

Memorandum

TO: Docket Number EPA-HQ-OAR-2015-0216 (Control Techniques Guideline for the Oil and Natural Gas Industry)

DATE: February 15, 2018

SUBJECT: Estimated Avoided Costs and Forgone Emission Reductions Associated with the Potential Withdrawal of the Control Techniques Guidelines for the Oil and Natural Gas Industry

INTRODUCTION

The Environmental Protection Agency (EPA) is proposing to withdraw the *Control Techniques Guidelines for the Oil and Natural Gas Industry* (CTG). The notice for the CTG was published in the Federal Register on October 27, 2016.¹ Recommendations in the CTG in part rely on the analysis and conclusions in the 2016 Final Rule “Oil and Natural Gas Sector: Emission Standards for New, Reconstructed and Modified Sources” (2016 NSPS Rule), which the agency has since announced would undergo a broad reconsideration.² This memorandum presents estimates of the avoided regulatory compliance costs and forgone emission reductions associated with the potential withdrawal of the CTG.

The memorandum presents background on the final CTG and the methods used to assess the potential impacts of the proposal to withdraw the CTG. The memorandum adjusts the potential costs and emissions reductions associated with the final CTG³ for state rules that have been finalized since the CTG was released, as well as adjusts compliance costs from 2012\$ to 2016\$. These estimates then provide the basis to present potential avoided compliance costs and forgone emissions reductions from the potential withdrawal of the CTG under two perspectives:

1. Expenditures and emissions changes in the oil and natural gas industry, assuming all

¹ The notice of availability of the CTG can be found at 81 FR 74798. The notice of proposed withdrawal of the CTG can be found at *[placeholder for final publication]*.

² 81 FR 35823

³ Oil and Natural Gas Industry Estimated Reasonably Available Control Technology Emission Reductions and Cost of Control. Docket ID No. EPA-HQ-OAR-2015-0216-0227.

states fully adopt controls under the CTG, but would avoid any controls in the absence of the CTG; and

2. Net expenditures and emissions changes across all industries, reflecting that some sources in Non-attainment areas (NA) will still need to incur costs to obtain emission reductions under NAAQS state implementation plans in the scenario the CTG is withdrawn.

The two perspectives are described in more detail in the background and methods section. To better understand how costs and emissions changes under the two analytical perspectives are estimated, we present the Venn Diagram in Figure 1 illustrating the relationship of regions in which sources are affected by the CTG.

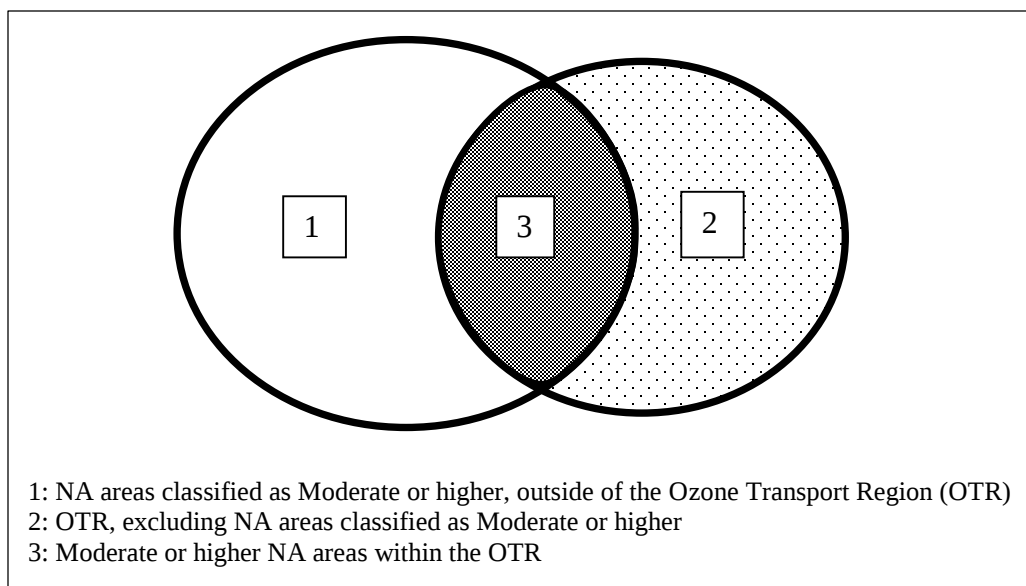


Figure 1. CTG Affected Areas

Area 1 corresponds to Moderate or higher NA areas in states that are not in the Ozone Transport Region (OTR). Area 2 corresponds to the portions of the OTR that are outside of Moderate or higher NA areas. Area 3 corresponds to the portions of the Moderate or higher NA areas that are also in the OTR. Under the first analytic perspective, estimates of expenditures and emissions changes correspond to oil and natural gas sector sources in all areas in the Venn diagram, those in Areas 1, 2, and 3, being affected by the potential withdrawal of the CTG. Under the second analytical perspective, expenditure and emissions changes correspond to those experienced by oil and natural gas sources in Area 2 only, since sources in the Moderate or higher NA areas will need to obtain emission reductions even in absence of the CTG.

These estimates are presented annually over the 2021-2035 horizon. The estimates are also presented in present value (PV) and equivalent annual value (EAV) forms. As the state implementation plan (SIP) submission deadline for sources covered by the CTG is October 27, 2018, and the deadline for emissions sources to implement the emission controls for the oil and natural gas sector laid out in SIPs is January 1, 2021,⁴ the EPA assumes that, to date, there have been no regulatory compliance costs expended as a result of the CTG and that the potential withdrawal of the CTG will result in avoided costs and forgone emission reductions.

