MID-STATES CORRIDOR

APPENDIX RR: GREENHOUSE GAS ANALYSIS

Mid-States Corridor
Tier 1 Environmental Impact Statement

Prepared for

Indiana Department of Transportation

Mid-States Corridor Regional Development Authority

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1. INTRODUCTION

This analysis addresses *National Environmental Policy Act Guidance on Consideration of Greenhouse Gas Emissions and Climate Change – Notice of Interim Guidance* (Guidance), published in the January 9, 2023 *Federal Register*. This interim guidance requested comments by March 10, 2023. This interim guidance is effective as of the date of its publication. This guidance was provided to assist Federal agencies in considering the effect of Greenhouse Gas (GHG) emissions and climate change on proposed federal actions being considered under the National Environmental Policy Act (NEPA).

This analysis addresses this guidance in a manner appropriate for a Tier 1 NEPA study. As described in the following sections, some of the tools referenced in the Guidance are more appropriate for a typical NEPA study, which analyzes information at a more detailed level. Project staff contacted the Council on Environmental Quality and the Department of Energy by email on April 21, 2023 to enquire about specific applications of the Guidance. This email is included in pages A3-A4 of the Appendix to this document. As of May 31, 2023, no further information was provided in response to this request.

This document describes the various factors influencing net GHG emissions annually and the resiliency of the project to increased effects of climate change. The analysis determined that the most significant activities generating GHG were construction activities and effects on carbon sequestration due to clearing of forests for the project as well as planting of new forests for mitigation. Changes in GHG due to changes in motor vehicle operations were a minor factor compared to these other sources. As noted later in the discussion under "Emissions by Vehicle Type," electrical vehicles (EVs) are estimated to result in a 27 percent reduction in GHG emissions per vehicle mile (VMT).

At the conclusion of the analysis, the discounted costs of GHG emissions are provided for each alternative.

2. NET EMISSIONS AND COSTS

Analysis Framework

The factors influencing net GHG emissions of the Mid-States project are given following sections:

- Carbon emissions due to construction activities.
- Loss of carbon sequestration due to tree clearing during construction activities.
- Added carbon sequestration due to planting of new forest acreage as mitigation.
- Changes in vehicle emissions due to the project. This analysis also considers the effects of changes in fleet mix over time, as well as the emissions characteristics of different vehicle types.

The following sections describe the analytical framework used to consider varying activities which occur at different times over the analysis period.

This analysis reviewed several resources available at the U.S. Department of Energy's *GHG Tools and Resources* (https://ceq.doe.gov/guidance/ghg-tools-and-resources.html). Those used for this analysis are individually cited in the References section at the end of this document.

The activities enumerated in the bulleted text above occur at different points in time. Their relevant emissions were calculated for each year when they occur. Evaluating these emissions requires a robust tool which can provide emissions costs on a year-by-year basis. Some tools which were cited in the Guidance and other literature provide costs only for specific emissions years. In addition, this information provides discounted costs without providing the underlying emissions costs in nominal (current year terms).[1] Use of these sources to compare the effects of emissions from a variety of sources would require significant interpolation and analytical assumptions.

The Indiana Department of Transportation referred project staff to the US Department of Transportation publication *Benefit-Cost Analysis Guidance for Discretionary Grant Programs, January 2023*.[2] Table A-6 in this document provides year-by-year damage costs for emissions per metric ton for GHG emissions for each year from 2022 to 2050. This table is provided on pages A1-A2 of the Appendix to this document. This table cites sources from which these costs were derived. These values were used to calculate the costs of emissions in the year in which they occurred. The analysis tool described in the following paragraph can calculate discounted costs to the base year for any discount rate.

An Excel workbook was designed to separately calculate the GHG emissions attributable to each project activity. These workbook components are described in the following sections. A summary worksheet added all emissions from various activities in each year they occurred. The discounted cost of these emissions was determined by applying both the discount factor appropriate for each year and the GHG cost identified for that year in the USDOT publication. Summary worksheets are provided on pages A5-A5 of the Appendix to this document.

To provide a reasonable basis for comparing the GHG impacts of alternatives while maintaining a reasonable level of analytical effort, all alternatives were compared for the expressway facility type. This facility type provides a "worst-case" level of GHG impacts. The two exceptions are for **RPA2** and **Alternative R**. Both of these have only a Super-2 facility type, which was used in the comparative calculations.

The workbook also includes a worksheet with key assumptions, which allows quick recalculations to consider changes in assumptions. These assumptions and their values used in this analysis are as follows. The rationales for these assumptions are provided in the following sections.

- Ratio of annual Vehicle Miles Traveled (VMT)/vehicle for electric and gasoline-powered vehicles. Annual VMT for Electric Vehicles (EVs) is assumed to be 76 percent of the annual VMT for internal combustion engine (ICE) vehicles.
- Ratio of GHG emissions per VMT for electric and gasoline-powered vehicles. For Indiana, EVs are specified to produce 73 percent of the emissions per VMT of ICEs.
- Discount rate. The analysis applied discount rates of 2.5 percent and three percent. The USDOT guidance (p. 50) specifies a three percent discount rate for emissions analysis, while recommending a seven percent discount rate for all other costs and benefits.

[1] For example, the 2021 *Interagency Working Group on Social Costs of Greenhouse Gases* provides discounted costs for three discount rates at five-year intervals (see **Table ES-1**). The US Environmental Protection Agency's *External Review Draft of Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances* provides discounted cost for three discount rates at 10-year intervals (see listing of tables on p. iii of Table of Contents).

[2] https://www.transportation.gov/sites/dot.gov/files/2023-01/Benefit%20Cost%20Analysis%20Guidance%202023%20Update.pdf

- Beginning year of analysis. The base year to which all costs are discounted. For this analysis, the base year is 2023.

The analysis determined that nearly all GHG emissions due to the project were attributable to construction activities and land clearing. The impacts of changes in GHG emissions due to changes in VMT were miniscule. For example, for the DEIS Preferred Alternative P, the following undiscounted emissions in all years were attributable to the expressway facility type.

- Construction activities – 98,100 metric tons (tonnes) of CO_2
- Tree clearing and loss of carbon sequestration – 17,200 tonnes of CO_2
- Increases in VMT for the build alternative – 149 tonnes of CO_2.

The available tools for construction activities and carbon sequestration measured impacts only for CO_2, and did not account for other GHG. Given their predominance in the impacts of each alternative, the analysis of GHG impacts due to VMT changes also were confined to CO_2 only.

The analysis period begins in the year 2027, when initial land clearing for construction activities is assumed to begin. It continues to the year 2050. The following sections describe the time frame for each project-related activity.

Throughout this analysis, the abbreviations ICE and EV are used to refer to vehicles powered by internal combustion engines and electrical power plants, respectively.

Construction Activity

Greenhouse gas emissions have been tabulated utilizing the Michigan Technological University Project Emissions Estimator (PE-2)[3]. All greenhouse gas emissions have been quantified in metric tons. A summary of greenhouse gas emissions for each alternative can be found below in **Table 1** at the end of this section.

For each alternative analyzed as part of this EIS, the quantity computations from FEIS Appendix E were utilized to quantify individual item greenhouse gas emissions. These items were then summarized to find the total alternative greenhouse gas emissions.

Construction Items Quantified

To achieve consistency among all alternatives, the quantities that had a comparable item on the PE-2 Build Materials List were utilized. A list of items as well as their PE-2 comparison material is listed below.

- Common Excavation – 902 Sound Earth
- Rock Excavation – 902 Sound Earth
- Borrow - 902 Sound Earth
- Embankment Foundation Soils Treatment – 902 Aggregate Coarse CS-2
- Subgrade Treatment, Type IB – 902 Aggregate 21AA
- QC/QA Surface, 9.5mm – 924 HMA

[3] https://www.construction.mtu.edu/cass_reports/webpage/

- QC/QA, Intermediate, 19.0mm – 924 HMA
- QC/QA, Base, 25.0mm – 924 HMA
- Compacted Aggregate, No. 53 – 902 Aggregate 21AA
- Revetment Riprap – 916 Riprap Plain
- Geotextiles for Riprap – 916 Fabric
- Underdrain, 4" – 909 Pipe Perforated Underdrain
- Aggregate for Underdrain – 902 Aggregate 6A
- Geotextiles for Underdrain - 910 Geotextile Blanket
- Pavement Markings – 920 Pavement Mark Type R 4 in. White
- Fence, Right-of-Way – Fence Chain Link
- Culvert, Circular – Pipe RCP, 24 in.
- Culvert, 4-sided Box – Pipe RCP, 72 in.
- Bridge – 923 Concrete

Project Emissions Estimator

The Michigan Technology University PE-2 Project Emission Estimator, Highway Construction GHG Calculator (mtu.edu), estimated the emission factors for roadway construction projects in order to calculate roadway life-cycle environmental impacts. This estimator was utilized to calculate the overall life-cycle greenhouse gas emissions for each alternative.

