

Chapter 14: Greenhouse Gas Emissions and Resilience

14.1 INTRODUCTION

This chapter presents the evaluation that the Federal Railroad Administration (FRA) and the New Jersey Transit Corporation (NJ TRANSIT) conducted of the impacts of the Hudson Tunnel Project with respect to greenhouse gas (GHG) emissions and resilience to severe weather events. The chapter was prepared based on general guidance related to environmental analysis pursuant to the National Environmental Policy Act (NEPA), New York State Department of Environmental Conservation (NYSDEC) policy,¹ the 2020 *City Environmental Quality Review (CEQR) Technical Manual*,² and the Federal Transit Administration (FTA) guidance related to assessing GHG emissions.³ The analysis approach is also consistent with New Jersey's general guidance for Environmental Impact Statement (EIS) preparation regarding sustainability.⁴ The analysis quantifies GHG emissions and effects of the Project, to allow an evaluation of the Project's consistency with goals and policies related to resilience and climate change. The Port Authority of New York and New Jersey (PANYNJ), in its role as Project Sponsor, has accepted and relied on the evaluations and conclusions of this chapter.

Following completion of the Draft Environmental Impact Statement (DEIS), the PANYNJ became the Project Sponsor for the Hudson Tunnel Project (see Chapter 1, "Purpose and Need," Section 1.1.2, for more information). Consistent with the roles and responsibilities defined in Section 1.1.1, as the current Project Sponsor, the PANYNJ will comply with mitigation measures and commitments identified in the Record of Decision (ROD).

This chapter reflects the following changes made since the DEIS for the Hudson Tunnel Project:

- It includes a discussion of guidance of the Federal Transit Administration (FTA) related to assessing GHG emissions.
- It incorporates updated information related to flooding and resilience, including updated maps related to flood zones.
- The analysis incorporates revisions and refinements to the construction staging approach in New Jersey, including the addition of a new potential haul route for truck access to the Hoboken staging site. The analysis incorporates revisions and refinements to the construction methods in New York. For both New Jersey and New York, it includes more refined information on construction equipment that may be used at the construction sites.

Section 14.2 of this chapter addresses the effect of GHG emissions generated by the construction and operation of the Preferred Alternative and Section 14.3 addresses the resilience of proposed infrastructure to severe weather events under future conditions.

¹ NYSDEC. *DEC Policy: Assessing Energy Use and Greenhouse Gas Emissions in Environmental Impact Statements*. July 15, 2009.

² New York City Mayor's Office of Environmental Coordination. *City Environmental Quality Review Technical Manual*. 2020.

³ Federal Transit Administration. *Greenhouse Gas Emissions from Transit Projects: Programmatic Assessment*. FTA Report No. 0097. January 2017.

⁴ State of New Jersey. *Attachment to Executive Order No. 215 of 1989: Guidelines for the Preparation of An Environmental Impact Statement/Environmental Assessment*. Revised and Updated - April 23, 2002.

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14.2 GREENHOUSE GAS EMISSIONS

14.2.1 REGULATORY CONTEXT

GHGs are gaseous constituents of the atmosphere, both natural and caused by human activity, that can result in the general warming of the earth's atmosphere, or the greenhouse effect. Water vapor, carbon dioxide (CO₂), nitrous oxide (N₂O), methane, and ozone are the primary GHGs in the earth's atmosphere.

There are also a number of GHGs in the atmosphere resulting entirely from human activity such as halocarbons and other chlorine- and bromine-containing substances that damage the stratospheric ozone layer (and contribute to the ozone hole). Since these compounds are being replaced and phased out, there is no need to address them in GHG assessments for most projects. Although ozone itself is also a major GHG, it does not need to be assessed in this context because it is a rapidly reacting chemical and efforts are ongoing to reduce ozone concentrations as a criteria pollutant (see Chapter 13, "Air Quality," Section 13.2). Similarly, water vapor is of great importance to global climate change, but is not directly of concern as an emitted pollutant because the quantities emitted from anthropogenic sources are negligible.

CO₂ is the primary pollutant of concern from sources related to human activity. CO₂ is by far the most abundant and, therefore, the most influential GHG. CO₂ is emitted from any combustion process; some industrial processes, such as the manufacture of cement, mineral production, metal production, and the use of petroleum-based products; volcanic eruptions; and the decay of organic matter. CO₂ is removed (or sequestered) from the lower atmosphere by natural processes such as photosynthesis and uptake by the oceans. CO₂ is included in any analysis of GHG emissions.

Methane and N₂O also play an important role since the removal processes for these compounds are limited and because they have a relatively high impact on global climate change as compared with an equal quantity of CO₂. Emissions of these compounds, therefore, are included in GHG emissions analyses when the potential for substantial emission of these gases exists.

In addition, where relevant, GHG assessments consider certain other GHGs, including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), nitrogen trifluoride (NF₃), and sulfur hexafluoride (SF₆). For the Preferred Alternative, there would be no significant direct or indirect sources of HFCs, PFCs, NF₃, or SF₆ associated with construction activities or operation.

This analysis of GHG emissions from the Preferred Alternative focuses on CO₂, N₂O, and methane. To present a complete inventory of all GHGs, the analysis in this chapter adds together the component emissions and presents them as carbon dioxide equivalent (CO₂e) emissions—a unit representing the quantity of each GHG weighted by its effectiveness in changing the energy balance, using CO₂ as a reference. This is achieved by multiplying the quantity of each GHG emitted by a factor called global warming potential (GWP). GWPs account for the lifetime and the radiative forcing⁵ of each chemical over a period of 100 years (e.g., CO₂ has a much shorter atmospheric lifetime than SF₆, and therefore has a much lower GWP). The GWPs for the main GHGs discussed here are presented in **Table 14-1**.

**Table 14-1
Global Warming Potential (GWP) for Major GHGs**

Greenhouse Gas	100-year Horizon GWP
Carbon dioxide (CO ₂)	1
Methane (CH ₄)	25
Nitrous oxide (N ₂ O)	298
Hydrofluorocarbons (HFCs)	675 to 14,800
Perfluorocarbons (PFCs)	7,390 to 12,200
Nitrogen trifluoride (NF ₃)	17,200
Sulfur hexafluoride (SF ₆)	22,800
<p>Note: The GWPs presented above are based on the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report (SAR) of 2007 to maintain consistency in GHG reporting. The IPCC has since published updated GWP values that reflect new information on atmospheric lifetimes of GHGs and an improved calculation of the radiative forcing of CO₂. In some instances, if combined emission factors were used from updated modeling tools, some slightly different GWP may have been used for this study. Since the emissions of GHGs other than CO₂ represent a very minor component of the emissions, these differences are negligible.</p> <p>Source: U.S. Environmental Protection Agency (EPA). <i>Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2018</i>. 2020.</p>	

14.2.2 METHODOLOGY FOR PROJECTING GHG EMISSIONS

14.2.2.1 INTRODUCTION

During development of this EIS, the FRA and NJ TRANSIT developed methodologies for evaluating the potential effects of the Hudson Tunnel Project in coordination with the Project's Cooperating and Participating Agencies (i.e., agencies with a permitting or review role for the Project). The methodologies used for analysis of GHG emissions are summarized in this chapter.

Identifying potential GHG emissions from a proposed action can help decision makers identify practicable opportunities to reduce GHG emissions and ensure consistency with policies aimed at reducing overall emissions. There are no established thresholds for assessing the significance of a project's GHG emissions; instead, the analysis seeks to identify GHG sources and practicable means to reduce them. Therefore, this analysis presents the total GHG emissions potentially associated with the Preferred Alternative and identifies measures that would be implemented and measures that are still under consideration to limit emissions. In addition, the analysis provides a

⁵ *Radiative forcing* is a measure of the influence a gas has in altering the balance of incoming and outgoing energy in the earth-atmosphere system and is an index of the importance of the gas as a GHG.



qualitative assessment of the potential effect of the No Action Alternative with respect to GHG emissions.

FRA and NJ TRANSIT prepared the detailed analyses in this chapter using an anticipated construction schedule for the Preferred Alternative that was to begin in 2019. However, FRA, NJ TRANSIT, and the PANYNJ now anticipate that construction would begin later. Construction of the new Hudson River Tunnel could begin in 2022 and be complete in 2030; rehabilitation of the North River Tunnel could begin in 2030 and be complete in 2033, an overall delay of three years. As engine technology improves and fleets are gradually updated each year, emission factors associated with construction equipment and vehicles would decrease in later years. Therefore, the conclusions regarding GHG emissions in later years would be similar or lower than the conclusions of this analysis and the analysis is conservative (worst case).