Table 1 shows the PV and EAV of the avoided costs under the two analytical perspectives mentioned above. For the first perspective, the changes expected in the oil and natural gas industry are shown in the “All Areas” column in the table. The PV of avoided costs over 2021 through 2035 under this perspective is estimated to be \$599 million assuming a 3 percent discount rate and \$439 million assuming a discount rate of 7 percent. The EAV from this perspective is approximately \$45 million per year and \$49 million per year assuming 3 percent and 7 percent discount rates, respectively. Under the second perspective, the estimates that reflect expenditures and emissions changes across all industries are presented in the “OTR” column of the table. The PV of avoided costs over 2021 through 2035 under this perspective is estimated to be \$14 million assuming a 3 percent discount rate and \$16 million assuming a discount rate of 7 percent. The EAV from this perspective is approximately \$1.2 million per year and \$1.6 million per year assuming 3 percent and 7 percent discount rates, respectively. The table also shows the forgone emission reductions per year.

⁴ Memorandum: Implementing Reasonably Available Control Technology Requirements for Sources Covered by the 2016 Control Techniques Guidelines for the Oil and Natural Gas Industry. Docket ID No. EPA-HQ-OAR-2015-0216-0238.

Table 1. Estimated Avoided Compliance Costs and Forgone Emission Reductions of Affected Sources from Withdrawing CTG

		All Areas	OTR Outside of Moderate and higher NA Areas
Discounted Avoided Total Costs (millions, 2016\$)			
3%	PV	\$599	\$14
	EAV	\$49	\$1.2
7%	PV	\$439	\$16
	EAV	\$45	\$1.6
Forgone Emission Reductions (tons per year)			
	VOC	64,200	15,900
	Methane ¹	199,700	58,200
	HAP	2,400	610

¹ Methane is measured in short tons.

BACKGROUND AND METHODS

States with Moderate or higher NA areas must achieve required volatile organic compound (VOC) and oxides of nitrogen (NO_x) emissions reductions in those areas sufficient to timely attain the National Ambient Air Quality Standards (NAAQS). The final CTG does not require facilities in the oil and natural gas industry to adopt specific control technologies, but recommends reasonably available control technology (RACT) for oil and natural gas emission sources in Moderate or higher ozone NA areas and the OTR. The CTG obligates states with NA areas classified Moderate or higher and states within the OTR to consider RACT for non-major sources in the oil and natural gas industry in their state when creating or revising their SIPs.⁵ A withdrawal of the CTG would relieve states from the obligation of considering RACT for all non-major emissions sources specified in the CTG for the oil and natural gas sector.

This memorandum estimates regulatory compliance cost reductions from the potential withdrawal of the CTG for two analytical perspectives. First, the memorandum estimates the avoided expenditures by the oil and natural gas sector if all non-major sources in relevant NA areas and the OTR avoided adopting any controls in the absence of the CTG. This perspective

⁵ The Clean Air Act (CAA) requires all states with Moderate or higher NA areas and OTR states must review and adopt RACT for all major emissions sources of VOC and NO_x (per section CAA section 182(b)(2)(C)), including those in the oil and natural gas sector, regardless of whether the CTG is in effect. The compliance cost and emissions reductions estimates for the final CTG did not include impacts of this requirement to control major emission sources of VOC and NO_x.

focuses on changes in the oil and natural gas industry alone. Second, the memorandum estimates the avoided incremental expenditures across all industries from the potential withdrawal of the CTG, recognizing that NA areas will still require emission reductions to meet the NAAQS.⁶ This perspective assumes that, in the absence of the CTG, all NA areas classified as Moderate or higher will incur costs to sources not affected by the CTG equal to the costs that would have been incurred by the non-major oil and gas sources in the CTG if the CTG is not withdrawn. Therefore, the avoided incremental expenditures across all industries from the withdrawal of the CTG is estimated as the avoided costs in the OTR.

When the CTG was published, EPA made available estimates of the emission reductions and compliance expenditures required by the oil and natural gas industry under a hypothetical scenario where states with potentially affected oil and natural gas emission sources adopt the recommended RACT.⁷ The scope of that document did not account for the possibility that emission reductions in the oil and natural gas sector induced by the CTG would displace other emission reductions, as states with NA areas classified as Moderate or higher must plan for VOC and NOx emission reductions to demonstrate their NA area can model attainment for the NAAQS, regardless of whether the oil and natural gas CTG is in place. As a result, the estimates in the CTG analysis reflected the potential expenditures in the oil and natural gas sector from adopting the recommended RACT, but were not an assessment of the potential change in compliance expenditures across all industries.

The perspective that considers changes in compliance expenditures across all industries provides an estimate of the incremental impacts to society of the CTG. These estimates reflect that, in NA areas, CTG-based state requirements on oil and natural gas sector sources might displace reductions and costs from these and other sources resulting from SIPs developed in absence of the CTG. In contrast, any oil and natural gas sector CTG-related costs and emissions reductions in OTR areas that are not in NA areas might not displace costs and emission reductions occurring in absence of the CTG. Therefore, the estimated cost of the CTG in these

⁶ This analysis involves estimates on compliance costs for affected emissions sources, and does not address the burdens of state governments to develop and implement RACT SIPs. These burdens are addressed in OMB-approved Information Collection

Requests covering implementation on the ozone NAAQS.

⁷ Oil and Natural Gas Industry Estimated Reasonably Available Control Technology Emission Reductions and Cost of Control. Docket ID No. EPA-HQ-OAR-2015-0216-0227.

non-NA OTR areas provides an estimate of the net impact of the CTG across all industries.

Although some states may be able to achieve enough emission reductions without considering emission reductions from CTG-specified sources, others may find it necessary to develop SIPs that include at least some reductions through adoption of the control technologies recommended in the CTG, regardless of the status of the CTG. Without a detailed assessment of specific NA source characteristics and predictions of SIPs, the EPA is unable to accurately determine which states, if any, would implement RACT for oil and natural gas sources under a withdrawal of the CTG. For that reason, under the analytic perspective focusing on expenditures in the oil and natural gas sector alone, the estimate of reduced expenditures due to the proposed withdrawal of the CTG is an upper bound.