The Michigan Technology Project Emission Estimator sources the following 14 projects to generate average greenhouse gas emissions:

- I-69: Concrete Reconstruction
- US-131: Asphalt Relief Layer; Reconstruction; Crush and Shape
- I-196: Unbonded Concrete Overlay
- US-31: HMA Reconstruction
- US-41: HMA Reconstruction and Roadway Realignment
- US-41: Roadway Reconstruction HMA and Concrete
- M-20: HMA Cold Milling and Overlay
- M-37: Full Depth Pavement Joint and Crack Repairs
- M-55: HMA Cold Milling and Overlay
- M-28: Concrete Patch Repairs and HMA Resurfacing
- US-31: Overband Crack Fill and Micro surface
- US-31: Transverse and Long. Joint Cutting and Resealing (Concrete)
- US-131: Overband Crack Seal and Micro surface

- US-127: Micro surface

Comparable items were identified using the Michigan Department of Transportation Standard Specifications. To compare Mid-States alternative quantities with MDOT comparable quantities; unit conversions were needed in some cases.

Alternative	GHG Output Value (Metric Tons of CO_2)					
	Super-2			Expressway		
	Mainline	Local Improvements	Total	Mainline	Local Improvements	Total
B	41,500	10,000	51,500	47,100	10,000	57,100
C	50,400	8,000	58,400	62,100	8,000	70,100
M	94,200	15,400	109,600	114,100	15,400	129,500
O	63,200	12,700	75,900	90,300	12,700	103,000
RPA P1 (DEIS P)	66,200	14,300	80,500	83,800	14,300	98,100
RPA P2	68,300	14,300	82,600			
RPA P3	65,000	14,300	79,300	83,300	14,300	97,600
RPA P4	61,400	14,300	75,700	84,700	14,300	99,000
R	49,300		49,300			

TABLE 1: GHG (CO_2) EMISSIONS BY ALTERNATIVE

All alternatives were assumed to have a 10-year construction period extending from 2028 to 2037. All emissions were assumed to occur at equal levels during each year of the construction period. **Table 1** provided emissions for construction of both Super-2 and expressway facility types. As noted earlier, only the expressway facility type was used to make a comparison of GHG impacts for all emissions sources.

Carbon Sequestration Losses

To analyze the loss of carbon sequestration potential of forest land per alternative, the carbon stock loss was calculated from regional estimates of carbon stock per acre. These values were acquired from the look-up tables within the USDA *Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States* (Smith et al., 2006). All impacted areas are assumed to consist of live trees of predominately maple, beech or birch species and approximately 55 years of age.

Alternative	Total Forest Loss (acres)	Carbon Stock Loss (metric tons of carbon)
B	347	7,529.9
C	556	12,065.2
RPA P, 2P1 (P2West)	792	17,186.4
RPA P, 3P2	607	13,171.9
RPA P, 2P3	802	17,403.4
RPA P, 2P4	874	18,965.8
R	97	2,104.9
M	2,311	50,148.7
O	1,756	38,105.2

TABLE 2 – CARBON STOCK LOSS DUE TO TREE CLEARING

All tree clearing was assumed to occur in a 9-year period between 2027 and 2035. Tree clearing was assumed to occur in equal quantities during each of these nine years.

A review of existing tools to quantify the carbon sequestration potential of cropland and herbaceous areas did not identify a method appropriate for a Tier 1 level of analysis. The link most applicable to this task within the U.S. Department of Energy (USDOE) toolkit is the report by the USDA Technical Bulletin titled "Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory" (https://www.usda.gov/sites/default/files/documents/USDATB1939_07072014.pdf). Beginning on PDF page 127 (Chapter 3.5.1 - Biomass Carbon Stock Changes), the report details the IPCC method for calculating biomass carbon stock change for the year following a land use change. These methods are applicable to small scale analyses. This Tier 1 study uses GIS imagery for multiple alternatives, with cropland impacts as much as 1,500 acres. Specific data which this tool requires are not available in Tier 1. As shown in the email included on pages A3-A4 of the Appendix, USEPA and USDOE were contacted to determine the availability of other tools which could be used for this study. No further information was provided from either agency. Accordingly, impacts to the carbon sequestration in cropland and herbaceous areas were not incorporated into this analysis.

Carbon Sequestration Gains

To analyze the potential gain of carbon sequestration from mitigation efforts per alternative, the carbon stock gain was calculated from regional estimates of carbon stock per acre in the Smith et al., 2006 publication as well. All mitigation is assumed to consist of live trees of predominately maple, beech or birch species. It is also assumed that each tree will be planted on previously non-forest land and will be planted as saplings (starting age of 0 years). Carbon stock was estimated for five, 15 and 25 years after planting to demonstrate increasing mitigation benefits. At a Tier 1 level, mitigation is assumed to occur at a 2:1 planting ratio.

Alternative	Total Forest Loss (acres)	Mitigation, 2:1 Reforestation (acres)	Reclaimed Carbon Stock, 5 Years After Planting (metric tons of carbon)	Reclaimed Carbon Stock, 15 Years After Planting (metric tons of carbon)	Reclaimed Carbon Stock, 25 Years After Planting (metric tons of carbon)
B	347	694	1,457.4	2,984.2	5,205.0
C	556	1,112	2,335.2	4,781.6	8,340.0
RPA P, 2P1 (P2West)	792	1,584	3,326.4	6,811.2	11,880.0
RPA P, 3P2	607	1,214	2,549.4	5,220.2	9,105.0
RPA P, 2P3	802	1,604	3,368.4	6,897.2	12,030.0
RPA P, 2P4	874	1,748	3,670.8	7,516.4	13,110.0
R	97	194	407.4	834.2	1,455.0
M	2,311	4,622	9,706.2	19,874.6	34,665.0
O	1,756	3,512	7,375.2	15,101.6	26,340.0

TABLE 3: CARBON GAINS FROM A 2:1 MITIGATION (PLANTING) SCENARIO

Forest mitigation planting was assumed to occur in an eight-year period between 2029 and 2036. Equal acreages of planting are assumed to occur in each of these eight years. Sequestration benefits were assumed to accrue beginning in 2030. Forests were assumed to reach the five-year, 15-year and 25-year levels of sequestration benefits beginning in 2035, 2045 and 2055, respectively. Interpolation was applied to the values in the above table to calculate the estimated added sequestration benefit in each year.

Vehicle Operations

Changes in VMT and CO_2 Emissions Over Time

Increased CO_2 emissions were calculated based upon the additional VMT generated by each build alternative compared to the No-Build Alternative. Automotive emissions were calculated using emissions rates provided in the USEPA Office of Transportation and Air Quality publication, "Greenhouse Gas Emissions from a Typical Passenger Vehicle," EPA-40-F-18-008, March 2018 (https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100U8YT.pdf). Truck emissions were calculated using parameters from the TREDIS economic analysis tool. These values are shown in FEIS Vol. I, **Table 3.9-4.** For more details about TREDIS, please refer to **Appendix B**.

Each alternative was assumed to be open to traffic between I-64 and SR 56 in the year 2031. This assumption reflects that the Mid-States project will be constructed in stages. No decision has been made about the timing or sequencing of Tier 2 NEPA studies and subsequent construction activities. This assumption is made to reflect that construction and related activities will be phased in over a number of years. Interim traffic assignments for the No-Build Alternative and each expressway Build alternative were made for both a 2031 interim year (based on these assumptions of partial completion of the project) and for a 2045 forecast year.

Table 4 provides the forecasted VMT and CO_2 emissions for the 2031 interim opening year for a portion of each alternative. **Table 5** provides the forecasted VMT and CO_2 emissions for the 2045 forecast year, reflecting the full build condition for each alternative.