This chapter estimates the GHGs emissions associated with the construction of the Preferred Alternative, including emissions associated with use of electricity, emissions from on-road and non-road vehicle use, emissions embedded in the materials used during construction, and effects of tree removal required for the Preferred Alternative. These emissions are estimated based on specific estimates of construction activity. A detailed description of construction activities is provided in Chapter 3, "Construction Methods and Activities."

Operationally, there would be no substantial change in GHG emissions associated with the Preferred Alternative since locomotive or on-road transportation would not be substantially affected by the Preferred Alternative; and changes in electricity use for systems (e.g., ventilation, lighting) would be relatively small given that the Preferred Alternative would not result in a change in rail operations from the No Action Alternative. Therefore, the change in GHG emissions is discussed qualitatively.

As discussed above, this analysis considers CO₂, which is the primary pollutant of concern from emission sources related to human activity, as well as N₂O, and methane. This analysis provides a sum of the various GHG emissions added together, presented as metric tons CO₂e emissions per year (see Section 14.2.1 above).

The chapter discusses potential measures to reduce GHG emissions, such as energy-efficient design and construction options, qualitatively. Where practicable, the chapter includes quantified estimates.

Note that since the concern for GHG analyses is related to total worldwide GHG emissions, and since most of the emissions are not local and cannot be easily tied to geographic regions (by state or on the Hudson River), this discussion presents total emissions rather than providing separate discussions of emission sources related to the Preferred Alternative in New Jersey and New York.

14.2.2.2 APPLICATION OF FTA PROGRAMMATIC ASSESSMENT FOR GHG EMISSIONS

FTA has published a guidance document for assessing GHG emissions from transit projects, *Greenhouse Gas Emissions from Transit Projects: Programmatic Assessment*, FTA Report No. 0097, January 2017. This guidance provides two levels of assessment. The first, a programmatic-level assessment, serves to identify whether a proposed transit project merits detailed analysis of its GHG emissions. It also a source of data for reference when detailed, project-level analysis is warranted.

The guidance document includes a GHG emissions Typology Matrix that will estimate partial lifecycle emissions for the construction, operations, and maintenance phases of projects, including bus rapid transit (BRT), streetcar, light rail, commuter rail, and heavy rail projects. The manual states that this matrix "offers practitioners a simplified resource for estimated GHG emissions

using limited Project information.” According to the manual, “In cases in which project characteristics and assumptions are similar to those analyzed here, transit agencies considering BRT, streetcar, light rail, commuter rail, and heavy rail projects may incorporate this programmatic assessment by reference into their NEPA [National Environmental Policy Act] analyses. It is recommended that light, commuter, and heavy rail projects that have characteristics that differ from the sample analyzed here use the Matrix or another locally-recommended approach to make project-specific GHG emissions estimates in their NEPA analyses.”

Given the complexity of construction activities for the Preferred Alternative, which include construction of new tracks on surface alignment and below-ground and rehabilitation of existing tracks, and the fact that once the Preferred Alternative is complete, rail operations would not change notably from existing conditions, FRA and NJ TRANSIT determined that using the programmatic approach presented in the FTA guidance manual would not be appropriate for the Preferred Alternative. Instead, they conducted a detailed, Project-level analysis for GHG emissions using the methodology described below.

14.2.2.3 GRID POWER EMISSIONS

The Preferred Alternative would use electric power from the region's electricity grid during construction to power tunnel boring machines, freeze and grout plants, and other activities at the tunnel construction and rehabilitation sites. FTA and NJ TRANSIT prepared estimates of electricity use required for the construction of the Preferred Alternative based on the detailed construction activity discussed in Chapter 3, “Construction Methods and Activities.” Electricity use was estimated at 160,139 megawatt hours (MWh)—125,408 MWh and 34,732 MWh for New Jersey and New York, respectively. This chapter estimates GHG emissions that would result from that use of electricity using emission factors referenced in the 2016 New York City⁶ GHG Emissions Inventory and appropriate factors from the latest New Jersey GHG Emissions Inventory for electricity sourced in New York and New Jersey, respectively. Operational grid power use and associated emissions are discussed qualitatively.

14.2.2.4 MOBILE SOURCE EMISSIONS

Construction activities for the Preferred Alternative would also result in energy demand and pollutant emissions related to new vehicle trips, such as truck trips for deliveries and worker trips to arrive at and depart from the construction site, as well as construction equipment at the construction sites that are powered by fuel rather than electricity. This chapter presents the results of GHG emissions estimates associated with those mobile sources.

FRA and NJ TRANSIT estimated the number of annual vehicle trips by mode (e.g., cars, trucks) that would result from construction activities for the Preferred Alternative. For this calculation, they used information on the likely construction means and methods that is described in Chapter 3, “Construction Methods and Activities,” and the information on construction-related vehicle trips that is presented in Chapter 5A, “Traffic and Pedestrians”. To determine the total miles of the new trips, they estimated travel distances based on information about materials sourcing and disposal, and average commuting distances for the area from the New York State Addendum to the 2009 National Household Travel Survey and/or other relevant data. They calculated on-road engine emission factors based on the U.S. Environmental Protection Agency's (EPA) Motor Vehicle Emission Simulator (MOVES) emissions model.

FRA and NJ TRANSIT calculated construction nonroad engine emissions (i.e., engines for construction equipment at the construction sites) based on the usage data developed for the air

⁶ The City of New York Mayor's Office of Long-Term Planning and Sustainability. *Inventory of New York City Greenhouse Gas Emissions in 2014*. April 2016.



quality analysis, applying the EPA NONROAD model to provide fuel consumption estimates, and fuel emission factors from EPA inventory methods.

Based on the latest fuel lifecycle model from Argonne National Laboratory,⁷ emissions from producing and delivering fuel (well-to-pump) add an estimated additional 25 percent to the GHG emissions from gasoline and 27 percent from diesel. The analysis in this chapter included total well-to-wheels emissions by applying emission factors and average fuel efficiency rates available from EPA and the Energy Information Administration (EIA) and/or other applicable sources.

14.2.2.5 CONSTRUCTION MATERIALS EMISSIONS

Processes and methods for manufacture and delivery of construction materials, such as steel, rebar, aluminum, and concrete, generate GHG emissions. This analysis considers those embedded GHGs for the construction materials for the Preferred Alternative. The analysis estimates the emissions embedded in the extraction or recycling, production, and transport of materials, including upstream emissions from steel, rebar, aluminum, and cement used for construction, based on quantity estimates for the Preferred Alternative and carbon intensity information for steel and cement from available lifecycle analyses and other information from EPA.

Construction activities for the Preferred Alternative would require an estimated total of 120,453 metric tons of cement. An emission factor of 0.928 metric tons of CO₂e per metric ton of cement produced was applied to estimate emissions associated with energy consumption and process (chemical) emissions for cement production.⁸ The origin of cement for the Preferred Alternative is unknown at this time; however, this analysis assumes an average GHG production rate considering that source and production methods vary widely.

Construction activities for the Preferred Alternative would require an estimated total of 67,452 metric tons of steel. An emission factor of 0.6 metric tons of CO₂e per metric ton of steel product produced was applied to estimate emissions associated with production energy consumption,⁹ and 0.65 metric tons of CO₂e per metric ton of steel product produced for process (chemical) emissions associated with iron and steel production were applied.¹⁰

14.2.2.6 TREE REMOVAL

CO₂ is removed (sequestered) from the lower atmosphere by natural processes such as photosynthesis. Therefore, tree removal can have an adverse effect with respect to GHGs. In general, the preservation of trees has a more significant impact on carbon sequestration in large forested areas, where forestation can be ongoing (trees die and new ones grow in their place) and where carbon can be transferred to soils, providing long-term carbon storage and increased density over time. Tree removal for the Preferred Alternative would be limited to a few trees that may be removed from the Twelfth Avenue median in Manhattan, trees on the periphery of the portal construction site near Tonnelle Avenue in North Bergen, and trees encroaching on the right-of-way along the Northeast Corridor's (NEC) surface tracks through the Meadowlands where construction would occur. Based on visual observations, fewer than 500 trees would be removed, mostly less than 12 inches in diameter (trees in the right-of-way are likely to be mostly of smaller size since large trees near the tracks are typically removed as a part of normal maintenance of

⁷ Argonne National Laboratory. *The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model Software*. GREET 1 Version 2016 Revision 1. January 26, 2017.

⁸ The Portland Cement Association. *Life Cycle Inventory of Portland Cement Manufacture*. 2006.

⁹ Arpad Horvath et al. *Pavement Life-cycle Assessment Tool for Environmental and Economic Effects, Consortium on Green Design and Manufacturing*. UC Berkeley. 2007.