ANALYSIS AND RESULTS

Adjustments in Final CTG Cost and Emissions Reductions for Dollar Year and New State Requirements

We begin with estimating the avoided compliance costs to the industry from the proposed withdrawal of the CTG, drawing upon the analysis that accompanied the final CTG. We adjust the cost estimates from 2012\$ to 2016\$ using the Gross Domestic Product-Implicit Price Deflator (GDP-IPD). We also update this analysis to account for the requirements finalized by California on October 1, 2017.⁸ California's "Greenhouse Gas Emission Standards for Crude Oil and Natural Gas Facilities" (CA Rule) affects numerous new and existing oil and natural gas sector sources,⁹ and likely would have supplanted the need for additional requirements under the final CTG, had the CTG been implemented as written by California in their SIPs. Important for this analysis of the potential withdrawal of the CTG, the CA requirements affect fugitive emissions (§95669. Leak Detection and Repair) and storage vessels (§95668(a). Separator and Tank Systems). We are soliciting comment on any information or data from state rules, in addition to the CA Rule, that would have supplanted the need for additional requirements under the final CTG. We are also soliciting comment on state actions with respect to achieving emission reductions from non-major oil and natural gas sources that

⁸ <https://www.arb.ca.gov/regact/2016/oilandgas2016/oilandgas2016.htm>. Accessed 1/25/18.

⁹ [https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=I401BB8146DA14B519A991D7827913AEE&originationContext=documenttoc&transitionType=Default&contextData=\(sc.Default\)](https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=I401BB8146DA14B519A991D7827913AEE&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default)). Accessed 1/25/18.

would be affected by the CTG in the absence of the CTG.

Table 2 presents the annualized regulatory compliance costs that would be incurred by the oil and natural gas sector as presented in the final CTG from the Original 2016 Analysis (in 2012\$ and in 2016\$), and from the Updated Analysis we performed (in 2016\$), which accounts for the CA Rule, as well as for adjusting the assumed value of recovered wellhead natural gas from \$4.00/mcf to \$4.10/mcf to be consistent with 2017 Annual Energy Outlook (AEO) projections.¹⁰ The table also presents the emission reductions from the original analysis and the updated analysis. The costs and emission reductions estimated in Table 2 are based on the analytical perspective that focuses on expenditures in the oil and natural gas sector alone, assuming all states fully adopt RACT under the CTG but would avoid controls in the absence of the CTG. These costs and emissions reductions are the total costs and emissions reductions for all OTR and Moderate and higher NA areas. Source-level summary tables of the costs and emission reductions of the original analysis (in 2016\$) and of the updated analysis can be found in the Table A.1 through Table A.4 in the Appendix.

Table 2. Estimates of the Annualized Regulatory Compliance Costs Incurred by the Oil and Natural Gas Sector from the Final 2016 CTG (in 2012\$ and in 2016\$) and with Updates (in 2016\$)¹

Total Annualized Costs⁴ (millions)	Original 2016 Analysis²		Updated Analysis³
	(2012\$)⁵	(2016\$)	(2016\$)
Without Product Recovery	\$135	\$139	\$113
With Product Recovery	\$101	\$102	\$77
Emission Reductions (tons per year)			
VOC	79,900		64,300
Methane (short tons)	204,900		199,600
Hazardous Air Pollutants (HAP)	2,900		2,400

¹ Assumes states with potentially affected sources implement RACT as written in the final 2016 CTG.

² The avoided costs of the OTR and the Moderate or higher NA areas, as estimated in the original 2016 analysis.

³ The avoided costs of the OTR and the Moderate or higher NA areas, after accounting for the recently finalized oil and gas regulations in California (CA) and adjusting the assumed value of recovered wellhead natural gas from \$4.00/mcf to \$4.10/mcf to be consistent with 2017 Annual Energy Outlook (AEO) projections.

⁴ Total capital cost annualized at a 7 percent interest rate, plus on year of avoided operations and maintenance costs

¹⁰ EPA used the Energy Information Administration's (EIA) 2017 Annual Energy Outlook's (AEO) "no Clean Power Plan (CPP)" case projections for the price of natural gas in order to estimate the value of forgone product recovery. AEO presents Henry Hub prices in 2016 dollars in \$/MMBtu. Using 1 MMBtu = 1.028 Mcf, and assuming Henry Hub prices are 11 percent higher than at the wellhead, prices were converted into \$/Mcf at the wellhead. As a result of using the 2017 AEO, for Table 1, we adjusted the assumed value of natural gas product recovery to be \$4.10/Mcf in 2021.

minus the value of one year of forgone product recovery.

5 Rounding conventions in the original analysis show these values as \$140 and \$100, respectively. It was changed for this memo to better illustrate the difference between the results in 2012\$ and in 2016\$.

Avoided Cost Impacts over the 2021 to 2035 Time Horizon

Table 3 shows a summary of the estimated compliance costs that will not be incurred by the oil and natural gas sector under the potential withdrawal of the CTG. The avoided costs are split into avoided costs within all Moderate or higher NA areas (either within or outside the OTR) (\$70 millions) and costs avoided within other areas of the OTR (\$7 million). These two groups correspond to Area 1 plus Area 3, and Area 2, respectively, in the Venn diagram in Figure 1. As described in the previous section, the total across these areas (\$77 million) represents the potentially avoided costs under an analytic perspective that focuses on changes in the oil and natural gas sector assuming sources in all areas would avoid any controls in the absence of the CTG. An analytic perspective that focuses on net changes across all industries reflects that sources in Moderate or higher NA areas might need to incur costs to obtain emission reductions under SIPs in the scenario the CTG is withdrawn. We estimate the costs for this analytical perspective as those accruing to sources in the portions of the OTR outside of Moderate and higher NA areas. Based on the estimates in Table 3, under this analytic scope, the net annualized compliance cost savings from the withdrawal of the CTG is estimated to be \$7 million (2016\$).