2031 Assignment Year		
Alternative	Annual VMT (Millions)	Total CO_2 Thousands of Metric Tons
No Build	3734	1821.5
B	3746	1828.6
C	3747	1827.9
M	3742	1825.9
O	3745	1827.1
P/RPA	3741	1825.5
RPA 2	3736	1822.5
R	3737	1822.7

TABLE 4: 2031 VMT AND CO_2 EMISSIONS BY ALTERNATIVE

2045 Assignment Year		
Alternative	Annual VMT (Millions)	Total CO_2 Thousands of Metric Tons
No Build	4652	2297.1
B	4688	2316.2
C	4686	2314.2
M	4671	2307.0
O	4689	2315.4
P/RPA	4674	2308.2
RPA 2	4666	2303.8
R	4661	2300.7

TABLE 5: 2045 VMT AND CO_2 EMISSIONS BY ALTERNATIVE

Added CO_2 emissions are calculated as the difference in emissions between each alternative and the No-Build Alternative for that year. Increases in VMT and CO_2 are forecasted to 2031. Between 2031 and the anticipated opening year of 2038 for the entire project, changes in VMT and CO_2 emissions were calculated using the percentage change in VMT and CO_2 emissions between 2031 and 2045. The same percentage was applied to VMT changes between the 2038 opening year and 2050.

Fleet Changes Over Time

No information was forthcoming in the request to USEPA and DOE regarding anticipated fleet composition changes over time. Project staff identified a July 2020 report from Deloitte Insights, "Electric Vehicles, Setting a Course for 2030" https://www2.deloitte.com/us/en/insights/focus/future-of-mobility/electric-vehicle-trends-2030.html. Figure 3 in the report cited/forecasted the market shares for EV sales in the United States for the following years.

- 2020 – four percent
- 2025 – nine percent
- 2030 – 27 percent

Based upon further discussion in the article, staff estimated that EV sales in the United States would reach 40 percent by 2040 and 50 percent by 2050.

The Indiana Department of Transportation provided the information in **Table 6** showing the average age Indiana's motor vehicle fleet in recent years, as well as forecasts to the year 2050. It is based upon vehicle registrations.

		Average Age		Forecast					
STID	Description	2017	2022	2025	2030	2035	2040	2045	2050
11-32	Passenger Vehicles	11.3	11.7	12.0	12.5	12.9	13.4	13.9	14.5
41-43	Buses	11.4	11.4	11.5	11.5	11.6	11.6	11.7	11.7
54	Motor Home	12.9	11.5	10.8	9.6	8.6	7.7	6.9	6.2
52-53	SU Truck	18.6	18.3	18.1	17.8	17.5	17.2	16.9	16.6
61-62	MU Truck	18.5	19.5	20.1	21.1	22.2	23.4	24.6	25.9
NA/Null	Other	3.1	3.9	4.5	5.7	7.3	9.2	11.7	14.8
	Total:	11.4	11.8	12.1	12.5	12.9	13.4	13.8	14.3

TABLE 6: AVERAGE AGE, INDIANA MOTOR VEHICLE FLEET

The analysis assumed that the average duration for which a vehicle remains in the motor vehicle fleet is approximately double these average ages. As a simplifying assumption, vehicles throughout the analysis period were assumed to have a 25-year life in the vehicle fleet. Based on these assumptions, percentages of EVs in Indiana's motor vehicle fleet were calculated for each year of the analysis. The percentages calculated for representative years are as follows:

- 2030 – 5.6 percent of fleet
- 2040 – 19.2 percent of fleet
- 2050 – 35.8 percent of fleet

Annual VMT by Vehicle Type

In 2019 *Applied Economic Letters* published the article, "How Much Are Electric Vehicles Driven"https://faculty.haas.berkeley.edu/ldavis/Davis%20AEL%202019.pdf. It analyzed EV and ICE vehicle usage from the 2017 U. S. Department of Transportation *National Household Travel Survey*. It found that the typical EV is driven 7,000 miles annually, compared to 10,200 miles for the typical ICE. This ratio of VMT by vehicle type was applied to the fleet composition in each year to estimate the proportion of VMT incurred by electric vehicles.

Emissions by Vehicle Type

Earlier in this analysis, the USEPA average emissions factors by vehicle type were cited. Published research by the University of Washington identifies GHG emissions for both ICE vehicles and several types of EVs. These emissions were calculated based upon the sources of electricity generated in each state. For Indiana, 85 percent of electricity is generated from coal, eight percent from natural gas and three percent from wind and solar power[4]. It found that for Indiana, ICE vehicles emit 0.84 pounds of GHG per mile. It also found that EVs cause emissions of 0.58 to 0.66 pounds of GHG per mile. The average EV emission rate was compared to the ICE emission rate. This ratio of 0.73 was applied to the emissions analysis to reflect the reductions in emissions due to the use of EVs.

Discounting Carbon Impacts and Costs

Emissions from each source, by year, were compiled in a master spreadsheet. For each year, the carbon cost for that year from the USDOT benefit-cost guidance was applied. The total costs for each year were discounted by both 2.5 percent and three percent. The spreadsheets showing these results are on pages A5-A5 of the Appendix to this document.

Net Emissions and Costs Calculation

Table 7 compares the discounted costs of carbon emissions for each alternative, for both a 2.5 percent and three percent discount rate.

Discounted GHG Costs - Millions of 2023 Dollars			
Alternative	Facility Type	Discounted Emissions Costs at:	
		2.5 percent	3.0 percent
B	Expy	$ 3.24	$ 3.10
C	Expy	$ 4.05	$ 3.87
M	Expy	$ 8.20	$ 7.87
O	Expy	$ 6.49	$ 6.23
P, RPA P1	Expy	$ 5.67	$ 5.42
RPA P2	Super-2	$ 4.74	$ 4.53
RPA P3	Expy	$ 5.64	$ 5.40
RPA P4	Expy	$ 5.76	$ 5.51
R	Super-2	$ 2.67	$ 2.55

TABLE 7: DISCOUNTED COSTS OF CO_2 EMISSIONS BY ALTERNATIVE

[4] https://labs.ece.uw.edu/community/EnvironmentalImpacts/ElectricVehiclesByState/#Indiana.

Discussion

Following are some key insights from this analysis.

Role of Vehicle Emissions

For a major construction project such as the Mid-States Corridor, changes in vehicle travel have a negligible role in overall increased GHG emissions. For the example of Alternative P/RPA P1 cited earlier, they constitute approximately 0.1 percent of the total increase in emissions.

Construction Activities

The most significant contribution to GHG emissions are construction activities. For the example of Alternative P/RPA 1, they constitute about 85 percent of total emissions attributable to the project. This analysis does not quantify emissions from other construction activities which could be undertaken by the Indiana Department of Transportation if the Mid-States Corridor project were not undertaken. It is likely that most of these emissions would occur on other projects if this project did not proceed and its funding were directed elsewhere.

Alternatives M and O are both the most effort-intensive alternatives to construct as well as those which require the most clearing of forested land. This is the cause of their higher cost of GHG emissions.

Forest Mitigation

Significant increases in carbon sequestration are forecasted to occur beginning in about 2030. Beginning in the year 2038, the only project related activities which lead to changes in GHG emissions are slight increases in vehicle travel as well as increases in carbon sequestration due to replanted forest. These increases in carbon sequestration are 10 to 100 times greater than the increases in vehicle emissions, depending upon the alternative.

GHG Costs in Context

The discounted GHG costs for alternatives are small compared to the construction costs incurred. For all alternatives, the discounted GHG costs range from 0.43 percent to 0.65 percent of total construction costs. For the 18 combinations of alternatives studied and discount rate assumptions, the average ratio is 0.53 percent. This suggests that an appropriate planning-level estimate for GHG costs as a percentage of total construction costs is approximately one-half of one percent.

3. CLIMATE RESILIENCY

Key environmental elements have been assessed during this Tier 1 study. They will be further developed during Tier 2 studies. Each is briefly discussed below.

Flooding

A minimum of one foot of free board above the 1 percent storm exceedance probability, more commonly known as the 100-year storm, was included in the Tier 1 engineering assessment for all alternatives. During Tier 2 studies the design team will rely on local, state and federal agencies to determine if and to what level of critical infrastructure the preferred alternative should be designed. This could require assessing the alternative at higher exceedance intervals such as 200-year or 500-year storm events to maintain resiliency due to changing climate conditions.

Fire/weather

The roadway clear zone concept developed as a part of the Interstate highway system to provide recovery space for errant vehicles. A clear zone is an area adjacent to the roadway void of trees and vertical obstructions. This clear zone extends between 30 and 75 feet from the edge of the travel lanes, depending upon terrain and facility type. This break in vegetation also provides a fire break in wildfire situations and provides clearer travel should trees fall during storm events.

