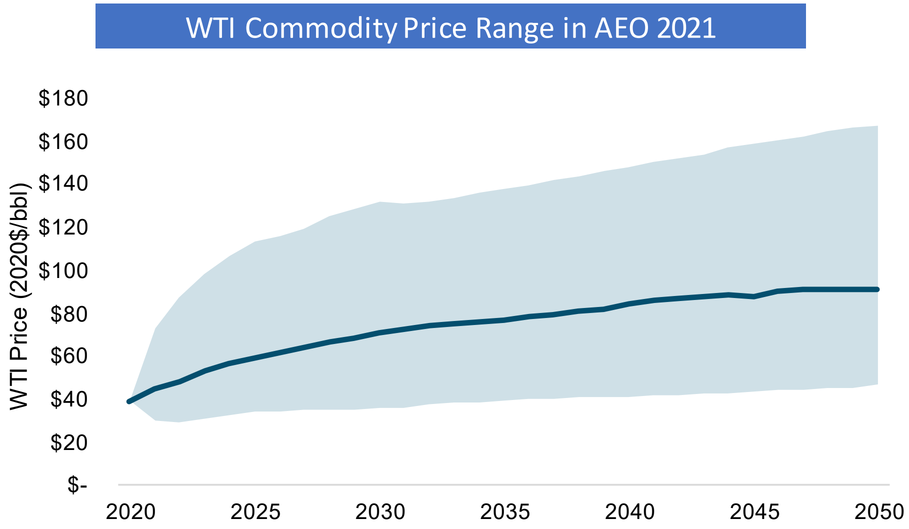
Fuel Prices

> Range of commodity fuel prices sourced from EIA Annual Energy Outlook

> Cost of electricity consumption is treated within the RESOLVE modeling framework

> Prices for renewable fuels and zero carbon fuels (such as hydrogen) based on E3 analysis of feedstocks and feedstock to fuel pathways. Hydrogen production via electrolysis is included in the RESOLVE modeling framework