Table 3. Avoided Compliance Costs to Affected Sources from withdrawing the CTG (millions, 2016\$)

	Total Avoided Capital Cost	Forgone Annual Operating and Maintenance Cost	Forgone Annual Value of Product Recovery	Total Avoided Cost with Savings	Total Avoided Annualized Cost w/ savings
Mod and higher NA areas	\$289	\$57	\$32	\$313	\$70
OTR outside of Mod and higher NA areas	\$51	\$8.6	\$14	\$45	\$7.0
All Areas	\$339	\$65	\$46	\$358	\$77

Totals may not sum due to independent rounding

The costs and emission reductions that would have been incurred in adopting the control technology recommended in the CTG continue over the assumed lifetime of the technology. To better understand the avoided costs over time, the EPA estimates a stream of avoided costs from 2021 through 2035, as well as the PV of those avoided costs. The EPA estimates avoided costs

beginning in 2021 because RACT would have to be adopted by 2021, as explained above. The EPA chooses to estimate these avoided costs through the year 2035 to represent the full assumed lifetime of longest-lived type of equipment that would have been purchased if the RACT were adopted (see Table 4). In addition, the EPA assumes that the affected source counts do not change over time. The number of affected sources that would have been potentially affected by CTG may change over time due to sources being taken offline, a modification that would trigger entrance into the 2016 Rule, or future standards and designation changes.

The assumed lifetime of the recommended RACT discussed in the CTG ranges from 3 to 15 years and is shown in Table 4 for each emission source assessed. These lifetimes are used in determining when the capital expenditures would have been re-incurred as equipment is assumed to be replaced.

Table 4. Lifetime of Assessed RACT

Emission Source	Lifetime (years)
Fugitives – Natural Gas Well Sites	8
Fugitives - Oil Well Sites	8
Fugitives – Gathering and Boosting (G&B) Stations	8
Equipment Leaks - Processing Plants	8
Reciprocating Compressors - G&B Stations	3
Reciprocating Compressors - Processing	3
Centrifugal Compressors – Processing	10
NG Driven Pneumatic Controllers – Production	15
NG Driven Pneumatic Controllers – Processing	10
NG Driven Pneumatic Controllers - Production - Diaphragm	10
Storage Vessels	15

Over the 15 years assessed in this PV analysis, the price of natural gas is expected to increase by about 11 percent, though there is a slight decrease projected between 2020 and 2022. For this analysis, the EPA used the Energy Information Administration’s (EIA) 2017 AEO’s “no Clean Power Plan (CPP)” case projections for the price of natural gas in order to estimate the value of forgone product recovery.¹¹ AEO presents Henry Hub prices in 2016 dollars in \$/MMBtu. Using 1 MMBtu = 1.028 Mcf, and assuming Henry Hub prices are 11

¹¹ Available at <https://www.eia.gov/outlooks/aeo/data/browser/>

percent higher than at the wellhead, prices were converted into \$/Mcf at the wellhead.¹²

Projected natural gas prices under both the reference (CPP) case and the No CPP case in \$/Mcf at the wellhead from 2018 through 2040 are shown in Figure 2.¹³ As can be seen in this figure, difference between natural gas prices with and without CPP are small, so the choice of projection scenario has little influence on overall cost results.

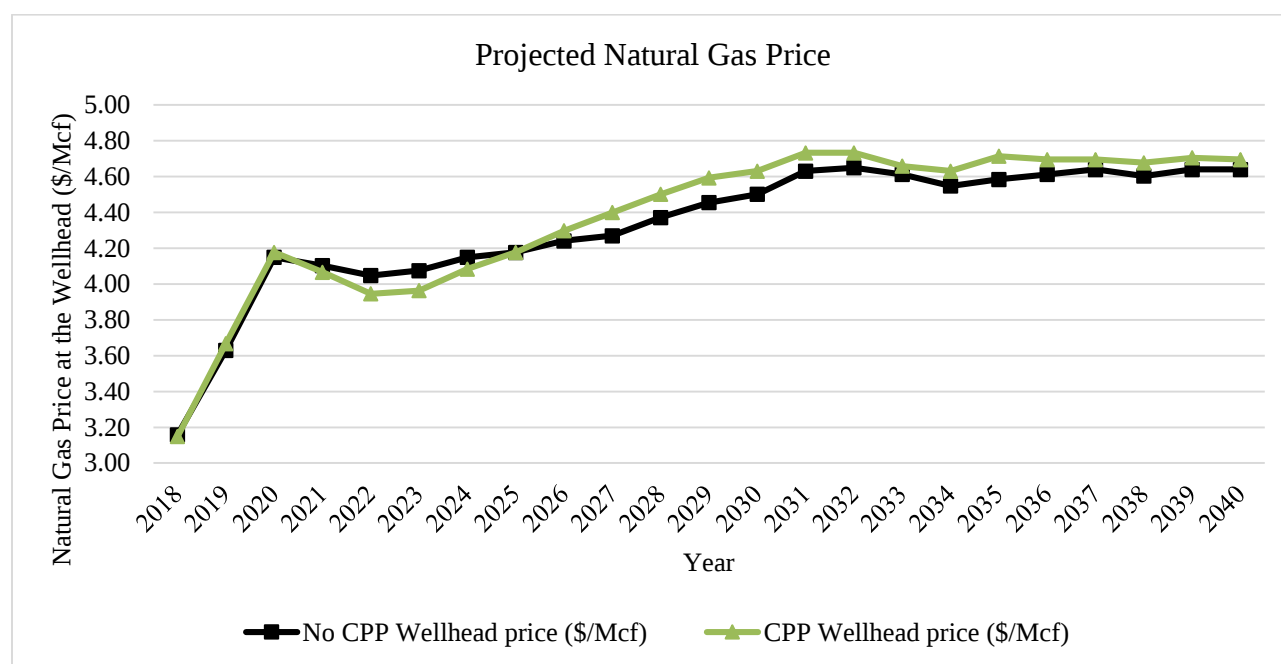


Figure 2. EIA Projected Natural Gas Prices Under the CPP and No CPP Scenarios (\$/Mcf at the Wellhead)