Emissions

Emissions from standing vehicles contribute to GHG emissions. Allowing vehicles to travel more efficiently reduces the number of hours vehicles are running and emitting greenhouse gases. By improving regional accessibility, the Mid-States Corridor will provide for more efficient vehicle operations. Tier 2 studies will focus on access considerations to further improve the efficiency of vehicle operations.

Construction Materials

Resources such as stone, oil, metal and wood are all used in roadway construction. An estimate of greenhouse gas emissions due to the construction of each alternative is provided earlier in this document. In Tier 2, use of sustainable materials and practices such as recycled asphalt and warm mix asphalt will be considered. This could result in lifecycle reductions in emissions compared with those for traditional materials and techniques.

4. REFERENCES

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U.S. Department of Transportation

Benefit-Cost Analysis Guidance for Discretionary Grant Programs

Office of the Secretary

U.S. Department of Transportation

January 2023

*Table A-6: Damage Costs for Emissions per Metric Ton**

Recommended Monetized Value(s)

Emission Type	**NO_X**	**SO_X**	**$PM_{2.5}$****	**CO_2**
2022	$16,600	$44,300	$796,700	$56
2023	$16,800	$45,100	$810,500	$57
2024	$17,000	$46,000	$824,500	$58
2025	$17,200	$46,900	$838,800	$59
2026	$17,500	$47,800	$852,100	$60
2027	$17,900	$48,700	$865,600	$61
2028	$18,200	$49,500	$879,400	$62
2029	$18,600	$50,400	$893,400	$63
2030	$18,900	$51,300	$907,600	$65
2031	$18,900	$51,300	$907,600	$66
2032	$18,900	$51,300	$907,600	$67
2033	$18,900	$51,300	$907,600	$68
2034	$18,900	$51,300	$907,600	$69
2035	$18,900	$51,300	$907,600	$70
2036	$18,900	$51,300	$907,600	$72
2037	$18,900	$51,300	$907,600	$73
2038	$18,900	$51,300	$907,600	$74
2039	$18,900	$51,300	$907,600	$75
2040	$18,900	$51,300	$907,600	$76
2041	$18,900	$51,300	$907,600	$78
2042	$18,900	$51,300	$907,600	$79
2043	$18,900	$51,300	$907,600	$80
2044	$18,900	$51,300	$907,600	$81
2045	$18,900	$51,300	$907,600	$82
2046	$18,900	$51,300	$907,600	$84
2047	$18,900	$51,300	$907,600	$85
2048	$18,900	$51,300	$907,600	$86
2049	$18,900	$51,300	$907,600	$87
2050	$18,900	$51,300	$907,600	$88

*Applicants should carefully note whether their emissions data is reported in short tons or metric tons. A metric ton is equal to 1.1015 short tons.

**Applicants should be careful to not apply the $PM_{2.5}$ value to estimates of total emissions of PM_{10}.

References and Notes

Technical Support Document: Estimating the Benefit per Ton of Reducing PM2.5 Precursors from 17 Sectors (February 2018)"
https://www.epa.gov/sites/default/files/2018-02/documents/sourceapportionmentbpttsd_2018.pdf

NO_X, SO_X, and $PM_{2.5}$ values are inflated from 2015 to 2021 dollars using the GDP deflator.

Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990 (February 2021)
https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf

Note: Fuel saved (gasoline, diesel, natural gas, etc.) can be converted into metric tons of emissions using EPA guidelines available at https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

Note: The recommended values for reducing CO_2 emissions reported in Table A-6 represent the values of future economic damages that can be avoided by reducing emissions in each future year by one metric ton. After using per-ton values to estimate the total value of reducing CO2 emissions in any *future year*, the result must be further discounted to its present value as of the analysis year used in the BCA, also using a **3 percent** discount rate.

From:	Michael Grovak
To:	fn-ceq-nepa@ceq.eop.gov; EHSSUserSupport@hq.doe.gov
Cc:	Jason DuPont; Bryan Cross; Grace Brewington; Sharif Ullah
Subject:	NEPA/CEQ Questions and Feedback
Date:	Friday, April 21, 2023 11:36:31
Attachments:	image988887.png image589789.png image885032.png image105748.png image355626.png image472463.png image668698.png image069646.png

Hello,

Lochmueller Group currently is conducting a Tier 1 EIS for the Indiana Department of Transportation for the Mid-States Corridor Project in southern Indiana. The Notice of Intent for this project was published in the July 25, 2019 Federal Register. A Final EIS for this project is anticipated in summer, 2023. The FEIS is in its final stages of preparation. Lochmueller Group is the lead consultant preparing the FEIS.

As described in the interim guidance published in the January 9, 2023 Federal Register, "National Environmental Policy Act Guidance on Consideration of Greenhouse Gas Emissions and Climate Change" (https://www.federalregister.gov/documents/2023/01/09/2023-00158/national-environmental-policy-act-guidance-on-consideration-of-greenhouse-gas-emissions-and-climate) the FEIS is providing a Tier 1-level analysis of the GHG impacts of this project. Using the CEQ GHG Tools and Resources webpage referenced in the Guidance (https://ceq.doe.gov/guidance/ghg-tools-and-resources.html), we have been unsuccessful in identifying tools to accomplish some components of this analysis. The Guidance advises that "agencies are encouraged to identify and communicate any data or tool gaps that they encounter to CEQ." As suggested, we are providing for your review and feedback components of the analysis for which we have not identified clear methodologies for this Tier 1 Study:

- **Assumptions about vehicle fleet mix over time:** We have not identified authoritative sources that forecast the composition of fleet mixes (both auto and truck) for future years. This is an essential component of our analyses regarding GHG emissions. The analysis will anticipate increased use of electric and other low-emission vehicle technologies approximately 25 years into the future. We have not been able to identify reliable sources that provide clear guidance for forecasting the composition of the fleet mix over time.
- **Carbon sequestration of cropland and herbaceous areas:** The Mid-States Corridor project will serve rural areas, impacting farmland. We wish to quantify the carbon sequestration potential of cropland and herbaceous areas that may be used for the project. The source most applicable to this task within the CEQ toolkit is the report by the USDA Technical Bulletin titled "Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory" (https://www.usda.gov/sites/default/files/documents/USDATB1939_07072014.pdf). Beginning on PDF page 127 (**Section 3.5.1 - Biomass Carbon Stock Changes**), the report details the IPCC method for calculating biomass carbon stock change for the year following a

land use change. However, these analytics are most applicable to small scale landowners. The Study Area for this Tier 1 EIS includes over 4,700 square miles encompassing 12 counties.

Given that this is a Tier 1 EIS with a large study area, all resource data used to analyze impacts are GIS-based. Resource data will be field-verified in later Tier 2 studies. The FEIS considers impacts to seven alternatives located throughout the Study Area. Estimated cropland impacts are estimated to be as great as 1,500 acres. The tool identified in the previous paragraph is not suited to a project with potential impacts of this magnitude, and without the level of detail associated with detailed, field-verified data. The type of data incorporated into this tool will not be available until Tier 2 studies.

For this Tier 1 analysis, it is appropriate to quantify the carbon stock in cropland and herbaceous areas with the assumption of homogeneity, such that one value for biomass carbon stock per acre could be applicable to each alternative with a simple calculation of the rate times the area impacted. We have been unable to identify a source for such a high-level factor.

- **CO_2 Equivalents for Vehicle Emissions.** The National Association of Environmental Professionals on February 27, 2023 conducted a webinar, *Understanding CEQ's Recent Guidance on Considering Greenhouse Gases and Climate Change in NEPA*. Several presenters emphasize including the CO_2 equivalents of other GHG, especially methane and oxides of nitrogen. These additional GHGs have much higher warming potential than CO_2. We have identified a University of Washington study which provides an estimate of CO_2 equivalents of 0.84 pounds/VMT for passenger cars. The link providing these results is given at the end of this bullet point. Our question is whether you can refer us to a similar factor for diesel truck operation.
  https://labs.ece.uw.edu/community/EnvironmentalImpacts/ElectricVehicleCalculations/#:~:text=Methane%20Emissions%20(in%20units%20of,or%200.375%20grams%20per%20gallon

As noted, this is a Tier 1 study. The techniques to analyze the GHG impacts of this project incorporate the level of analysis for a Tier 1 EIS. Subsequent Tier 2 studies will conduct more detailed analyses.

We look forward to hearing back from you.