¹⁰ Based on 42.3 teragrams of CO₂e emitted and 65,460 thousand tons produced; EPA, Inventory of U.S. Climate Change and Sinks: 1990–2009, April 15, 2011.

the right-of-way). Any trees removed in the median of Twelfth Avenue would be replaced. The removal of trees from the right-of-way would result in some GHG emissions and a reduction of future sequestration capacity.

Based on the above estimates of size and number, the currently sequestered carbon in the existing trees may be currently on the order of 100 metric tons CO₂, and over a 50-year period would represent up to approximately 5,000 metric tons CO₂.^{11,12,13} As the trees die and decompose, this sequestered carbon would largely return to the atmosphere. The temporary benefit of this storage would be lost due to the tree removal. Overall, this effect would be relatively small. Given the large uncertainty regarding the details of the trees to be removed and what would be done with the wood after removal, and since the overall effect is small, tree removal is addressed qualitatively.

14.2.3 AFFECTED ENVIRONMENT: EXISTING AND FUTURE CONDITIONS

The environment affected by GHG emissions includes the global atmospheric GHG concentrations and the long term effect they have on the earth's energy balance, the ensuing climatic conditions, and the resulting effect on many human and natural systems. Detailed information on this topic is not included in this EIS but is available in reference documents, such as the IPCC's latest synthesis report,¹⁴ the U.S. *Third National Climate Assessment*,¹⁵ and the most recent New York City Panel on Climate Change (NPCC) report, incorporated here by reference.¹⁶

14.2.4 IMPACTS OF NO ACTION ALTERNATIVE

Under the No Action Alternative, future GHG emissions would continue as projected. Emissions associated with the operation and maintenance of the existing North River Tunnel would continue similar to the existing condition, and may decrease over time as electricity generation becomes more efficient and incorporates higher levels of renewable generation. In general, transportation related emissions and emissions associated with buildings would continue to occur as projected in regional and nationwide inventories.

In addition, for purposes of analysis in this FEIS, FRA and NJ TRANSIT have assumed that with the No Action Alternative, the North River Tunnel will remain usable at least through the FEIS analysis year of 2033. As part of the ongoing maintenance in the tunnel, Amtrak will implement a North River Tunnel Interim Reliability Improvements Program, a program to advance critical repair work during short-term tunnel outages to improve reliability and safety in the North River Tunnel in the near term, before complete rehabilitation of the North River Tunnel would occur as proposed in the Hudson Tunnel Project (see Chapter 2, "Project Alternatives and Description of the

¹¹ Carbon sequestration was calculated using the allometric method to estimate Appalachian tree mass based on caliper, and assuming a carbon content of 45 percent on a mass basis, 200 trees removed, 9-inch diameter each, and a survival rate of 50 percent, and 10 percent growth per year.

¹² Martin, Kloeppel, Schaefer, Kimbler, and McNulty. *Aboveground biomass and nitrogen allocation of ten deciduous southern Appalachian tree species*. Canadian Journal of Forest Research 28: 1648-1659. 1998.

¹³ USDOE-EIA. Method for Calculating Carbon Sequestration by Trees in Urban and Suburban Settings. April 1998.

¹⁴ IPCC. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. 2014.

¹⁵ U.S. Global Change Research Program. *Third National Climate Assessment: Climate Change Impacts in the United States*. May 2014.

¹⁶ NPCC. New York City Panel on Climate Change 2019. Report. Ann. N.Y. Acad. Sci. 1439. 2019.



Preferred Alternative,” Section 2.4). Despite the ongoing maintenance that would continue in the No Action Alternative, damage to the North River Tunnel caused by Superstorm Sandy will continue to degrade systems in the tunnel. This deterioration combined with the North River Tunnel’s age and intensity of use will likely lead to increasing instability of rail operations in the tunnel, and may lead to its eventual closure. In such a scenario, while some trips may shift to ferry service during the increasingly frequent disruptions, there would likely be a notable shift of trip mode from rail to on-road (within the limits of the existing Hudson River crossings), resulting in additional increases in traffic volume and congestion at various locations and the ensuing net increases in operational GHG emissions. This condition would continue to occur intermittently as disruptions occur.

In the No Action Alternative, it is also possible that eventually the existing North River Tunnel may become unusable resulting in a full closure. In such a scenario, while some trips may shift to ferry service, there would likely be a large shift of trip mode from rail to on-road (within the limits of the existing Hudson River crossings), resulting in considerable increases in traffic volume and congestion at various locations and the ensuing net increases in operational GHG emissions. This condition would continue until another transportation option becomes available or indefinitely.

14.2.5 CONSTRUCTION IMPACTS OF THE PREFERRED ALTERNATIVE

14.2.5.1 GHG EMISSIONS FROM CONSTRUCTION

Over the approximately 11-year construction period, the construction activities for the Preferred Alternative would result in the emission of approximately 395,170 metric tons CO₂e. A summary of GHG emissions is presented in **Table 14-2**.

Table 14-2
GHG Emissions from Construction
(metric tons CO₂e)

Sector	New Hudson River Tunnel Construction	North River Tunnel Rehabilitation	Total
Non-road construction equipment	53,940	6,173	60,113
On-road vehicles	54,856	7,051	61,906
Electricity use	65,610	11,734	77,344
Construction materials:			
Cement	102,834	8,945	111,779
Steel	81,328	2,700	84,028
Total	358,568	36,602	395,170
Note: Totals may not add due to rounding.			

Approximately half of the construction GHG emissions would be associated with the extraction, production, and delivery of cement and steel. Note that while some additional emissions would be associated with various other materials not included in the analysis, these components are the largest contributors by far. Most of the electricity use would be associated with tunnel boring machines, which would be powered by electricity from the regional grid and delivered via substations at the construction staging sites, with some additional consumption for other electric equipment and lighting.

14.2.5.2 MEASURES TO AVOID, MINIMIZE, AND MITIGATE GHG EMISSIONS FROM CONSTRUCTION

The Project Sponsor will require that construction of the Preferred Alternative is in accordance with Project-specific sustainable design criteria based on best practices related to sustainability. These design criteria would contribute to reducing GHG emissions from construction. Contract documents will define and require specific measurable sustainable design performance targets to be implemented. The Project Sponsor will use the following measures to avoid, minimize, and mitigate GHG emissions in order to reduce GHG emissions associated with Project construction; the lead Federal agency will be responsible for ensuring that the Project Sponsor implements these measures, which will be identified in the ROD:

- **Use of Recycled Materials:** Contracts will include a performance target to use building materials with recycled content, including cement replacements (e.g., fly ash or ground granulated blast furnace slag), recycled steel, and other materials such as insulation or gypsum board where relevant.
 - *Recycled steel:* Most steel used in construction is recycled. The estimates of the Preferred Alternative's GHG emissions are based on a carbon intensity of steel for U.S.-average steel production and delivery, which includes recycled steel. Construction contracts would ensure the use of recycled steel by requiring a minimum fraction of recycled steel and other metals.
 - *Cement substitutes and optimization:* The use of cement substitutes, if practicable, can substantially reduce the emissions associated with the extraction, production, and delivery of cement. Contracts would require, to the extent practicable, the use of recycled post-industrial waste products such as slag, silica fume, or fly ash, which would reduce the carbon footprint of the replaced cement by 100 percent, and/or interground limestone, which reduces the carbon footprint associated with cement by 85 percent.¹⁷ These materials would be included at varying quantities depending on the cement performance requirements and would be specifically defined with performance targets for the various components. For the Preferred Alternative, the maximum use of replacements is generally estimated at a maximum of 33 percent of the cement content,¹⁸ equivalent to up to 36,887 metric tons CO₂e, but the amount of cement substitutes that would actually be used would likely be less than the amount estimated. In addition, since the carbon footprint of concrete depends on the cement content, optimizing concrete for the strength required (including safety factors) would be required to help avoid unnecessary waste.
- **Selecting local materials:** The use of local materials, where practicable, can substantially reduce emissions associated with materials transport. Contracts will include, as a performance target, that building materials be manufactured within 500 miles of the jobsite (which was assumed in the analyses above).
- **Construction nonroad engine emissions:** GHG emissions from diesel engines can be reduced by requiring the use of biodiesel blends of 20 percent (B20, which is a blend of 80 percent standard diesel and 20 percent biodiesel). B20 can be used as a "drop in" fuel for diesel engines with minimal management and preparation. If all diesel fuel used for nonroad construction engines were B20, emissions would be reduced by 15 percent, estimated at a reduction of approximately 9,000 metric tons CO₂e for the Preferred Alternative. The Project

¹⁷ Athena Institute. *Cement and Structural Concrete Products: Life Cycle Inventory Update #2*. Tables 4.2 and 4.8. 2005.