To estimate the PV and EAV of avoided costs, the EPA first estimates an undiscounted stream of avoided costs, under the assumptions regarding the equipment lives and natural gas prices as described above.¹⁴ Avoided capital costs that the EPA estimates would have occurred under the CTG are assumed to be re-incurred with the replacement of control technology at the end of estimated lifetimes, as seen in Table 4. As source counts are estimated to remain constant over time, the avoided annual O&M costs and the estimated amount of natural gas that is not recovered under the withdrawal of the CTG are assumed to be constant as well. However, since

¹² An EIA study indicated that the Henry Hub price is, on average, about 11 percent higher than the wellhead price. See <http://www.eia.gov/oiaf/analysispaper/henryhub/>.

¹³ The CPP is currently under review by the EPA.

¹⁴ To see the undiscounted streams of costs, see Tables A.9 through A.11 in the appendix.

the estimated price of natural gas changes over time, as seen in Figure 2, the value of the forgone product recovery varies.

The undiscounted costs for each year are then discounted to 2016 using 3 and 7 percent discount rates and summed to estimate the PV of avoided costs.¹⁵ The PV represents the sum of the total annual costs over the lifetime of the control technologies discounted back to 2016. The PV is then used to estimate the EAV. The EAV is the annualized present values of the avoided costs. In other words, EAV takes the “lumpy” stream of costs and converts them into a single value, that when added together, equals the original stream of values in present value terms. The value of forgone product recovery is included in the calculation of the PV of avoided costs, and is therefore reflected in the EAV.

Table 5 shows the PV and EAV over the 2021-2035 horizon of the estimated avoided compliance costs to the oil and natural gas sector for the updated analysis, as well as the breakdown between the Moderate or higher NA areas and the OTR. As in the previous section, the total across these areas (“All Areas”) represents the potentially avoided costs under an analytic perspective that focuses on changes in the oil and natural gas industry alone, assuming all states fully adopt RACT under the CTG but would avoid any controls in the absence of the CTG. Based on the estimates in Table 5, under the perspective that focuses on changes in the oil and natural gas industry alone, the PV of avoided costs over 2021 through 2035 is estimated to be \$599 million assuming a 3 percent discount rate and \$439 million assuming a discount rate of 7 percent. The EAV from this perspective is approximately \$14 million per year and \$16 million per year assuming 3 percent and 7 percent discount rates, respectively.

An analytic perspective that focuses on net changes across all industries reflects that sources in Moderate or higher NA areas might need to incur costs to obtain emission reductions under SIPs in the scenario the CTG is withdrawn. The avoided costs under this perspective are reflected in the estimates of avoided costs in the OTR. Based on the estimates in Table 4, under the perspective that focuses on net changes across all industries, the PV of avoided costs over 2021 through 2035 is estimated to be \$14 million assuming a 3 percent discount rate and \$16 million assuming a discount rate of 7 percent. The EAV from this perspective is approximately \$1.2 million per year and \$1.6 million per year assuming 3 percent and 7 percent discount rates,

¹⁵ To see the discounted streams of costs, see Table A.12 through Table A.14 in the appendix.

respectively. The table also shows the forgone emission reductions per year.

Given the range of avoided costs between the two perspectives, we are soliciting comment on the uncertainty in the range of estimates. As mentioned above we are asking for any information related to state rules that would have supplanted the need for additional requirements under the final CTG, as well as on state actions with respect to sources that would be affected by the CTG in the absence of the CTG. This includes information on regulations in SIPs that would affect non-major oil and natural gas sources in the CTG, regardless of the status of the CTG.

Table 5. Avoided Compliance Costs and Forgone Emission Reductions for Affected Sources from Withdrawing the CTG

		Mod. or higher NA Areas	OTR outside of Mod. or higher NA Areas	All Areas
Discounted Avoided Total Costs (millions, 2016\$)				
3%	PV	\$585	\$14	\$599
	EAV	\$48	\$1.2	\$49
7%	PV	\$423	\$16	\$439
	EAV	\$43	\$1.6	\$45
Forgone Emission Reductions (tons per year)				
	VOC	48,300	15,900	64,200
	Methane¹	141,500	58,200	199,700
	HAP	1,800	610	2,400

Note: Totals may not sum due to independent rounding

¹ Methane is measured in short tons

Forgone emission reductions by source can be found in Table A.5 through Table A.8 in the appendix. Detailed summaries of the streams of avoided costs by source can be found in Table A.9 through Table A.14 in the appendix.

APPENDIX

The total estimated avoided capital costs, one year of avoided annual operating and maintenance (O&M) costs and one year of the forgone value of product recovery as estimated in the original analysis, in the updated analysis, for the Moderate or higher NA areas, and for the OTR are shown in Table A.1 through Table A.4, below. For more information on how the universe of affected sources was estimated, see the analysis associated with the final CTG.¹⁶ The table presents the avoided capital and annual O&M costs, the value of forgone product recovery, and the total annualized avoided cost for each emission source. Note that the total avoided costs figures presented in the table include the full avoided capital cost, one year of avoided annual O&M cost and one year of forgone product recovery. Note that the original analysis estimated all costs in 2012\$, and used a price of \$4.00/Mcf to estimate the value of product recovery, while avoided costs in the updated analysis are in 2016\$, and a price of \$4.10/Mcf is used to estimate the value of product recovery in Table A-1 through Table A-4.