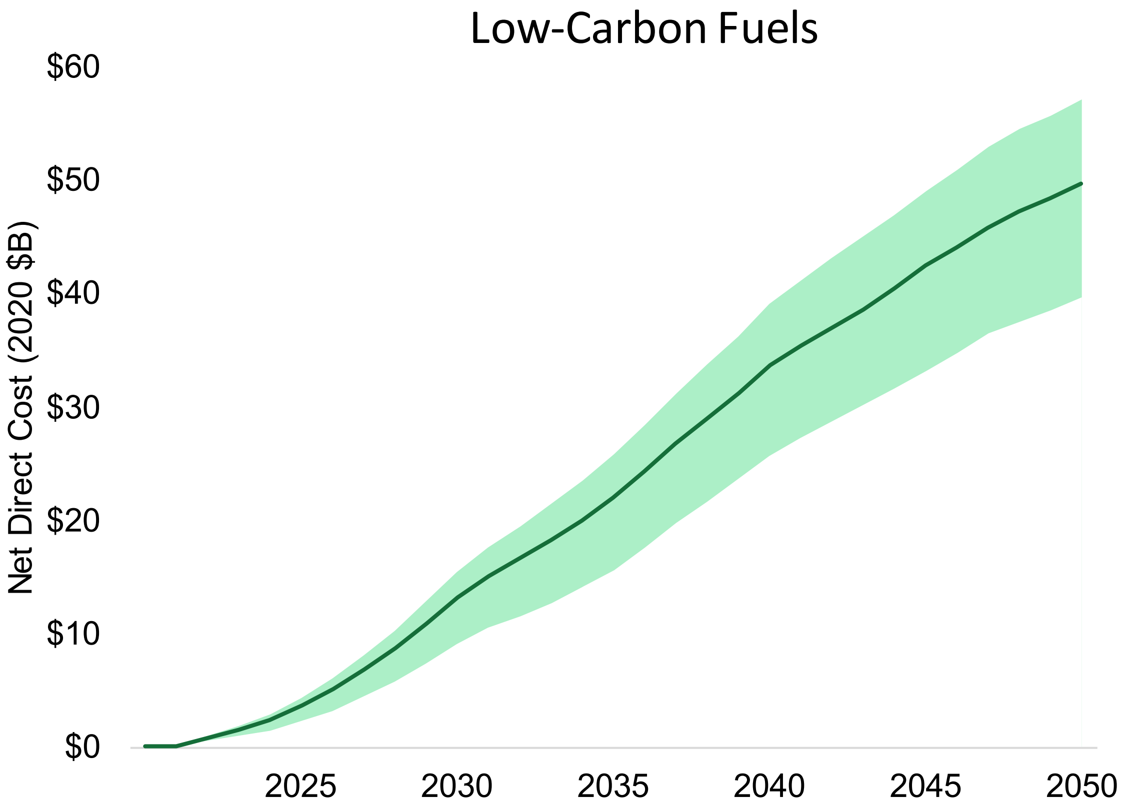


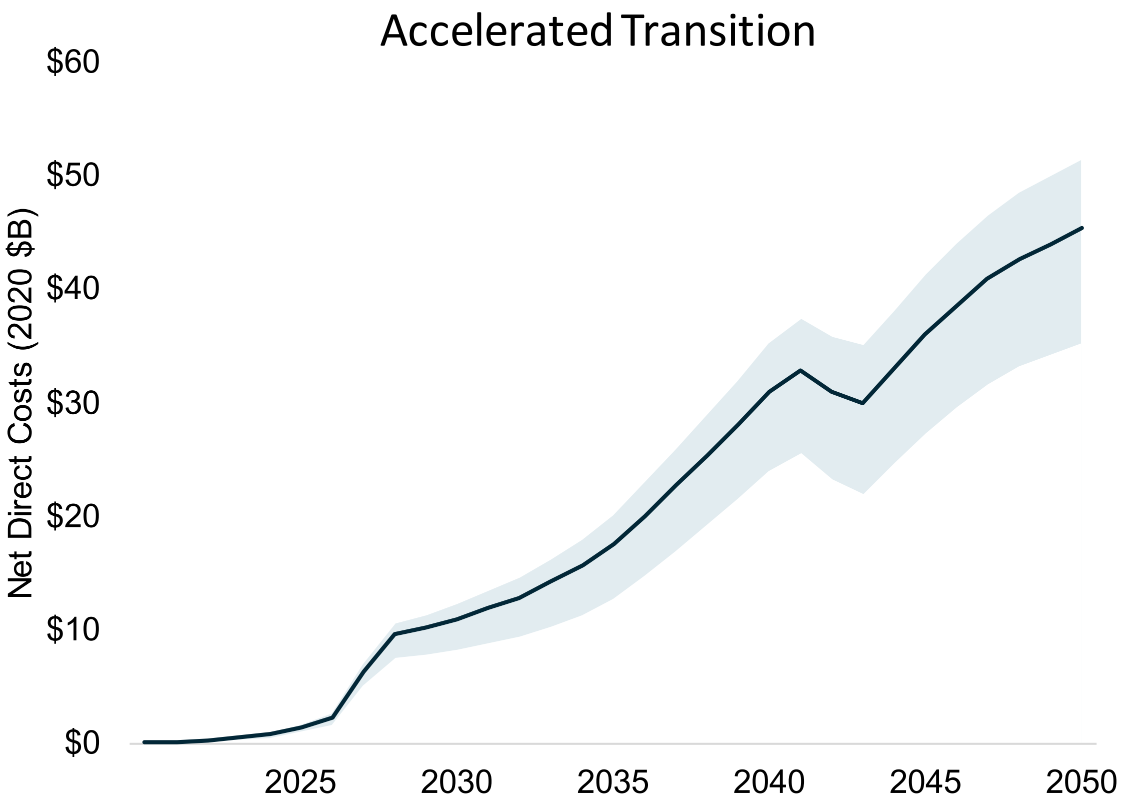


Fuel Price Sensitivity

Annual net direct costs relative to Reference

> Scenario costs are very sensitive to the price of fossil fuels. This graphic includes fuel price sensitivities from AEO 2021