Thank you,

LOCHMUELLER GROUP

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Alternative	Category	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050		
B	Forest Sequestration Losses	836	836	836	836	836	836	836	836	912																	
	Construction Emissions		5,710	5,710	5,710	5,710	5,710	5,710	5,710	5,710	5,710	5,710															
	Forest Mitigation Gains			0	(250)	(250)	(250)	(250)	(250)	(250)	(150)	(150)	(150)	(150)	(150)	(150)	(150)	(150)	(150)	(150)	(220)	(220)	(220)	(220)	(220)		
	Auto Emission Increases					7	7	7	7	7	7	7	15	16	16	16	16	16	16	16	16	16	16	16	16		
	Net Increases	836	6,546	6,546	6,296	6,303	6,303	6,303	6,303	6,379	5,567	5,567	(135)	(134)	(134)	(134)	(134)	(134)	(134)	(134)	(204)	(204)	(204)	(204)	(204)		
	Cost/Metric Ton Undiscounted	$ 61	$ 62	$ 63	$ 65	$ 66	$ 67	$ 68	$ 69	$ 70	$ 72	$ 73	$ 74	$ 75	$ 76	$ 78	$ 79	$ 80	$ 81	$ 82	$ 84	$ 85	$ 86	$ 87	$ 88		
2.50%	Discount Factor	0.904	0.881	0.859	0.838	0.817	0.796	0.776	0.757	0.738	0.720	0.702	0.684	0.667	0.650	0.634	0.618	0.603	0.588	0.573	0.559	0.545	0.531	0.518	0.505		
$3,243,000	Discounted Value	$46,100	$357,600	$354,300	$342,800	$339,700	$336,300	$332,700	$329,200	$329,500	$288,400	$285,100	($6,800)	($6,700)	($6,600)	($6,600)	($6,500)	($6,500)	($6,400)	($6,300)	($9,600)	($9,400)	($9,300)	($9,200)	($9,100)		
Alternative	Category	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050		
C	Forest Sequestration Losses	1,331	1,331	1,331	1,331	1,331	1,331	1,331	1,331	1,452																	
	Construction Emissions		7,010	7,010	7,010	7,010	7,010	7,010	7,010	7,010	7,010	7,010															
	Forest Mitigation Gains				(383)	(384)	(383)	(383)	(384)	(383)	(250)	(250)	(250)	(250)	(250)	(250)	(250)	(250)	(250)	(250)	(350)	(350)	(350)	(350)	(350)		
	Auto Emission Increases					6	6	6	6	6	6	6	14	14	14	14	14	14	14	14	15	15	15	15	15		
	Net Increases	1,331	8,341	8,341	7,958	7,963	7,964	7,964	7,963	8,085	6,766	6,766	(236)	(236)	(236)	(236)	(236)	(236)	(236)	(236)	(335)	(335)	(335)	(335)	(335)		
	Cost/Metric Ton Undiscounted	$ 61	$ 62	$ 63	$ 65	$ 66	$ 67	$ 68	$ 69	$ 70	$ 72	$ 73	$ 74	$ 75	$ 76	$ 78	$ 79	$ 80	$ 81	$ 82	$ 84	$ 85	$ 86	$ 87	$ 88		
2.50%	Discount Factor	0.904	0.881	0.859	0.838	0.817	0.796	0.776	0.757	0.738	0.720	0.702	0.684	0.667	0.650	0.634	0.618	0.603	0.588	0.573	0.559	0.545	0.531	0.518	0.505		
$4,050,000	Discounted Value	$73,400	$455,700	$451,400	$433,300	$429,200	$424,900	$420,400	$415,900	$417,700	$350,500	$346,500	($11,900)	($11,800)	($11,700)	($11,700)	($11,500)	($11,400)	($11,200)	($11,100)	($15,700)	($15,500)	($15,300)	($15,100)	($14,900)		
		2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050		
M	Forest Sequestration Losses	5,511	5,511	5,511	5,511	5,511	5,511	5,511	5,511	6,012																	
	Construction Emissions		12,950	12,950	12,950	12,950	12,950	12,950	12,950	12,950	12,950	12,950															
	Forest Mitigation Gains				(1,617)	(1,616)	(1,617)	(1,617)	(1,616)	(1,617)	(1,020)	(1,020)	(1,020)	(1,020)	(1,020)	(1,020)	(1,020)	(1,020)	(1,020)	(1,020)	(1,480)	(1,480)	(1,480)	(1,480)	(1,480)		
	Auto Emission Increases					4	4	4	4	4	5	5	8	8	8	8	8	8	8	8	8	9	9	9	9		
	Net Increases	5,511	18,461	18,461	16,844	16,849	16,848	16,848	16,849	17,349	11,935	11,935	(1,012)	(1,012)	(1,012)	(1,012)	(1,012)	(1,012)	(1,012)	(1,012)	(1,472)	(1,471)	(1,471)	(1,471)	(1,471)		
	Cost/Metric Ton Undiscounted	$ 61	$ 62	$ 63	$ 65	$ 66	$ 67	$ 68	$ 69	$ 70	$ 72	$ 73	$ 74	$ 75	$ 76	$ 78	$ 79	$ 80	$ 81	$ 82	$ 84	$ 85	$ 86	$ 87	$ 88		
2.50%	Discount Factor	0.904	0.881	0.859	0.838	0.817	0.796	0.776	0.757	0.738	0.720	0.702	0.684	0.667	0.650	0.634	0.618	0.603	0.588	0.573	0.559	0.545	0.531	0.518	0.505		
$8,199,000	Discounted Value	$303,800	#########	$999,100	$917,000	$908,100	$898,800	$889,400	$880,000	$896,200	$618,300	$611,200	($51,200)	($50,600)	($50,000)	($50,000)	($49,400)	($48,800)	($48,200)	($47,500)	($69,100)	($68,100)	($67,200)	($66,300)	($65,300)		
		2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050		
O	Forest Sequestration Losses	4,191	4,191	4,191	4,191	4,191	4,191	4,191	4,191	4,572																	
	Construction Emissions		10,300	10,300	10,300	10,300	10,300	10,300	10,300	10,300	10,300	10,300															
	Forest Mitigation Gains				(1,233)	(1,234)	(1,233)	(1,233)	(1,234)	(1,233)	(770)	(770)	(770)	(770)	(770)	(770)	(770)	(770)	(770)	(770)	(1,120)	(1,120)	(1,120)	(1,120)	(1,120)		
	Auto Emission Increases					6	6	6	6	6	6	6	16	17	17	17	17	18	18	18	19	19	19	20	20		
	Net Increases	4,191	14,491	14,491	13,258	13,263	13,264	13,264	13,263	13,645	9,536	9,536	(754)	(753)	(753)	(753)	(753)	(752)	(752)	(752)	(1,101)	(1,101)	(1,101)	(1,100)	(1,100)		
	Cost/Metric Ton Undiscounted	$ 61	$ 62	$ 63	$ 65	$ 66	$ 67	$ 68	$ 69	$ 70	$ 72	$ 73	$ 74	$ 75	$ 76	$ 78	$ 79	$ 80	$ 81	$ 82	$ 84	$ 85	$ 86	$ 87	$ 88		
2.50%	Discount Factor	0.904	0.881	0.859	0.838	0.817	0.796	0.776	0.757	0.738	0.720	0.702	0.684	0.667	0.650	0.634	0.618	0.603	0.588	0.573	0.559	0.545	0.531	0.518	0.505		
$6,486,000	Discounted Value	$231,000	$791,600	$784,300	$721,800	$714,900	$707,600	$700,200	$692,700	$704,900	$494,000	$488,400	($38,200)	($37,700)	($37,200)	($37,200)	($36,800)	($36,300)	($35,800)	($35,300)	($51,700)	($51,000)	($50,300)	($49,500)	($48,900)		
		2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050		
P1	Forest Sequestration Losses	1,892	1,892	1,892	1,892	1,892	1,892	1,892	1,892	2,064																17,200	
	Construction Emissions		9,810	9,810	9,810	9,810	9,810	9,810	9,810	9,810	9,810	9,810														98,100	
	Forest Mitigation Gains				(550)	(550)	(550)	(550)	(550)	(550)	(350)	(350)	(350)	(350)	(350)	(350)	(350)	(350)	(350)	(350)	(510)	(510)	(510)	(510)	(510)	(9,350)	
	Auto Emission Increases					4	4	4	4	4	4	4	9	9	9	9	9	9	9	9	9	10	10	10	10	149	115,449