¹⁶ Oil and Natural Gas Industry Estimated Reasonably Available Control Technology Emission Reductions and Cost of Control. Docket ID No. EPA-HQ-OAR-2015-0216-0227

Table A.1. Detailed Summary of the Costs to the Oil and Natural Gas Sector of the Original 2016 Analysis (2016\$)

Emission Source	Number of Sources in RACT Areas			Total Avoided Costs (Thousands, 2016\$)					
	Non-Attainment Outside of Ozone Transport	Ozone Transport Regions	Non-Attainment and Ozone Transport	Total Capital Cost	Annual Operating and Maintenance Cost	Total Cost	Value of Product Recovery	Total Cost with Savings	Total Annualized w/ savings (\$/yr)
Fugitive Emissions - Gas Well Sites	6,115	1,841	7,956	\$6,700,000	\$18,000,000	\$25,000,000	\$6,200,000	\$19,000,000	\$13,000,000
Fugitive Emissions - Oil Well Site - w/ GOR $\geq$ 300	2,686	13	2,699	\$2,300,000	\$6,100,000	\$8,400,000	\$1,100,000	\$7,400,000	\$5,400,000
Fugitive Emissions - Gathering and Boosting Stations	408	225	633	\$1,600,000	\$17,000,000	\$18,000,000	\$4,200,000	\$14,000,000	\$12,000,000
Equipment Leaks - Processing Plants	55	13	68	\$610,000	\$850,000	\$1,500,000	\$260,000	\$1,200,000	\$660,000
Reciprocating Compressors - Gathering and Boosting Stations	2,946	1,623	4,569	\$27,000,000	\$0	\$27,000,000	\$7,400,000	\$20,000,000	\$2,700,000
Reciprocating Compressors – Processing	514	117	631	\$2,900,000	\$0	\$2,900,000	\$2,600,000	\$230,000	-\$1,600,000
Centrifugal Compressors w/ Wet Seals – Processing	57	13	70	\$1,700,000	\$0	\$1,700,000	\$0	\$1,700,000	\$240,000
Natural Gas-Driven Pneumatic Controllers - Oil and Gas Production	5,634	5,095	10,729	\$31,000,000	\$0	\$31,000,000	\$13,000,000	\$18,000,000	-\$10,000,000
Natural Gas-Driven Pneumatic Controllers – Processing	13	3	16	\$33,077	\$0	\$33,000	\$3,700	\$29,000	\$1,100
Natural Gas-Driven Pneumatic Pumps - Production - Diaphragm	8,220	7,433	15,653	\$68,000,000	\$0	\$68,000,000	\$12,000,000	\$56,000,000	\$9,100,000
Storage Vessels	2,754	40	2,794	\$311,000,000	\$41,000,000	\$352,000,000	\$230,000	\$352,000,000	\$71,000,000
Note: Minor differences may result from rounding.	Total			\$430,000,000	\$83,000,000	\$535,000,000	\$47,000,000	\$488,000,000	\$102,000,000

Table A.2. Detailed Summary of the Costs to the Oil and Natural Gas Sector of the Updated Analysis

Emission Source	Number of Sources in RACT Areas			Total Avoided Costs (2016\$)					
	Non-Attainment Outside of Ozone Transport	Ozone Transport Regions	Non-Attainment and Ozone Transport	Total Capital Cost	Annual Operating and Maintenance Cost	Total Cost	Value of Product Recovery	Total Cost with Savings	Total Annualized w/ savings (\$/yr)
Fugitive Emissions - Gas Well Sites	5,970	1,841	7,811	\$6,600,000	\$18,000,000	\$24,000,000	\$6,100,000	\$18,000,000	\$13,000,000
Fugitive Emissions - Oil Well Site - w/ GOR $\geq$ 300	1,685	13	1,698	\$1,400,000	\$3,900,000	\$5,300,000	\$670,000	\$4,600,000	\$3,400,000
Fugitive Emissions - Gathering and Boosting Stations	408	225	633	\$1,600,000	\$17,000,000	\$18,000,000	\$4,200,000	\$14,000,000	\$12,000,000
Equipment Leaks - Processing Plants	55	13	68	\$610,000	\$850,000	\$1,500,000	\$260,000	\$1,200,000	\$660,000
Reciprocating Compressors - Gathering and Boosting Stations	2,946	1,623	4,569	\$27,000,000	\$0	\$27,000,000	\$7,400,000	\$20,000,000	\$2,700,000
Reciprocating Compressors – Processing	514	117	631	\$2,900,000	\$0	\$2,900,000	\$2,600,000	\$230,000	-\$1,600,000
Centrifugal Compressors w/ Wet Seals - Processing	57	13	70	\$1,700,000	\$0	\$1,700,000	\$0	\$1,700,000	\$240,000
Natural Gas-Driven Pneumatic Controllers - Oil and Gas Production	5,634	5,095	10,729	\$31,000,000	\$0	\$31,000,000	\$13,000,000	\$18,000,000	- \$10,000,000
Natural Gas-Driven Pneumatic Controllers - Processing	13	3	16	\$33,077	\$0	\$33,000	\$3,700	\$29,000	\$1,100
Natural Gas-Driven Pneumatic Pumps - Production - Diaphragm	8,220	7,433	15,653	\$68,000,000	\$0	\$68,000,000	\$12,000,000	\$56,000,000	\$9,100,000
Storage Vessels	1,751	35	1,786	\$199,000,000	\$26,000,000	\$225,000,000	\$100,000	\$225,000,000	\$48,000,000
Note: Minor differences may result from rounding.	Total			\$339,000,000	\$65,000,000	\$405,000,000	\$46,000,000	\$358,000,000	\$77,000,000

Table A.3. Detailed Summary of the Avoided Costs of the Moderate or Higher NA Areas