¹⁸ AASHTO. *Greenhouse Gas Mitigation Measures for Transportation Construction, Maintenance, and Operations Activities*. NCHRP Project 25-25 Task 58. August 2010.



Sponsor will evaluate the use of B20 for all or part of the diesel powered construction engines, as the design progresses, and require B20 use if found to be practicable.

14.2.6 PERMANENT IMPACTS OF THE PREFERRED ALTERNATIVE

14.2.6.1 OPERATIONAL GHG EMISSIONS

Once the Preferred Alternative is complete and both the new Hudson River Tunnel and the rehabilitated North River Tunnel are in service, operational GHG emissions would be related to transportation and to electricity used for the tunnel systems. Transportation-related emissions include electricity used to power the passenger trains (traction power) and on-road vehicle engine emissions that are reduced by the availability of passenger rail. The transportation-related emissions would not change substantially since the Preferred Alternative would not notably increase train trips and would not substantially change the track length or grade; therefore, the Preferred Alternative would not substantially alter traction power use or passenger mode split.

Tunnel system electricity use would be associated with the ventilation system and with lights, signals, security and safety systems, and other tunnel maintenance and operational systems in both tunnels.

For the rehabilitated North River Tunnel, some energy efficiency improvements would be introduced for the lighting systems, since the older systems would be replaced with light-emitting diode (LED) lighting, which is much more efficient (in both power consumption and durability, resulting in less maintenance and overall manufacturing emissions¹⁹), resulting in a decrease in associated GHG emissions.

For the new Hudson River Tunnel, ventilation, lighting, signals, safety and security systems, and other tunnel operation and maintenance system would be newly constructed, resulting in an increase in GHG emissions. These systems will be designed, constructed, and maintained to be energy efficient.

14.2.6.2 MEASURES TO AVOID, MINIMIZE, AND MITIGATE GHG EMISSIONS FROM OPERATIONS

The Project Sponsor will require that construction for the Preferred Alternative follow Project-specific sustainable design criteria, many of which would also contribute to reducing GHG emissions from operations. Contract documents will define and require specific measurable sustainable design performance targets to be implemented. The Project Sponsor will incorporate the following measures to avoid, minimize, and mitigate GHG emissions in order to reduce GHG emissions associated with operation of the new tunnel and the rehabilitated North River Tunnel; the lead Federal agency will be responsible for ensuring that the Project Sponsor implements these measures, which will be identified in the ROD:

- Contracts will require Energy Star labeled products and appliances (e.g., mechanical systems) where applicable, National Electrical Manufacturers Association (NEMA) premium efficiency motors for fans and pumps, and variable speed drives for fans, pumps, and motors;
- Contracts will require energy efficient lamps and fixtures for programmatic spaces, and LED lighting for all components where practicable;

¹⁹ Although LED lights are more energy-intensive to manufacture than incandescent and fluorescent lights, because of their long useful life, overall they are more efficient than these other two types of lights.

- The Project Sponsor, in cooperation with the other Project Partners, will design energy systems to be as efficient as practicable;
- The Project Sponsor will undertake energy commissioning for systems after installation to ensure they are properly installed and operated; and
- The Project Sponsor will optimize systems through the installation of a Building Management System (BMS) in the Project's fan plants that monitors all energy and water consumption.

14.3 RESILIENCE TO CLIMATE CHANGE

14.3.1 REGULATORY CONTEXT

In New York City, the Climate Change Adaptation Task Force is tasked with fostering collaboration and cooperation between public and private organizations working to build the resilience of the city's critical infrastructure against rising seas, higher temperatures, and changing precipitation patterns. The Task Force is composed of over 57 New York City and New York State agencies, public authorities, and companies that operate, regulate, or maintain critical infrastructure in New York City. Led by the Mayor's office of Resilience and Recovery, the Task Force works together to assess risks, prioritize strategies, and examine how standards and regulations may need to be adjusted in response to a changing climate.

To assist the Task Force, the New York City Panel on Climate Change (NPCC) prepared a set of climate change projections for the New York City region,²⁰ which was subsequently updated, and has suggested approaches to create an effective adaptation program for critical infrastructure. The NPCC includes leading climatologists, sea level rise specialists, adaptation experts, and engineers, as well as representatives from the insurance and legal sectors. The projections include a summary of previously published baseline and projected climate conditions throughout the 21st century including heat waves and cold events, intense precipitation and droughts, sea level rise, and coastal storm levels and frequency. These projections, applied by both New York State and New York City, along with the flood elevations provided in the preliminary flood insurance rate maps available from the Federal Emergency Management Agency (FEMA), are the most recent and relevant data for the study area and were used for the resilience analysis.

14.3.2 METHODOLOGY FOR EVALUATING RESILIENCE

During development of this EIS, the FRA and NJ TRANSIT developed methodologies for evaluating the potential effects of the Hudson Tunnel Project in coordination with the Project's Cooperating and Participating Agencies (i.e., agencies with a permitting or review role for the Project). The methodologies used for the analysis of resilience to climate change are summarized in this chapter.

This section of this chapter evaluates the Preferred Alternative's resilience with respect to severe storms, like Superstorm Sandy, which inundated the North River Tunnel and inflicted long-lasting damage. It considers the vulnerability to future storms and flooding of critical infrastructure included in the Preferred Alternative—including the new Hudson River Tunnel, its approach tracks, and its ancillary facilities; and the rehabilitated North River Tunnel. It also describes resiliency measures included in the Preferred Alternative to address those vulnerabilities.

This section also evaluates the Preferred Alternative's resilience with respect to potential changes in temperature and precipitation climate.

²⁰ NPCC. *Climate Change Adaptation in New York City: Building a Risk Management Response*. Annals of the New York Academy of Sciences, May 2010.



The analysis uses the NPCC's most recent analysis of potential future climate conditions in the Project area in considering what the future risks may be, and additional sources are cited as necessary. The NPCC's analysis includes projections for the 2020s, 2050s, 2080s, and the year 2100. The design lifetime of the Preferred Alternative would be 50 years for system components, and 100 years for the structures overall.²¹ Therefore, this analysis focusses on the 2080s and 2100 scenarios from NPCC.

14.3.3 AFFECTED ENVIRONMENT: EXISTING AND FUTURE CONDITIONS

This section describes the existing and potential future climatic conditions in the study area related to sea level rise and storm surge, temperature and precipitation, and the locations of elements of the Preferred Alternative that could be affected by changes to these climatic conditions. This section also describes other transportation-related resilience projects that are planned to be implemented in the area that would have an effect on the study area.

14.3.3.1 OVERVIEW

The best, most recent, and most complete analysis of potential future climate conditions in the study area are those available from the NPCC. The following summarizes the NPCC's findings that are most relevant to the Preferred Alternative.

14.3.3.1.1 Sea Level Rise and Storm Surge

The current NPCC report, which builds on a 2015 NPCC report,²² notes that sea level rise in New York City is expected to "exceed global mean values," but there is uncertainty regarding the probability of the projected levels and timescale. In addition, the severity of storms is also likely to increase. The current NPCC report relies on the assessment of storm-driven floods presented in the 2015 NPCC report. In the 2015 report, intense hurricanes are characterized as "more likely than not" to increase in intensity and/or frequency, and the likelihood of changes in other large storms (Nor'easters) are characterized as unknown. Therefore, the projections for future 1-percent probability coastal storm surge levels for the area include only sea level rise at the time of the 2015 NPCC report, and do not account for changes in storm frequency.

In its current report, NPCC analyzed a new upper-end, low-probability sea level rise scenario that addresses the possibility of Antarctic Ice Sheet destabilization. However, as emphasized in the current report, the sea level rise projections in the 2015 NPCC report "represent the current scientific foundation for New York City decision making and planning." In its 2015 report, NPCC analyzed three sea-level rise scenarios for each projection year: Low, Middle Range, and High. These scenarios were not updated in the current NPCC report. The Low scenario represents approximately a case in which sea level would continue to rise at the average rate it has been in recent decades. Most studies indicate that sea level rise is already accelerating, and the probability of this scenario is therefore unsuitable for most planning purposes. Note also that the High scenario, while representing the 90th percentile of current modeling, does not represent the potential worst-case scenario, and also does not yet include additional factors being studied which may lead to higher projections for the end of the century. The NPCC's sea level rise estimates ranging from the high end of the Middle Range scenario to the High scenario indicate the following:

²¹ Structures and buildings will be designed for continued operation over a minimum period of 50 years before complete refurbishment and renovations are necessary due to normal wear and tear and obsolescence, and the design life of the ventilation structures, tunnels, retaining walls, and marine structures will be 100 years.