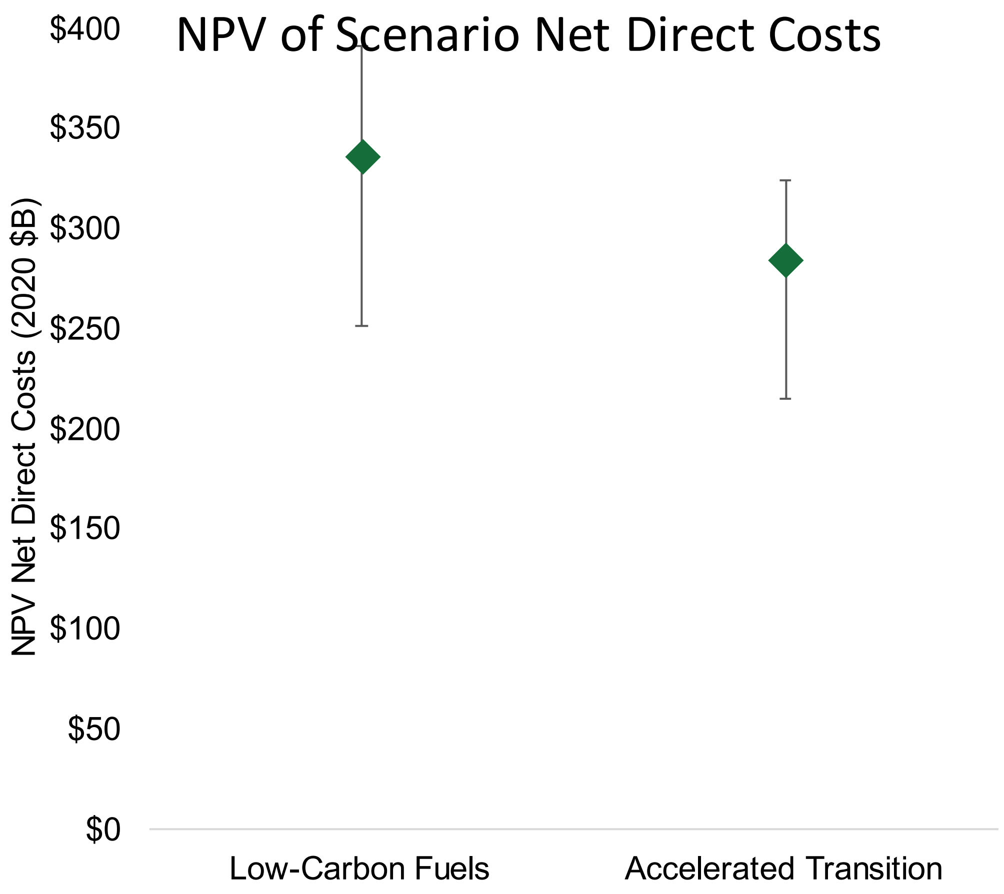


Scenario Costs

Net Present Value of costs relative to Reference, including net direct costs

> Error bars represent low and high fossil fuel price projections

- Technology costs held at core case levels



Technology Cost Sensitivity

> Integration Analysis includes sensitivity on cost for key demand side technologies, meant to represent an "innovation" world view in which these technologies achieve significant price declines relative to reference case forecast

- This includes a 20% decrease in price for heat pumps, electric vehicles

> For electric generating units, Integration Analysis includes future cost declines for wind, solar, and storage as projected by NREL's Annual Technology Baseline "Mid Case"