Emission Source	Number of Sources in Mod or higher NA Areas	Total Avoided Costs (2016\$)					
		Total Capital Cost	Annual Operating and Maintenance Cost	Total Cost	Value of Product Recovery	Total Cost with Savings	Total Annualized w/ savings (\$/yr)
Fugitive Emissions - Gas Well Sites	6,339	\$5,400,000	\$14,000,000	\$20,000,000	\$5,000,000	\$15,000,000	\$10,000,000
Fugitive Emissions - Oil Well Site - w/ GOR $\geq$ 300	1,688	\$1,400,000	\$3,800,000	\$5,300,000	\$660,000	\$4,600,000	\$3,400,000
Fugitive Emissions - Gathering and Boosting Stations	453	\$1,100,000	\$12,000,000	\$13,000,000	\$3,000,000	\$10,000,000	\$8,900,000
Equipment Leaks - Processing Plants	58	\$520,000	\$720,000	\$1,200,000	\$220,000	\$1,000,000	\$560,000
Reciprocating Compressors - Gathering and Boosting Stations	3,271	\$20,000,000	\$0	\$20,000,000	\$5,300,000	\$14,000,000	\$2,000,000
Reciprocating Compressors - Processing	537	\$2,400,000	\$0	\$2,400,000	\$2,200,000	\$190,000	-\$1,400,000
Centrifugal Compressors w/ Wet Seals - Processing	59	\$1,500,000	\$0	\$1,500,000	\$0	\$1,500,000	\$210,000
Natural Gas-Driven Pneumatic Controllers - Oil and Gas Production	6,654	\$19,000,000	\$0	\$19,000,000	\$8,100,000	\$11,000,000	-\$6,500,000
Natural Gas-Driven Pneumatic Controllers - Processing	13	\$28,000	\$0	\$28,000	\$3,200	\$25,000	\$910
Natural Gas-Driven Pneumatic Pumps - Production - Diaphragm	9,709	\$42,000,000	\$0	\$42,000,000	\$7,400,000	\$34,000,000	\$5,400,000
Storage Vessels	1,758	\$196,000,000	\$26,000,000	\$222,000,000	\$99,000	\$222,000,000	\$47,000,000
Note: Minor differences may result from rounding.	Total	\$289,000,000	\$57,000,000	\$345,000,000	\$32,000,000	\$313,000,000	\$70,000,000

Table A.4. Detailed Summary of the Avoided Costs of the OTR, Excluding Moderate or Higher NA Areas

Emission Source	Number of Sources in the OTR	Total Avoided Costs (2016\$)					
		Total Capital Cost	Annual Operating and Maintenance Cost	Total Cost	Value of Product Recovery	Total Cost with Savings	Total Annualized w/ savings (\$/yr)
Fugitive Emissions - Gas Well Sites	1,472	\$1,200,000	\$3,400,000	\$4,600,000	\$1,200,000	\$3,400,000	\$2,400,000
Fugitive Emissions - Oil Well Site - w/ GOR $\geq$ 300	10	\$8,500	\$23,000	\$31,000	\$3,900	\$27,000	\$20,000
Fugitive Emissions - Gathering and Boosting Stations	180	\$460,000	\$4,700,000	\$5,200,000	\$1,200,000	\$4,000,000	\$3,500,000
Equipment Leaks - Processing Plants	10	\$90,000	\$130,000	\$220,000	\$40,000	\$180,000	\$100,000
Reciprocating Compressors - Gathering and Boosting Stations	1,298	\$7,800,000	\$0	\$7,800,000	\$2,100,000	\$5,700,000	\$780,000
Reciprocating Compressors - Processing	94	\$420,000	\$0	\$420,000	\$390,000	\$33,000	-\$240,000
Centrifugal Compressors w/ Wet Seals - Processing	10	\$250,000	\$0	\$250,000	\$0	\$250,000	\$36,000
Natural Gas-Driven Pneumatic Controllers - Oil and Gas Production	4,074	\$12,000,000	\$0	\$12,000,000	\$4,900,000	\$6,700,000	-\$4,000,000
Natural Gas-Driven Pneumatic Controllers - Processing	2	\$4,900	\$0	\$4,900	\$550	\$4,400	\$160
Natural Gas-Driven Pneumatic Pumps - Production - Diaphragm	5,945	\$26,000,000	\$0	\$26,000,000	\$5,000,000	\$21,000,000	\$3,600,000
Storage Vessels	28	\$3,100,000	\$410,000	\$3,500,000	\$2,000	\$3,500,000	\$750,000
Note: Minor differences may result from rounding.	Total	\$51,000,000	\$8,600,000	\$59,000,000	\$14,000,000	\$45,000,000	\$7,000,000

The total estimated forgone emission reductions estimated in the original analysis to the oil and natural gas sector, in the updated analysis to the oil and natural gas sector, for the Moderate or higher NA Areas and for the OTR are shown in Table A.5 through Table A.8, below. The forgone VOC, methane and HAP emission reductions are shown by emission source.

Table A.5. Detailed Summary of the Emission Reductions in the Oil and Natural Gas Sector of the Original 2016 Analysis

Emission Source	Total Forgone Emission Reductions (short tons per year)		
	VOC	Methane	HAP
Fugitive Emissions - Gas Well Sites	7,300	26,200	270
Fugitive Emissions - Oil Well Site - w/ GOR $\geq$ 300	1,200	4,500	46
Fugitive Emissions - Gathering and Boosting Stations	4,900	17,800	190
Equipment Leaks - Processing Plants	310	1,100	12
Reciprocating Compressors - Gathering and Boosting Stations	8,700	31,300	330
Reciprocating Compressors - Processing	3,100	11,100	120
Centrifugal Compressors w/ Wet Seals - Processing	1,300	14,000	150
Natural Gas-Driven Pneumatic Controllers - Oil and Gas Production	15,200	54,700	570
Natural Gas-Driven Pneumatic Controllers - Processing	4	16	0
Natural Gas-Driven Pneumatic Pumps - Production - Diaphragm	10,700	38,600	400
Storage Vessels	27,200	5,600	850
Total	79,900	204,900	2,900

Note: Totals may not sum due to independent rounding

Table A.6. Detailed Summary of the Emission Reduction in the Oil and Natural Gas Sector of the Updated Analysis