	Net Increases	1,892	11,702	11,702	11,152	11,156	11,156	11,156	11,156	11,328	9,464	9,464	(341)	(341)	(341)	(341)	(341)	(341)	(341)	(341)	(501)	(500)	(500)	(500)	(500)		0
	Cost/Metric Ton Undiscounted	$ 61	$ 62	$ 63	$ 65	$ 66	$ 67	$ 68	$ 69	$ 70	$ 72	$ 73	$ 74	$ 75	$ 76	$ 78	$ 79	$ 80	$ 81	$ 82	$ 84	$ 85	$ 86	$ 87	$ 88		
2.50%	Discount Factor	0.904	0.881	0.859	0.838	0.817	0.796	0.776	0.757	0.738	0.720	0.702	0.684	0.667	0.650	0.634	0.618	0.603	0.588	0.573	0.559	0.545	0.531	0.518	0.505		
$5,665,000	Discounted Value	$104,300	$639,300	$633,300	$607,200	$601,300	$595,100	$588,900	$582,700	$585,200	$490,300	$484,700	($17,300)	($17,100)	($16,900)	($16,900)	($16,700)	($16,400)	($16,200)	($16,000)	($23,500)	($23,100)	($22,800)	($22,500)	($22,200)		
		2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050		
P2	Forest Sequestration Losses	1,452	1,452	1,452	1,452	1,452	1,452	1,452	1,452	1,584																	
	Construction Emissions		8,260	8,260	8,260	8,260	8,260	8,260	8,260	8,260	8,260	8,260															
	Forest Mitigation Gains				(417)	(416)	(417)	(417)	(416)	(417)	(270)	(270)	(270)	(270)	(270)	(270)	(270)	(270)	(270)	(270)	(390)	(390)	(390)	(390)	(390)		
	Auto Emission Increases					1	1	1	1	1	1	1	5	6	6	6	6	6	6	6	6	6	6	6	6		
	Net Increases	1,452	9,712	9,712	9,295	9,297	9,296	9,296	9,297	9,428	7,991	7,991	(265)	(264)	(264)	(264)	(264)	(264)	(264)	(264)	(384)	(384)	(384)	(384)	(384)		
	Cost/Metric Ton Undiscounted	$ 61	$ 62	$ 63	$ 65	$ 66	$ 67	$ 68	$ 69	$ 70	$ 72	$ 73	$ 74	$ 75	$ 76	$ 78	$ 79	$ 80	$ 81	$ 82	$ 84	$ 85	$ 86	$ 87	$ 88		
2.50%	Discount Factor	0.904	0.881	0.859	0.838	0.817	0.796	0.776	0.757	0.738	0.720	0.702	0.684	0.667	0.650	0.634	0.618	0.603	0.588	0.573	0.559	0.545	0.531	0.518	0.505		
$4,735,000	Discounted Value	$80,000	$530,500	$525,600	$506,100	$501,100	$495,900	$490,700	$485,600	$487,000	$414,000	$409,200	($13,400)	($13,200)	($13,000)	($13,100)	($12,900)	($12,700)	($12,600)	($12,400)	($18,000)	($17,800)	($17,500)	($17,300)	($17,100)		
P3		2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050		
	Forest Sequestration Losses	1,914	1,914	1,914	1,914	1,914	1,914	1,914	1,914	2,088																	
	Construction Emissions		9,760	9,760	9,760	9,760	9,760	9,760	9,760	9,760	9,760	9,760															
	Forest Mitigation Gains				(567)	(566)	(567)	(567)	(566)	(567)	(350)	(350)	(350)	(350)	(350)	(350)	(350)	(350)	(350)	(350)	(510)	(510)	(510)	(510)	(510)		
	Auto Emission Increases					4	4	4	4	4	4	4	9	9	9	9	9	9	9	9	9	10	10	10	10		
	Net Increases	1,914	11,674	11,674	11,107	11,112	11,111	11,111	11,112	11,285	9,414	9,414	(341)	(341)	(341)	(341)	(341)	(341)	(341)	(341)	(501)	(500)	(500)	(500)	(500)		
	Cost/Metric Ton Undiscounted	$ 61	$ 62	$ 63	$ 65	$ 66	$ 67	$ 68	$ 69	$ 70	$ 72	$ 73	$ 74	$ 75	$ 76	$ 78	$ 79	$ 80	$ 81	$ 82	$ 84	$ 85	$ 86	$ 87	$ 88		
2.50%	Discount Factor	0.904	0.881	0.859	0.838	0.817	0.796	0.776	0.757	0.738	0.720	0.702	0.684	0.667	0.650	0.634	0.618	0.603	0.588	0.573	0.559	0.545	0.531	0.518	0.505		
$5,644,000	Discounted Value	$105,500	$637,700	$631,800	$604,700	$598,900	$592,700	$586,600	$580,400	$583,000	$487,700	$482,100	($17,300)	($17,100)	($16,900)	($16,900)	($16,700)	($16,400)	($16,200)	($16,000)	($23,500)	($23,100)	($22,800)	($22,500)	($22,200)		
		2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050		
P4	Forest Sequestration Losses	2,090	2,090	2,090	2,090	2,090	2,090	2,090	2,090	2,280																	
	Construction Emissions		9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900															
	Forest Mitigation Gains				(617)	(616)	(617)	(617)	(616)	(617)	(380)	(380)	(380)	(380)	(380)	(380)	(380)	(380)	(380)	(380)	(560)	(560)	(560)	(560)	(560)		
	Auto Emission Increases					4	4	4	4	4	4	4	9	9	9	9	9	9	9	9	9	10	10	10	10		
	Net Increases	2,090	11,990	11,990	11,373	11,378	11,377	11,377	11,378	11,567	9,524	9,524	(371)	(371)	(371)	(371)	(371)	(371)	(371)	(371)	(551)	(550)	(550)	(550)	(550)		
	Cost/Metric Ton Undiscounted	$ 61	$ 62	$ 63	$ 65	$ 66	$ 67	$ 68	$ 69	$ 70	$ 72	$ 73	$ 74	$ 75	$ 76	$ 78	$ 79	$ 80	$ 81	$ 82	$ 84	$ 85	$ 86	$ 87	$ 88		
2.50%	Discount Factor	0.904	0.881	0.859	0.838	0.817	0.796	0.776	0.757	0.738	0.720	0.702	0.684	0.667	0.650	0.634	0.618	0.603	0.588	0.573	0.559	0.545	0.531	0.518	0.505		
$5,761,000	Discounted Value	$115,200	$655,000	$648,900	$619,200	$613,300	$606,900	$600,600	$594,200	$597,500	$493,400	$487,800	($18,800)	($18,600)	($18,300)	($18,300)	($18,100)	($17,900)	($17,700)	($17,400)	($25,900)	($25,500)	($25,100)	($24,800)	($24,400)		
		2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050		
R	Forest Sequestration Losses	231	231	231	231	231	231	231	231	252																	
	Construction Emissions		4,930	4,930	4,930	4,930	4,930	4,930	4,930	4,930	4,930	4,930															
	Forest Mitigation Gains				(67)	(66)	(67)	(67)	(66)	(67)	(40)	(40)	(40)	(40)	(40)	(40)	(40)	(40)	(40)	(40)	(70)	(70)	(70)	(70)	(70)		
	Auto Emission Increases					1	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3	3		
	Net Increases	231	5,161	5,161	5,094	5,096	5,095	5,095	5,096	5,116	4,891	4,891	(37)	(37)	(37)	(37)	(37)	(37)	(37)	(37)	(67)	(67)	(67)	(67)	(67)		
	Cost/Metric Ton Undiscounted	$ 61	$ 62	$ 63	$ 65	$ 66	$ 67	$ 68	$ 69	$ 70	$ 72	$ 73	$ 74	$ 75	$ 76	$ 78	$ 79	$ 80	$ 81	$ 82	$ 84	$ 85	$ 86	$ 87	$ 88		
2.50%	Discount Factor	0.904	0.881	0.859	0.838	0.817	0.796	0.776	0.757	0.738	0.720	0.702	0.684	0.667	0.650	0.634	0.618	0.603	0.588	0.573	0.559	0.545	0.531	0.518	0.505		
$2,671,000	Discounted Value	$12,700	$281,900	$279,300	$277,300	$274,700	$271,800	$269,000	$266,200	$264,300	$253,400	$250,500	($1,900)	($1,900)	($1,800)	($1,800)	($1,800)	($1,800)	($1,800)	($1,700)	($3,100)	($3,100)	($3,100)	($3,000)	($3,000)		