²² NPCC. *New York City Panel on Climate Change 2015 Report*. Ann. N.Y. Acad. Sci. 1336. 2015.

- 2080s: 39 to 58 inches
- 2100: 50 to 75 inches

There are two approaches to predicting future coastal flooding, accounting for the potential impact of sea level rise on storm surge: a static approach that adds sea level rise onto current storm tide levels, and a dynamic approach using models that capture the roles of friction and wind as well as sea level rise and tides. NPCC has studied the potential impact of sea level rise on storm surge, including a study of the effect of dynamic modeling. NPCC concluded that both static and dynamic modeling approaches are valid and reliable approximations of coastal flooding for most locations in the New York metropolitan region. The assessment in this chapter uses the static approach.

Applying the static approach, potential future flood levels consist of the range of projected sea level rise from NPCC described above added to the Base Flood Elevation (BFE) for the specific area of concern. The BFE is defined as the currently projected 1-percent probability storm elevations available from the preliminary Flood Insurance Rate Map (FIRM)²³ and pending National Flood Hazard data dated August 28, 2019.²⁴ The 1-percent probability storm (sometimes referred to as the 100-year storm) is a storm that has a 1 percent chance of occurring in any given year. The area that would be flooded in a 100-year storm is mapped by FEMA on its FIRMs. FEMA's maps also indicate the BFE, which is the height of flooding that can be expected in the 1-percent probability storm within the floodplain. The BFE is measured not from ground or sea level, but from a benchmark called the North American Vertical Datum of 1988 (NAVD88) established by the National Oceanic and Atmospheric Administration, which holds fixed the height of the primary tidal benchmark because of variations in sea surface topography.

14.3.3.1.2 Temperature

The current NPCC report compares observed trends in temperature to projections from the 2015 NPCC report and “confirms the temperature and precipitation projections of [the 2015 report] as those of record for use in planning.” The 2015 NPCC report projected that annual average temperature is extremely likely to increase. An average increase of up to 12°F by the end of the century was projected (less in some scenarios). Heatwaves (events with a duration of three or more days with maximum temperatures exceeding 90°F) are very likely to increase in frequency, with up to nine events projected in the high estimate by the 2080s in an average year, up from two events per average year in the baseline, and a duration of up to eight days per event, up from two days in the baseline. The number of days per average year with a maximum temperature exceeding 90°F in that same timeframe could increase from 18 to 87.

14.3.3.1.3 Precipitation

The 2019 NPCC report compares observed trends in temperature to projections from the previous NPCC report, published in 2015. As noted above, the current NPCC report confirms that precipitation projections from the previous report are those currently used for planning in New York City. The 2015 NPCC report projected that annual average precipitation is likely to increase, with projections ranging up to 25 percent by the end of the century (less in some scenarios). The

²³ FEMA. *Flood Insurance Rate Map, Hudson County, New Jersey—Preliminary*. Panel 43 of 118. Map 34017C0043E. December 20, 2013;

FEMA. *Flood Insurance Rate Map, Hudson County, New Jersey—Preliminary*. Panel 44 of 118. Map 34017C0043E. January 30, 2015; and

FEMA. *Flood Insurance Rate Map, Bergen County, New Jersey—Preliminary*. New Jersey Meadowlands Commission, Panel 268 of 332. Map 34003C0268J. August 29, 2014.

²⁴ FEMA. 2021. Hudson Co., NJ Preliminary FIRM Data Viewer. <http://www.region2coastal.com/view-flood-maps-data/view-preliminary-flood-map-data/>.



number of downpours (intense precipitation events shorter than a day and often shorter than an hour) is “very likely” to increase. By the 2080s, downpours of 1 inch or more could increase from an annual average of 13 events in the baseline to 18 events, and downpours of 4 inches or more from an annual average of 0.3 to 0.7 events.

More recently, the Northeast Regional Climate Center (NRCC) has partnered with the New York State Energy Research and Development Authority (NYSERDA) to downscale global climate model output and create extreme precipitation projections for New York State and the surrounding area, including the downstate area and meteorological stations in northern New Jersey.²⁵ Detailed data for each station are also available online.²⁶ A summary of the projected increases in precipitation for nearby stations in New York and New Jersey for the return periods relevant to runoff and drainage design are presented in **Table 14-3**.

Table 14-3
Projected Precipitation Increases, High Scenario

Projection Period	Return Period: 100-Year (%)	Return Period: 25-Year (%)	Return Period: 10-Year (%)	Return Period: 5-Year (%)
<i>New York Central Park, NY</i>				
2050s	26	13	11	12
2080s	39	28	23	21
<i>Newark Airport, NJ</i>				
2050s	25	13	11	10
2080s	35	27	21	18
Note:	The return period represents a probability of occurrence, and not an actual period of expected occurrence. The “100-year” represents a storm with a probability of occurrence of 1 percent in any given year. Similarly, “25-year” represents a 4 percent probability and “10-year” represents a 10 percent probability in any given year.			
Source:	NRCC 2021.			

14.3.3.2 NEW JERSEY

Average temperature and precipitation changes for the region would not vary by location.

For the Preferred Alternative, the areas of concern for flooding in New Jersey are the areas of the Project site currently within the BFE, which include the new Hudson River Tunnel’s portal at Tonnelle Avenue, the ventilation shaft and fan plant site in Hoboken, and the existing North River Tunnel portal and Weehawken ventilation shaft. The new NEC approach tracks through the Meadowlands west of the freight railroad tracks and Tonnelle Avenue would be on a berm and viaduct well above the existing and projected flood elevations, and the existing tracks are similarly elevated on a berm. The elevation of the area east of the freight railroad tracks is lower, but still above the current BFE.

As discussed above in Section 14.3.3.1.1, potential future flood levels consist of the range of projected sea level rise from NPCC added to the BFE, which is currently 9 feet NAVD88 at the

²⁵ Arthur T. DeGaetano, Christopher M. Castellano. *Future projections of extreme precipitation intensity-duration-frequency curves for climate adaptation planning in New York State*. Climate Services, Volume 5. January 2017.

²⁶ NRCC/NYSERDA *Intensity Duration Frequency Curves for New York State: Future Projections for a Changing Climate*. <http://ny-idf-projections.nrc.cornell.edu>. Accessed March 2021.

portal sites, 11 feet NAVD88 at the new fan plant and ventilation shaft, and 13 feet NAVD88 at the existing North River Tunnel Weehawken ventilation shaft.

As shown in **Table 14-4**, the resulting range of potential future flood elevations, taking into account the current BFE and potential future sea level rise, is up to an elevation of 14 feet NAVD88 by the 2080s and up to 15 feet NAVD88 by 2100 at the portal sites, a range of up to 16 feet NAVD88 by the 2080s and up to 17 feet NAVD88 by 2100 at the Hoboken fan plant site, and a range of up to 18 feet NAVD88 by the 2080s and up to 19 feet NAVD88 by 2100 at the existing North River Tunnel Weehawken ventilation shaft.

Table 14-4
Projected Potential 1-Percent Annual Probability Flood Elevations
New Jersey Sites (feet NAVD88)

Site	Current Base Flood Elevation ¹	2020s (+8" to +10" over Current BFE) ²	2080s (+39" to +58" over Current BFE) ²	2100 (+50" to +75" over Current BFE) ²
New and Existing Portals (North Bergen)	9'	10'	12' to 14'	13' to 15'
North River Tunnel Weehawken Vent Shaft	13'	14'	16' to 18'	17' to 19'
New Hoboken Vent Shaft and Fan Plant	11'	12'	14' to 16'	15' to 17'
Note: Projections are based on NPCC future flood elevations, middle to high range (NPCC, 2015).				
Sources: ¹ FEMA, 2013; FEMA, 2014; FEMA, 2015.				
² NPCC, 2015.				

14.3.3.3 HUDSON RIVER

The Hudson River environment would be affected by the climatic changes described in Section 14.3.3.1, in the same ways as described in Section 14.3.3.2, above. Water elevations would increase by the above described sea level rise with absolute elevations varying by location, tide, and storm conditions.

14.3.3.4 NEW YORK

Average temperature and precipitation changes for the region would not vary by location.