- This incorporates NY-specific and zone-specific resource costs and availability

> For highly uncertain technologies such as cost for direct air capture (DAC) meant to represent negative emissions technologies (NETs), we include a technology sensitivity meant to indicate an innovation perspective on learning over time

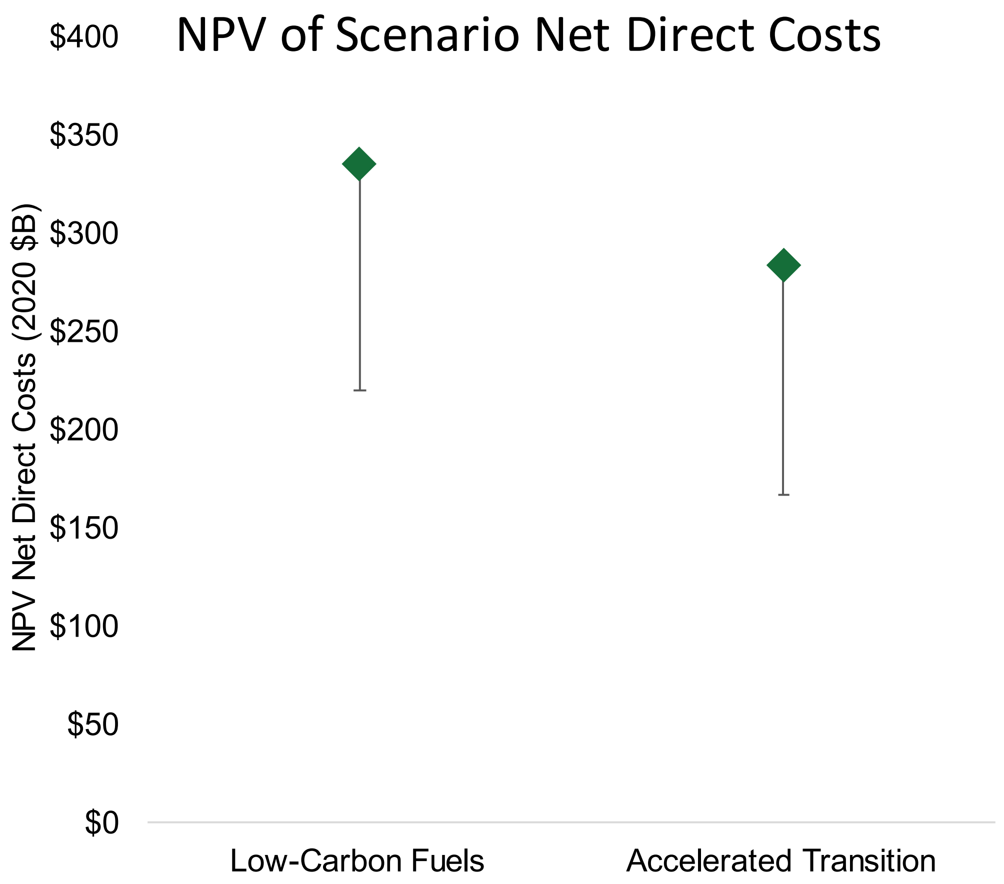
- Central case includes direct air capture cost estimates for first of a kind plant from literature (Keith et al) while low cost sensitivity includes nth-of-a-kind cost estimates: this results in an innovation cost of 30% less than the reference case cost for DAC

Scenario Costs

Net Present Value of costs relative to Reference, including net direct costs

> Error bars represent low/innovation device technology costs (heat pumps, electric vehicles, cost of NETs, cost of hydrogen storage)