Alternative	Category	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
B	Forest Sequestration Losses	836	836	836	836	836	836	836	836	912															
	Construction Emissions		5,710	5,710	5,710	5,710	5,710	5,710	5,710	5,710	5,710	5,710													
	Forest Mitigation Gains			0	(250)	(250)	(250)	(250)	(250)	(250)	(150)	(150)	(150)	(150)	(150)	(150)	(150)	(150)	(150)	(150)	(220)	(220)	(220)	(220)	(220)
	Auto Emission Increases					7	7	7	7	7	7	7	15	16	16	16	16	16	16	16	16	16	16	16	16
	Net Increases	836	6,546	6,546	6,296	6,303	6,303	6,303	6,303	6,379	5,567	5,567	(135)	(134)	(134)	(134)	(134)	(134)	(134)	(134)	(204)	(204)	(204)	(204)	(204)
	Cost/Metric Ton Undiscounted	$ 61	$ 62	$ 63	$ 65	$ 66	$ 67	$ 68	$ 69	$ 70	$ 72	$ 73	$ 74	$ 75	$ 76	$ 78	$ 79	$ 80	$ 81	$ 82	$ 84	$ 85	$ 86	$ 87	$ 88
3.00%	Discount Factor	0.885	0.859	0.833	0.808	0.784	0.760	0.737	0.715	0.694	0.673	0.653	0.633	0.614	0.596	0.578	0.561	0.544	0.527	0.512	0.496	0.481	0.467	0.453	0.439
$3,098,000	Discounted Value	$45,100	$348,500	$343,500	$330,700	$326,000	$321,000	$316,100	$311,100	$309,800	$269,800	$265,300	($6,300)	($6,200)	($6,100)	($6,000)	($5,900)	($5,800)	($5,700)	($5,600)	($8,500)	($8,300)	($8,200)	($8,000)	($7,900)

Alternative	Category	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
C	Forest Sequestration Losses	1,331	1,331	1,331	1,331	1,331	1,331	1,331	1,331	1,452															
	Construction Emissions		7,010	7,010	7,010	7,010	7,010	7,010	7,010	7,010	7,010	7,010													
	Forest Mitigation Gains				(383)	(384)	(383)	(383)	(384)	(383)	(250)	(250)	(250)	(250)	(250)	(250)	(250)	(250)	(250)	(250)	(350)	(350)	(350)	(350)	(350)
	Auto Emission Increases					6	6	6	6	6	6	6	14	14	14	14	14	14	14	14	15	15	15	15	15
	Net Increases	1,331	8,341	8,341	7,958	7,963	7,964	7,964	7,963	8,085	6,766	6,766	(236)	(236)	(236)	(236)	(236)	(236)	(236)	(236)	(335)	(335)	(335)	(335)	(335)
	Cost/Metric Ton Undiscounted	$ 61	$ 62	$ 63	$ 65	$ 66	$ 67	$ 68	$ 69	$ 70	$ 72	$ 73	$ 74	$ 75	$ 76	$ 78	$ 79	$ 80	$ 81	$ 82	$ 84	$ 85	$ 86	$ 87	$ 88
3.00%	Discount Factor	0.885	0.859	0.833	0.808	0.784	0.760	0.737	0.715	0.694	0.673	0.653	0.633	0.614	0.596	0.578	0.561	0.544	0.527	0.512	0.496	0.481	0.467	0.453	0.439
$3,873,000	Discounted Value	$71,900	$444,100	$437,700	$417,900	$411,900	$405,700	$399,400	$393,000	$392,700	$327,900	$322,400	($11,100)	($10,900)	($10,700)	($10,600)	($10,500)	($10,300)	($10,100)	($9,900)	($14,000)	($13,700)	($13,500)	($13,200)	($13,000)

		2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
M	Forest Sequestration Losses	5,511	5,511	5,511	5,511	5,511	5,511	5,511	5,511	6,012															
	Construction Emissions		12,950	12,950	12,950	12,950	12,950	12,950	12,950	12,950	12,950	12,950													
	Forest Mitigation Gains				(1,617)	(1,616)	(1,617)	(1,617)	(1,616)	(1,617)	(1,020)	(1,020)	(1,020)	(1,020)	(1,020)	(1,020)	(1,020)	(1,020)	(1,020)	(1,020)	(1,480)	(1,480)	(1,480)	(1,480)	(1,480)
	Auto Emission Increases					4	4	4	4	4	5	5	8	8	8	8	8	8	8	8	8	9	9	9	9
	Net Increases	5,511	18,461	18,461	16,844	16,849	16,848	16,848	16,849	17,349	11,935	11,935	(1,012)	(1,012)	(1,012)	(1,012)	(1,012)	(1,012)	(1,012)	(1,012)	(1,472)	(1,471)	(1,471)	(1,471)	(1,471)
	Cost/Metric Ton Undiscounted	$ 61	$ 62	$ 63	$ 65	$ 66	$ 67	$ 68	$ 69	$ 70	$ 72	$ 73	$ 74	$ 75	$ 76	$ 78	$ 79	$ 80	$ 81	$ 82	$ 84	$ 85	$ 86	$ 87	$ 88
3.00%	Discount Factor	0.885	0.859	0.833	0.808	0.784	0.760	0.737	0.715	0.694	0.673	0.653	0.633	0.614	0.596	0.578	0.561	0.544	0.527	0.512	0.496	0.481	0.467	0.453	0.439
$7,874,000	Discounted Value	$297,600	$982,900	$968,800	$884,600	$871,500	$858,200	$844,800	$831,600	$842,600	$578,300	$568,800	($47,400)	($46,600)	($45,800)	($45,600)	($44,800)	($44,000)	($43,200)	($42,500)	($61,400)	($60,200)	($59,100)	($58,000)	($56,900)

		2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
O	Forest Sequestration Losses	4,191	4,191	4,191	4,191	4,191	4,191	4,191	4,191	4,572															
	Construction Emissions		10,300	10,300	10,300	10,300	10,300	10,300	10,300	10,300	10,300	10,300													
	Forest Mitigation Gains				(1,233)	(1,234)	(1,233)	(1,233)	(1,234)	(1,233)	(770)	(770)	(770)	(770)	(770)	(770)	(770)	(770)	(770)	(770)	(1,120)	(1,120)	(1,120)	(1,120)	(1,120)
	Auto Emission Increases					6	6	6	6	6	6	6	16	17	17	17	17	18	18	18	19	19	19	20	20
	Net Increases	4,191	14,491	14,491	13,258	13,263	13,264	13,264	13,263	13,645	9,536	9,536	(754)	(753)	(753)	(753)	(753)	(752)	(752)	(752)	(1,101)	(1,101)	(1,101)	(1,100)	(1,100)
	Cost/Metric Ton Undiscounted	$ 61	$ 62	$ 63	$ 65	$ 66	$ 67	$ 68	$ 69	$ 70	$ 72	$ 73	$ 74	$ 75	$ 76	$ 78	$ 79	$ 80	$ 81	$ 82	$ 84	$ 85	$ 86	$ 87	$ 88
3.00%	Discount Factor	0.885	0.859	0.833	0.808	0.784	0.760	0.737	0.715	0.694	0.673	0.653	0.633	0.614	0.596	0.578	0.561	0.544	0.527	0.512	0.496	0.481	0.467	0.453	0.439
$6,227,000	Discounted Value	$226,300	$771,500	$760,400	$696,300	$686,100	$675,600	$665,100	$654,600	$662,700	$462,100	$454,500	($35,300)	($34,700)	($34,100)	($33,900)	($33,300)	($32,700)	($32,100)	($31,600)	($45,900)	($45,100)	($44,200)	($43,300)	($42,500)