For the Preferred Alternative, the areas of concern for flooding in Manhattan are the areas of the Project site within the current and future flood hazard area, which include:

- The site of the new Hudson River Tunnel east portal in New York and the existing North River Tunnel portal, which are both within the area of below-grade tracks west of Penn Station New York (PSNY) that was flooded during Superstorm Sandy;
- The existing North River Tunnel ventilation shaft near Eleventh Avenue, within that same below-grade track area;
- The proposed location for the Tenth Avenue fan plant (under the building located at 450 West 33rd Street, on the east side of Tenth Avenue between West 31st and West 33rd Streets); and
- The Twelfth Avenue fan plant and ventilation shaft site, which is east of Twelfth Avenue between West 29th and West 30th Streets.



Potential future flood levels at these locations consist of the range of projected sea level rise from NPCC added to the BFE. The current BFE available from the preliminary FIRM²⁷ is 12 feet NAVD88 by the Twelfth Avenue ventilation shaft and fan plant and 11 feet NAVD88 by the portals and the proposed location of the Tenth Avenue fan plant for the Hudson River Tunnel.

As shown in **Table 14-5**, the resulting range of potential future flood elevations taking into account the current BFE and potential future sea level rise is up to 17 feet NAVD88 by the 2080s and up to 18 feet NAVD88 by 2100 at the Twelfth Avenue fan plant site, and up to 16 feet NAVD88 by the 2080s and up to 17 feet NAVD88 by 2100 at the portal sites.

Table 14-5
Projected Potential 1-Percent Annual Probability Flood Elevations
New York Sites (feet NAVD88)

Site	Current Base Flood Elevation ¹	2020s (+8" to +10" over Current BFE) ²	2080s (+39" to +58" over Current BFE) ²	2100 (+50" to +75" over Current BFE) ²
Portals and Existing North River Tunnel Vent Shaft	11'	12'	14' to 16'	15' to 17'
Twelfth Avenue Vent Shaft and Fan Plant	12'	13'	15' to 17'	16' to 18'
Note: Projections are based on NPCC future flood elevations, middle to high range (NPCC, 2015).				
Sources: ¹ FEMA, 2013.				
² NPCC, 2015.				

14.3.3.5 OTHER ASSOCIATED TRANSPORTATION-RELATED RESILIENCE PROJECTS

By the 2033 analysis year for this EIS, two transportation-related resilience projects will provide added resilience against future flooding for transportation infrastructure in and near the Project site.

The Metropolitan Transportation Authority (MTA) Long Island Rail Road (LIRR) is currently planning a flood protection project, the West Side Yard Perimeter Protection Project, around the John D. Caemmerer West Side Yard, which also encompasses the North River Tunnel's existing vent shaft and portal. The West Side Yard Perimeter Protection Project will protect the West Side Yard and railroad infrastructure within the yard complex from flooding during storm events such as occurred during Superstorm Sandy. During Superstorm Sandy, flood waters entered the West Side Yard from the Hudson River; damaged critical infrastructure including trackbeds, switches, and signals; and entered the North River Tunnel's two tubes from their Manhattan portal at Tenth Avenue and the ventilation shaft at Eleventh Avenue. The West Side Yard Perimeter Protection Project will include drainage improvements, a new permanent wall, and additional deployable barriers to be implemented across driveways and access points in advance of storm events. The LIRR wall will surround the West Side Yard (along Twelfth and Tenth Avenues, West 33rd Street and approximately West 31st Streets) and be designed to a Design Flood Elevation (DFE) of 4 feet above the BFE, meaning that the new flood protection project will withstand floods that are four feet higher than the currently projected 1-percent probability storm elevations. This project will protect not only the West Side Yard, but also the other existing railroad infrastructure connected to the yard, including the portal and ventilation shaft for the North River Tunnel, the

²⁷ FEMA. *Flood Insurance Rate Map, New York County, New Jersey—Preliminary*. Panel 69 of 457. Map 3604970069G. December 5, 2013.

smaller rail storage yards east of Tenth Avenue, and the tracks and platforms at PSNY. The West Side Yard Perimeter Protection Project is being funded by the Federal Transit Administration through a Sandy resiliency grant.

The Weehawken ventilation shaft leading to the North River Tunnel was not flooded during Superstorm Sandy; the shaft is in the current 0.2-percent probability flood area, and may be in the potential future 1-percent probability flood area by the 2020s or 2030s. To protect the Weehawken ventilation shaft and the North River Tunnel against future flooding during a severe storm, Amtrak is planning to implement a standalone project or install deployable flood barriers at the ventilation shaft. Amtrak will undertake this floodproofing project separately from the Preferred Alternative as part of Amtrak's regular capital maintenance program. Amtrak will complete the Weehawken shaft floodproofing project no later than the completion of the North River Tunnel rehabilitation. Amtrak's standalone Weehawken shaft floodproofing project will be designed to a DFE of 5 feet above BFE.

14.3.4 IMPACTS OF NO ACTION ALTERNATIVE

For purposes of analysis in this FEIS, FRA and NJ TRANSIT have assumed that with the No Action Alternative, the existing North River Tunnel would continue to operate in its current condition at least through the FEIS analysis year of 2033. The flood protection projects discussed above in Section 14.3.3 will serve to provide some protection to the North River Tunnel from flooding and inundation, addressing some of the risk of flooding from storms like Superstorm Sandy and the increasing risk of flooding during weaker and more frequent storms (storms of higher probability). However, without rehabilitation of the North River Tunnel, the existing tunnel components would remain compromised by damage incurred during Superstorm Sandy and would be at risk of further damage from salt water incursion into the ballast and electronics, cables, and other infrastructure in the bench wall and on the tunnel walls should seawater intrusion occur again. With only a single passenger rail crossing of the Hudson River for the NEC, the No Action Alternative also would not provide redundancy to allow for continued railroad operations if operations in the existing North River Tunnel are compromised or impaired for any reason, such as flooding.

14.3.5 CONSTRUCTION IMPACTS OF THE PREFERRED ALTERNATIVE

14.3.5.1 OVERVIEW

During construction, the existing North River Tunnel and the new Hudson River Tunnel would continue to be at risk of severe storm flooding at the current levels. As part of the design of the Preferred Alternative, the Project Sponsor, in cooperation with the other Project Partners, will develop a storm risk management plan. The plan will identify the potential risks during each construction period and location. The plan will list the means that will be in place at the various sites and during all construction phases to prepare for severe storms and potential flooding to reduce the risk of damage to the facilities. The plan will also identify the procedures for determining when storm preparations should begin and the entities responsible for implementing storm preparations in advance of a potential severe storm. At a minimum, the plan will prepare for potential storms that include hurricane force winds and flooding up to the levels identified below. The Project Sponsor will include these requirements in the contract documents, and the Project contractor will be responsible for implementing the storm risk management plan. The lead Federal agency will be responsible for ensuring that the Project Sponsor implements these measures, which will be identified in the ROD.

Changes in temperature and precipitation climate in the short term, throughout the construction period, would be very small and would have no measurable impact on construction operations.



14.3.5.2 NEW JERSEY

As described above, in New Jersey, the existing and new tunnel portals and approaching rail tracks would be near a current flood hazard area, with a potential 1-percent probability flood elevation of 9 feet NAVD88. Both the existing and the new portal sites are above the flood elevation and not in the current flood hazard zone—the flood hazard zone would not change substantially within a few years due to sea level rise throughout the construction period. The existing track bed itself is on an embankment above the flood elevation, such that while the surrounding area is within the flood hazard area, the right-of-way itself is not. The area in which the new rail track leading to the new portal would be constructed is in the flood hazard area, and would be lower than the current flood elevation until the track bed along the surface alignment, including the new retained fill, bridge, and viaduct segments are built up above flood elevations.

The Hoboken fan plant site (which would be an open shaft for much of the construction period), is located within the current flood hazard area, with a potential 1-percent probability flood elevation of 11 feet NAVD88. As part of the early construction activity, walls will be built up around the perimeter of the shaft to protect the shaft from potential flood waters up to the potential flooding levels identified. The existing North River Tunnel Weehawken ventilation shaft is not in the current 1-percent annual probability flood hazard area, but is within the 0.2-percent (500-year) flood hazard area.

14.3.5.3 HUDSON RIVER

As described in Chapter 3, “Construction Methods and Activities,” Section 3.3.5, construction work to improve soil conditions at the river bottom would occur in the Hudson River. This work would be conducted within a cofferdam within the river, within which ground improvement would occur. The in-water construction work zone, including the cofferdam and barges moored within or around the cofferdam could be subject to damage from severe storms. If a severe storm (i.e., hurricane) were approaching, barges moored on the exterior of the cofferdam would be relocated to a safer location to minimize damage to the barges and associated damage to the cofferdam.