- Fossil fuel prices held at core projection

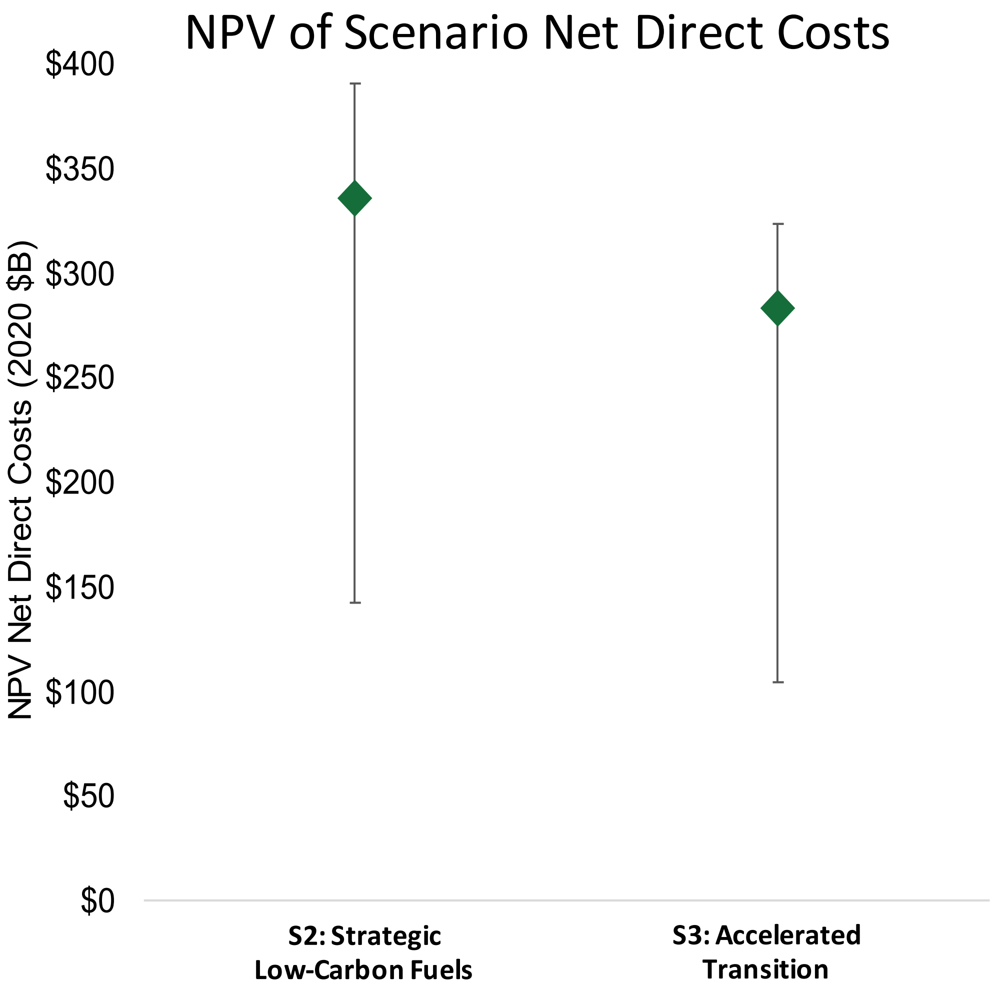


Scenario Costs

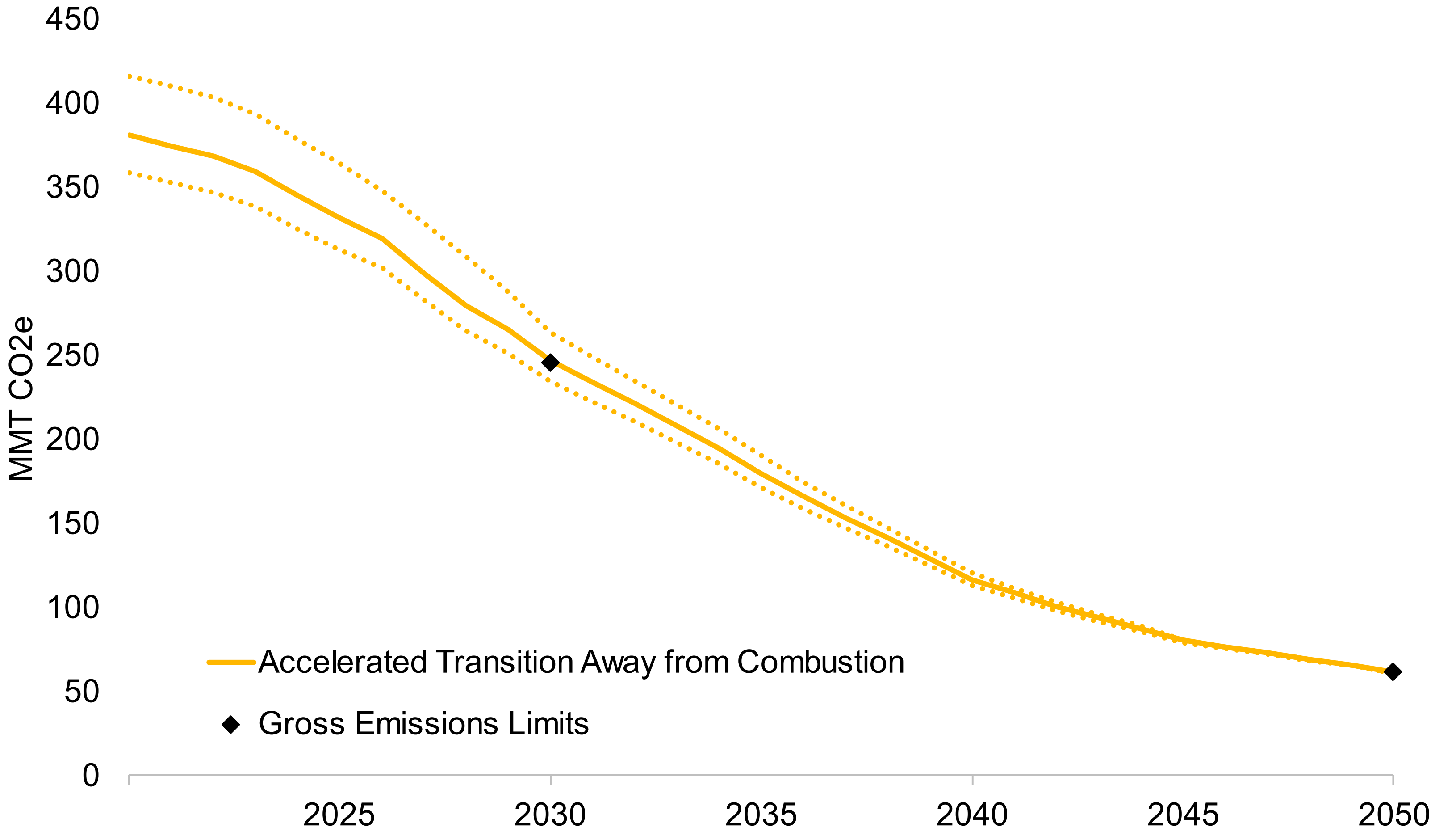
Net Present Value of costs relative to Reference, including net direct costs (2020 - 2050)

> Net direct costs (central estimate from $280 - $340 billion) are in the same range given uncertainty bounds
  - Reference Case system expenditure: $2.7 trillion
  - Net direct cost range from 10-12% over Reference Case system expenditures

> Error bars represent low and high fossil fuel price forecasts and low technology cost sensitivity



Sensitivity to Upstream Natural Gas Emission Factor



- High Upstream NG EF results in an **increase of 16 MMT CO2e** in 2030
- Low Upstream NG EF results in a **decrease of 13 MMT CO2e** in 2030

Low: 0.46 lb/mmbtu CH4
Med: 0.85 lb/mmbtu CH4
High: 1.47 lb/mmbtu CH4

2020 is a modelled year, reflecting historical trends