		2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050		
P1	Forest Sequestration Losses	1,892	1,892	1,892	1,892	1,892	1,892	1,892	1,892	2,064																17,200	
	Construction Emissions		9,810	9,810	9,810	9,810	9,810	9,810	9,810	9,810	9,810	9,810														98,100	
	Forest Mitigation Gains				(550)	(550)	(550)	(550)	(550)	(550)	(350)	(350)	(350)	(350)	(350)	(350)	(350)	(350)	(350)	(350)	(510)	(510)	(510)	(510)	(510)	(9,350)	
	Auto Emission Increases					4	4	4	4	4	4	4	9	9	9	9	9	9	9	9	9	10	10	10	10	149	115,449
	Net Increases	1,892	11,702	11,702	11,152	11,156	11,156	11,156	11,156	11,328	9,464	9,464	(341)	(341)	(341)	(341)	(341)	(341)	(341)	(341)	(501)	(500)	(500)	(500)	(500)		0
	Cost/Metric Ton Undiscounted	$ 61	$ 62	$ 63	$ 65	$ 66	$ 67	$ 68	$ 69	$ 70	$ 72	$ 73	$ 74	$ 75	$ 76	$ 78	$ 79	$ 80	$ 81	$ 82	$ 84	$ 85	$ 86	$ 87	$ 88		
3.00%	Discount Factor	0.885	0.859	0.833	0.808	0.784	0.760	0.737	0.715	0.694	0.673	0.653	0.633	0.614	0.596	0.578	0.561	0.544	0.527	0.512	0.496	0.481	0.467	0.453	0.439		
$5,418,000	Discounted Value	$102,200	$623,000	$614,100	$585,700	$577,100	$568,200	$559,400	$550,600	$550,200	$458,600	$451,000	($16,000)	($15,700)	($15,400)	($15,400)	($15,100)	($14,800)	($14,600)	($14,300)	($20,900)	($20,500)	($20,100)	($19,700)	($19,300)		

		2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
P2	Forest Sequestration Losses	1,452	1,452	1,452	1,452	1,452	1,452	1,452	1,452	1,584															
	Construction Emissions		8,260	8,260	8,260	8,260	8,260	8,260	8,260	8,260	8,260	8,260													
	Forest Mitigation Gains				(417)	(416)	(417)	(417)	(416)	(417)	(270)	(270)	(270)	(270)	(270)	(270)	(270)	(270)	(270)	(270)	(390)	(390)	(390)	(390)	(390)
	Auto Emission Increases					1	1	1	1	1	1	1	5	6	6	6	6	6	6	6	6	6	6	6	6
	Net Increases	1,452	9,712	9,712	9,295	9,297	9,296	9,296	9,297	9,428	7,991	7,991	(265)	(264)	(264)	(264)	(264)	(264)	(264)	(264)	(384)	(384)	(384)	(384)	(384)
	Cost/Metric Ton Undiscounted	$ 61	$ 62	$ 63	$ 65	$ 66	$ 67	$ 68	$ 69	$ 70	$ 72	$ 73	$ 74	$ 75	$ 76	$ 78	$ 79	$ 80	$ 81	$ 82	$ 84	$ 85	$ 86	$ 87	$ 88
3.00%	Discount Factor	0.885	0.859	0.833	0.808	0.784	0.760	0.737	0.715	0.694	0.673	0.653	0.633	0.614	0.596	0.578	0.561	0.544	0.527	0.512	0.496	0.481	0.467	0.453	0.439
$4,528,000	Discounted Value	$78,400	$517,100	$509,700	$488,200	$480,900	$473,500	$466,100	$458,900	$457,900	$387,200	$380,800	($12,400)	($12,200)	($12,000)	($11,900)	($11,700)	($11,500)	($11,300)	($11,100)	($16,000)	($15,700)	($15,400)	($15,100)	($14,800)

P3		2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
	Forest Sequestration Losses	1,914	1,914	1,914	1,914	1,914	1,914	1,914	1,914	2,088															
	Construction Emissions		9,760	9,760	9,760	9,760	9,760	9,760	9,760	9,760	9,760	9,760													
	Forest Mitigation Gains				(567)	(566)	(567)	(567)	(566)	(567)	(350)	(350)	(350)	(350)	(350)	(350)	(350)	(350)	(350)	(350)	(510)	(510)	(510)	(510)	(510)
	Auto Emission Increases					4	4	4	4	4	4	4	9	9	9	9	9	9	9	9	9	10	10	10	10
	Net Increases	1,914	11,674	11,674	11,107	11,112	11,111	11,111	11,112	11,285	9,414	9,414	(341)	(341)	(341)	(341)	(341)	(341)	(341)	(341)	(501)	(500)	(500)	(500)	(500)
	Cost/Metric Ton Undiscounted	$ 61	$ 62	$ 63	$ 65	$ 66	$ 67	$ 68	$ 69	$ 70	$ 72	$ 73	$ 74	$ 75	$ 76	$ 78	$ 79	$ 80	$ 81	$ 82	$ 84	$ 85	$ 86	$ 87	$ 88
3.00%	Discount Factor	0.885	0.859	0.833	0.808	0.784	0.760	0.737	0.715	0.694	0.673	0.653	0.633	0.614	0.596	0.578	0.561	0.544	0.527	0.512	0.496	0.481	0.467	0.453	0.439
$5,398,000	Discounted Value	$103,400	$621,500	$612,600	$583,300	$574,800	$565,900	$557,200	$548,400	$548,100	$456,200	$448,600	($16,000)	($15,700)	($15,400)	($15,400)	($15,100)	($14,800)	($14,600)	($14,300)	($20,900)	($20,500)	($20,100)	($19,700)	($19,300)

		2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
P4	Forest Sequestration Losses	2,090	2,090	2,090	2,090	2,090	2,090	2,090	2,090	2,280															
	Construction Emissions		9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900													
	Forest Mitigation Gains				(617)	(616)	(617)	(617)	(616)	(617)	(380)	(380)	(380)	(380)	(380)	(380)	(380)	(380)	(380)	(380)	(560)	(560)	(560)	(560)	(560)
	Auto Emission Increases					4	4	4	4	4	4	4	9	9	9	9	9	9	9	9	9	10	10	10	10
	Net Increases	2,090	11,990	11,990	11,373	11,378	11,377	11,377	11,378	11,567	9,524	9,524	(371)	(371)	(371)	(371)	(371)	(371)	(371)	(371)	(551)	(550)	(550)	(550)	(550)
	Cost/Metric Ton Undiscounted	$ 61	$ 62	$ 63	$ 65	$ 66	$ 67	$ 68	$ 69	$ 70	$ 72	$ 73	$ 74	$ 75	$ 76	$ 78	$ 79	$ 80	$ 81	$ 82	$ 84	$ 85	$ 86	$ 87	$ 88
3.00%	Discount Factor	0.885	0.859	0.833	0.808	0.784	0.760	0.737	0.715	0.694	0.673	0.653	0.633	0.614	0.596	0.578	0.561	0.544	0.527	0.512	0.496	0.481	0.467	0.453	0.439
$5,513,000	Discounted Value	$112,900	$638,400	$629,200	$597,300	$588,600	$579,500	$570,500	$561,600	$561,800	$461,500	$453,900	($17,400)	($17,100)	($16,800)	($16,700)	($16,400)	($16,100)	($15,900)	($15,600)	($23,000)	($22,500)	($22,100)	($21,700)	($21,300)

		2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
R	Forest Sequestration Losses	231	231	231	231	231	231	231	231	252															
	Construction Emissions		4,930	4,930	4,930	4,930	4,930	4,930	4,930	4,930	4,930	4,930													
	Forest Mitigation Gains				(67)	(66)	(67)	(67)	(66)	(67)	(40)	(40)	(40)	(40)	(40)	(40)	(40)	(40)	(40)	(40)	(70)	(70)	(70)	(70)	(70)
	Auto Emission Increases					1	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3	3
	Net Increases	231	5,161	5,161	5,094	5,096	5,095	5,095	5,096	5,116	4,891	4,891	(37)	(37)	(37)	(37)	(37)	(37)	(37)	(37)	(67)	(67)	(67)	(67)	(67)
	Cost/Metric Ton Undiscounted	$ 61	$ 62	$ 63	$ 65	$ 66	$ 67	$ 68	$ 69	$ 70	$ 72	$ 73	$ 74	$ 75	$ 76	$ 78	$ 79	$ 80	$ 81	$ 82	$ 84	$ 85	$ 86	$ 87	$ 88
3.00%	Discount Factor	0.885	0.859	0.833	0.808	0.784	0.760	0.737	0.715	0.694	0.673	0.653	0.633	0.614	0.596	0.578	0.561	0.544	0.527	0.512	0.496	0.481	0.467	0.453	0.439
$2,548,000	Discounted Value	$12,500	$274,800	$270,800	$267,500	$263,600	$259,500	$255,500	$251,500	$248,500	$237,000	$233,100	($1,700)	($1,700)	($1,700)	($1,700)	($1,600)	($1,600)	($1,600)	($1,600)	($2,800)	($2,700)	($2,700)	($2,600)	($2,600)