14.3.5.4 NEW YORK

As described above, in New York, the existing North River Tunnel portal at Tenth Avenue, the existing North River Tunnel ventilation shaft at Eleventh Avenue, and the proposed locations of the new tunnel portal and the Tenth Avenue fan plant are located within the current flood hazard area, with a potential 1-percent probability flood elevation of 11 feet NAVD88. If the West Side Yard Perimeter Protection Project is not complete when rehabilitation of the North River Tunnel begins, these sites would remain vulnerable during the tunnel rehabilitation.

The Twelfth Avenue ventilation shaft and fan plant site (which would be an open shaft for much of the construction period) is located within the current flood hazard area, with a potential 1-percent probability flood elevation of 12 feet NAVD88. As part of the early construction activity for the Preferred Alternative, walls would be built up around the perimeter of the shaft to protect the shaft from potential flood waters up to the potential flooding levels identified.

14.3.5.5 MEASURES TO AVOID, MINIMIZE, AND MITIGATE EFFECT OF CLIMATE CHANGE DURING CONSTRUCTION

To prepare for potential storms and related flooding at the construction sites, the Project Sponsor will prepare a storm risk management plan prior to construction. The plan will identify the potential risks during each construction period and location. The plan will list the means that will be in place at the various sites and during all construction phases to prepare for severe storms and potential flooding so as to reduce the risk of damage to the facilities. The plan will also identify the procedures for determining when storm preparations should begin and the entities responsible for

implementing storm preparations in advance of a potential severe storm. At a minimum, the plan will prepare for potential storms that would include hurricane force winds (including nor'easters and Category 1 hurricanes or stronger, with exact specifications to be developed by the Project Sponsor during final design) and flooding up to the current levels identified below in Section 14.3.6. The Project Sponsor will include these requirements in the contract documents, and the Project contractor will be responsible for implementing the storm risk management plan. The lead Federal agency will be responsible for ensuring that the Project Sponsor implements these measures, which will be identified in the ROD.

In addition, as part of the early construction activity, walls will be built up around the perimeter of the shaft to protect the shaft from potential flood waters up to the potential flooding levels identified.

14.3.6 PERMANENT IMPACTS OF THE PREFERRED ALTERNATIVE

14.3.6.1 OVERVIEW

The Preferred Alternative would introduce infrastructure with a design lifespan of approximately 100 years and would represent critical transit infrastructure in the region. Structures and buildings will be designed for continued operation over a minimum period of 50 years before complete refurbishment and renovations are necessary due to normal wear and tear and obsolescence, and the design life of the ventilation structures, tunnels, retaining walls, and marine structures will be 100 years. In addition, the Project would include measures to harden the existing North River Tunnel that would allow for faster recovery in the event of tunnel flooding, avoiding the type of damage that resulted from Superstorm Sandy. These measures would complement the other resiliency projects planned in the study area, described above in Section 14.3.3.5, including the West Side Yard Perimeter Protection Project and the Weehawken shaft floodproofing project.

Given the critical importance of the new tunnel and the vulnerability exhibited by the North River Tunnel during Superstorm Sandy, all Project features will be designed using a DFE that is 5 feet higher than FEMA's BFE. The use of this DFE for the Preferred Alternative would address the risk predicted by the future climate scenarios developed by the NPCC, including the projected potential 1-percent annual probability flood elevations shown in **Tables 14-4 and 14-5** above. Project elements would either be higher than the DFE or designed to be watertight and/or resistant to flooding. However, the DFE would not protect the Preferred Alternative against the longer term, "High" projections. To address this risk, when Project elements can be designed without substantial financial implications to a more conservative standard than the DFE, they will be.

The Project's DFE at each Project site location where it applies (i.e., at each location within the current BFE) is shown in **Table 14-6** below.

In addition to the design for resilience, described below, the Preferred Alternative in general is designed to provide resilience in the form of redundancy by providing both the rehabilitated North River Tunnel and the new Hudson River Tunnel as resilient options for use once all construction and rehabilitation are completed.

**Table 14-6
DFE for the Preferred Alternative (feet NAVD88)**

Site	Current BFE	Project DFE
NJ: New and Existing Portals	9'	14'
NJ: North River Tunnel Weehawken Vent Shaft	13'	18'
NJ: Hoboken Vent Shaft and Fan Plant	11'	16'
NY: Portals, Tenth Avenue Fan Plant, and Existing North River Tunnel Vent Shaft	11'	16'
NY: Twelfth Avenue Vent Shaft and Fan Plant	12'	17'



14.3.6.1.1 Coastal Flooding

Since the Preferred Alternative would not introduce any substantial changes in a coastal area such that it could affect wave impacts or otherwise affect flooding of other areas and uses, the Preferred Alternative would otherwise not affect or be affected by flooding.

The DFE for the Preferred Alternative is 5 feet higher than the current BFE at any given location. Since designs for storm surge would normally include 1 foot of “freeboard” to cover uncertainty in the data and rounding, additional protection may be needed at a point when sea level has risen by 4 feet—which is not predicted to occur until the 2070s at the earliest by the NPCC, in its High scenario. As detailed above in Section 14.3.3.5, some areas of the Project site would be protected by the future projects that will be undertaken separately from the Preferred Alternative by MTA and Amtrak. The West Side Yard Perimeter Protection Project will address flooding up to levels of 4 feet higher than the current BFE. Therefore, these elements may need to be reevaluated and upgraded earlier, with potential flooding elevations projected to reach that level by the late 2050s at the earliest.

The DFE for the Preferred Alternative was developed to address the potential risk associated with future flood levels, accounting for sea level rise. The design standard for the Preferred Alternative is to meet the DFE, and when Project elements can be designed without substantial financial implications to a more conservative standard, they will be; otherwise, they will be designed so that additional protection can be included at a later date if storm levels in the future make that appropriate.

The new Hudson River Tunnel would include floodgates on each side of the river tunnel, to protect both the tunnel and landside areas (e.g., PSNY) from future flooding such as occurred during Superstorm Sandy. Such floodgates could be deployed in advance of anticipated flooding so they would completely seal off the tunnel, preventing water from passing through. In New Jersey, a floodgate would be located in the tunnel at the ventilation shaft in Hoboken. In New York, floodgates would be located in the tunnel at the ventilation shaft at Twelfth Avenue and at the new tunnel’s eastern portal at Tenth Avenue. Figure 2-5 and Figure 2-6 in Chapter 2, “Project Alternatives and Description of the Preferred Alternative,” show the location of the floodgates.

The Hoboken and Twelfth Avenue ventilation shafts and associated fan plants for the new Hudson River Tunnel would be located within the 100-year floodplain and below the Project’s DFE. Therefore, all entrances and openings would be raised above the DFE or any entrances below the DFE would be watertight. The shafts would include hardening to protect against water incursion and any equipment within the shafts or fan plants would be above the DFE or flood-resistant.

The New Jersey portal for the new Hudson River Tunnel at Tonnelle Avenue would be slightly below the DFE, but the adjacent approach tracks and surrounding areas would be above the DFE. For example, the design for the Preferred Alternative through the Meadowlands calls for the surface alignment to be on a berm or viaduct that is at least 10 feet above the BFE. Since the tracks of the new alignment on the new berm and viaduct would be above the DFE, they would be constructed at elevations consistent with (and exceeding) the DFE. Soil berms and other design features would be included in the Project at this location to prevent floodwater from entering the tunnel.

Other aspects of the new Hudson River Tunnel’s design also incorporate resiliency and flood protection measures. Such measures would include the use of ballastless (direct fixation) track, which is more resistant to salt water incursion than ballasted track, and the use of concrete for the liner and bench walls that would withstand salt water.

In addition, the Project Sponsor would harden the drainage system in the North River Tunnel to continue operating during a flooded condition. Amtrak has already hardened the pumping systems such that they would continue to operate in the event of tunnel flooding. In addition, as part of the rehabilitation with the Preferred Alternative, the Project Sponsor would relocate electronic control systems out of the tunnel to locations that are protected from flooding, and install electronics and cables within the tunnel that are more flood-resilient. In addition, the rehabilitated tunnel would have ballastless (i.e., direct fixation) track, which is more resistant to salt water incursion than ballasted track. These measures would allow for faster recovery in the event of tunnel flooding, avoiding the type of damage that resulted from Superstorm Sandy. In addition, as discussed above in Section 14.3.3.5, Amtrak is planning to implement a standalone project or install deployable flood barriers to protect the Weehawken ventilation shaft of the North River Tunnel from future flooding. Amtrak will undertake this floodproofing project separately from the Preferred Alternative as part of Amtrak's regular capital maintenance program. Amtrak plans to complete the Weehawken shaft floodproofing project no later than the completion of the North River Tunnel rehabilitation. Amtrak's standalone Weehawken shaft floodproofing project will be designed to a DFE of 5 feet above BFE.

14.3.6.1.2 Temperature

As described in Section 14.3.3.1.2, average annual temperature will continue to increase over time, and heatwaves (events with a duration of three or more days with maximum temperatures exceeding 90°F) may quadruple in frequency, and double in duration (more heatwave events per year and longer events). The effect of high temperature on the Preferred Alternative would include increased energy use for tunnel ventilation and train air conditioning, but since the design for these needs is conservative, no special consideration needs to be given to capacities of those systems.

High temperatures have also been known to affect the function of catenary power, when sagging occurs, and affect railway tracks if buckling (rail deformation) occurs. The Preferred Alternative would include auto-tensioned catenary designed to ensure that overhead electrical contact systems do not sag during heatwaves, with a design temperature range of -10°F to 120°F. In general, track buckling occurs predominately on continuously welded rail, though it also can occur on older jointed track when the ends of the track become frozen in place.²⁸ Track buckling is most prevalent on an isolated hot day in the springtime or early summer, rather than mid to late summer when temperatures are more uniformly hot. Buckling also is more likely to occur in alternating sun/shade regions and in curves. Track design generally accounts for track buckling via design criteria—for the Preferred Alternative, design criteria address a range of zero to 120°F. The design criteria generally prevent buckling even at rail temperatures of up to 150°F.²⁹ The design would also accommodate changes in length of segments due to thermal movement, such as would occur during a heatwave. Since the track is more stable when the rail is in tension at temperatures below the neutral temperature, the target neutral temperature is generally 75 percent of the expected maximum temperature of the region. An increase in temperature may slightly raise the neutral temperature used for installation, but is unlikely to necessitate track design changes.

Preventive measures to reduce rail buckling derailment risk include:

- Improving weather forecast and predictive capacity for rail track temperature;

²⁸ European Commission. *Impacts of Climate Change on Transport: A Focus on Road and Rail Transport Infrastructures*. Available: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC108865/jrc108865_final.pdf. 2012.

²⁹ FHWA. *U.S. Climate Change Science Program Synthesis and Assessment Product 4.7: Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I*. March 2008.

- Using track materials that can withstand projected temperatures (such as concrete ties, continuous welded rail, and rail fasteners); and
- Applying speed limit restrictions during periods of high temperatures.

Overall, appropriate design, maintenance, and operational procedures for track buckling in the current condition would also address the future condition when heatwaves may be more frequent or intense.

14.3.6.1.3 Precipitation

As described in Section 14.3.3.1.3, NPCC projected that annual average precipitation is likely to increase and the number of downpours (intense precipitation events shorter than a day and often shorter than 1 hour) is “very likely” to increase. Shorter term downpour intensity is also projected to increase. In addition to coastal flood conditions discussed above, stormwater facilities would be designed to accommodate runoff based on short-term precipitation events, including 10- or 20-percent annual probability (“10-year” and “5-year”) events for New York City and New Jersey/New York State roadway and parking lot storm systems, respectively, 4-percent annual probability (“25-year”) events for track roadbed and for drains at low points that could flood roadways or track roadbed, and 1-percent annual probability (“100-year”) events for enclosed structures that could flood roadways or track roadbed. The projected increase in short-term precipitation intensity, presented in **Table 14-3** above, would be accounted for where relevant and practicable for drainage and runoff design purposes.

14.3.6.2 NEW JERSEY

As described above in Section 14.3.6.1, the DFE for the Preferred Alternative would be 5 feet above the current preliminary BFE, with some design elements exceeding these levels where practicable. The DFE in the area of the New Jersey portals and approach tracks would be 14 feet NAVD88. The existing NEC trackbed leading to the existing portal is surrounded by the current and future flood hazard area, but the trackbed elevates the tracks above the DFE. The new approach tracks to the new Hudson River Tunnel would be on a viaduct above the DFE.

The new portal to the Hudson River Tunnel at Tonnelle Avenue would be slightly below the DFE, which is approximately elevation 14 feet NAVD88 at that location. The adjacent track viaduct and embankment would be constructed to a higher elevation of more than 20 feet NAVD88. To avoid flooding at the portal, which could lead to water infiltration at the portal, the soil would be bermed and, if necessary following further evaluation during design, a below-grade cut-off wall may be installed.

The DFE at the new Hoboken ventilation shaft and fan plant would be 16 feet NAVD88, and the new fan plant would be designed so as to withstand flooding up to this elevation at a minimum. The site is lower than this elevation, so the fan plant entrances and all openings would be raised above this elevation to protect against inundation or any entrances below the DFE would be watertight. The shaft would include hardening to protect against water incursion and any equipment within the shaft and fan plant would be above the DFE or flood-resistant.

For the North River Tunnel, as discussed above in Section 14.3.3.5, Amtrak is planning to implement a standalone project or install deployable flood barriers at the Weehawken ventilation shaft.

Regarding temperature changes, as described above, all new rails outside of the tunnel structure would be designed to withstand a wide range of temperature and temperature changes which would include potential future increase in heatwave duration and severity.

14.3.6.3 HUDSON RIVER

Within the Hudson River, both the new Hudson River Tunnel and the rehabilitated North River Tunnel would be entirely below the river bottom and therefore there would be no concern related to storm damage or flooding within the river itself.

There are no special design considerations related to temperature or precipitation within the tunnel or effects of the Preferred Alternative on the surrounding environment in the Hudson River area.

14.3.6.4 NEW YORK

As described above, the DFE would be 5 feet above the current BFE, with some design elements exceeding these levels where practicable. The DFE in the area of the new Twelfth Avenue ventilation shaft and fan plant would be 17 feet NAVD88, and the Twelfth Avenue ventilation shaft and fan plant would be designed to withstand flooding up to this elevation at a minimum. In addition, as described above, the new Hudson River Tunnel would be protected by flood gates at the Twelfth Avenue ventilation shaft and the Tenth Avenue portal.

The West Side Yard Perimeter Protection Project described above in Section 14.3.3.5 would protect both tunnels' portals, the Tenth Avenue fan plant, and the North River Tunnel's ventilation shaft at Eleventh Avenue from future flooding at a DFE of four feet above the current BFE.

Regarding temperature changes, in the New York area there would be no new rail outside of the covered structure and, therefore, issues such as rail buckling are not relevant.

14.3.6.5 MEASURES TO AVOID, MINIMIZE, AND MITIGATE IMPACTS FOR RESILIENCE OF OPERATIONS

The Preferred Alternative in general is designed to provide resilience in the form of redundancy by providing both the rehabilitated North River Tunnel and the new Hudson River Tunnel as resilient options for use once all construction and rehabilitation are completed. In addition, the Project Sponsor will require that the design of the Preferred Alternative incorporates resilience measures developed to avoid, minimize, and mitigate the potential risks of severe storms and flooding in the future, including the following; the lead Federal agency will be responsible for ensuring that the Project Sponsor implements these measures, which will be identified in the ROD:

- DFE for all components will be 5 feet higher than the current BFE at any given location. BFE will be based on the latest and best data available from FEMA when the final design is complete.
- When Project elements can be designed without substantial financial implications to an even higher standard, they will be.
- The track bed supporting new track in the floodplain will be designed to resist flooding, so as to reduce the potential for flood damage.
- The new Hudson River Tunnel will include floodgates within the tunnel on each side of the river to protect both the tunnel and landside areas (e.g., PSNY) from future flooding events. These floodgates could be deployed in advance of anticipated flooding so they would completely seal off the tunnel, preventing water from passing through. However, if grading can be accomplished on the New Jersey site of the new tunnel portal and Hoboken shaft site, the need for a floodgate would be eliminated as the ground would be above the DFE.
- All entrances and openings to the Hoboken and Twelfth Avenue ventilation shafts and associated fan plants for the new Hudson River Tunnel will be raised above the DFE or any entrances below the DFE would be watertight.



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- The Hoboken and Twelfth Avenue ventilation shafts will include hardening to protect against water incursion and any equipment within the shafts or fan plants would be above the DFE or flood-resistant.
 - To avoid flooding at the new Hudson River tunnel portal in New Jersey, the Project will include soil berms and other design features to prevent floodwater from entering the tunnel. If necessary following further evaluation during design, a below-grade cut-off wall may be installed at the portal.
 - The new Hudson River Tunnel's design will incorporate resiliency and flood protection measures, including the use of materials within the tunnel that will withstand salt water.
 - All new rails outside of the new Hudson Tunnel structure will be designed to withstand a wide range of temperature and temperature changes which would include potential future increase in heatwave duration and severity, to avoid track buckling (rail deformation). *