Emission Source	Total Forgone Emission Reductions (short tons per year)		
	VOC	Methane	HAP
Fugitive Emissions - Gas Well Sites	7,200	25,800	270
Fugitive Emissions - Oil Well Site - w/ GOR $\geq$ 300	770	2,800	29
Fugitive Emissions - Gathering and Boosting Stations	4,900	17,800	190
Equipment Leaks - Processing Plants	310	1,100	12
Reciprocating Compressors - Gathering and Boosting Stations	8,700	31,300	330
Reciprocating Compressors - Processing	3,100	11,100	120
Centrifugal Compressors w/ Wet Seals - Processing	1,300	14,000	150
Natural Gas-Driven Pneumatic Controllers - Oil and Gas Production	15,200	54,700	570
Natural Gas-Driven Pneumatic Controllers - Processing	4	16	0
Natural Gas-Driven Pneumatic Pumps - Production - Diaphragm	10,700	38,600	400
Storage Vessels	12,100	2,500	380
Total	64,300	199,600	2,400

Note: Totals may not sum due to independent rounding

Table A.7. Detailed Summary of the Forgone Emission Reductions of the NA Areas Classified as Moderate or higher

Emission Source	RACT-Impacted OTR Forgone Emission Reductions (tpy)		
	VOC	Methane	HAP
Fugitive Emissions - Gas Well Sites	5,800	20,900	220
Fugitive Emissions - Oil Well Site - w/ GOR ≥ 300	760	2,800	29
Fugitive Emissions - Gathering and Boosting Stations	3,500	12,800	130
Equipment Leaks - Processing Plants	260	940	10
Reciprocating Compressors - Gathering and Boosting Stations	6,200	22,400	230
Reciprocating Compressors - Processing	2,600	9,400	99
Centrifugal Compressors w/ Wet Seals - Processing	1,100	11,900	130
Natural Gas-Driven Pneumatic Controllers - Oil and Gas Production	9,400	33,900	360
Natural Gas-Driven Pneumatic Controllers - Processing	4	13	0
Natural Gas-Driven Pneumatic Pumps - Production - Diaphragm	6,700	23,900	250
Storage Vessels	11,900	2,500	380
Total	48,300	141,500	1,800

Note: Totals may not sum due to independent rounding

Table A.8. Detailed Summary of the Forgone Emission Reductions of the OTR, Excluding Moderate or Higher NA Areas

Emission Source	RACT-Impacted OTR Forgone Emission Reductions (tpy)		
	VOC	Methane	HAP
Fugitive Emissions - Gas Well Sites	1,300	4,900	51
Fugitive Emissions - Oil Well Site - w/ GOR ≥ 300	5	16	0
Fugitive Emissions - Gathering and Boosting Stations	1,400	5,100	53
Equipment Leaks - Processing Plants	47	170	2
Reciprocating Compressors - Gathering and Boosting Stations	2,500	8,900	90
Reciprocating Compressors - Processing	460	1,600	17
Centrifugal Compressors w/ Wet Seals - Processing	190	2,100	22
Natural Gas-Driven Pneumatic Controllers - Oil and Gas Production	5,800	20,800	220
Natural Gas-Driven Pneumatic Controllers - Processing	1	2	0
Natural Gas-Driven Pneumatic Pumps - Production - Diaphragm	4,100	14,700	150
Storage Vessels	190	40	6
Total	15,900	58,200	610

Note: Totals may not sum due to independent rounding

The stream of avoided costs in the updated analysis to the oil and natural gas sector, for Moderate or higher NA areas and for the OTR from 2021 through 2035 are presented in Table A.9 through Table A.11. The tables include avoided capital costs, avoided annual O&M costs, value of forgone product recovery and total avoided costs (before and after accounting for product recovery). These costs are undiscounted and in 2016\$. The avoided capital costs estimated in years 2023 and beyond are the estimated capital costs associated with the replacement of control technology at the end of their estimated lifetimes.

Table A.9. Undiscounted Stream of Avoided Costs to the Oil and Natural Gas Sector for the Proposed Withdrawal of the CTG, All Areas (millions, 2016\$)

Year	Avoided Capital Cost	Avoided Annual O&M	Value of Forgone Product Recovery	Total Avoided Cost w/o Product Recovery	Total Avoided Cost w/Product Recovery
2021	\$339	\$65	\$46	\$405	\$358
2022	-	\$65	\$46	\$65	\$19
2023	-	\$65	\$46	\$65	\$19
2024	\$30	\$65	\$47	\$95	\$48
2025	-	\$65	\$47	\$65	\$18
2026	-	\$65	\$48	\$65	\$17
2027	\$30	\$65	\$48	\$95	\$47
2028	-	\$65	\$50	\$65	\$16
2029	\$10	\$65	\$50	\$75	\$25
2030	\$30	\$65	\$51	\$95	\$44
2031	\$69	\$65	\$52	\$130	\$82
2032	-	\$65	\$53	\$65	\$13
2033	\$30	\$65	\$52	\$95	\$43
2034	-	\$65	\$52	\$65	\$14
2035	-	\$65	\$52	\$65	\$13

Note: Totals may not sum due to independent rounding

Table A.10. Undiscounted Stream of Avoided Costs for NA Areas Classifies as Moderate or higher (millions, 2016\$)

Year	Avoided Capital Cost	Avoided Annual O&M	Value of Forgone Product Recovery	Total Avoided Cost w/o Product Recovery	Total Avoided Cost w/Product Recovery
2021	\$289	\$57	\$32	\$345	\$313
2022	-	\$57	\$32	\$57	\$25
2023	-	\$57	\$32	\$57	\$25
2024	\$22	\$57	\$32	\$79	\$46
2025	-	\$57	\$33	\$57	\$24
2026	-	\$57	\$33	\$57	\$23
2027	\$22	\$57	\$33	\$79	\$45
2028	-	\$57	\$34	\$57	\$22
2029	\$8	\$57	\$35	\$65	\$30
2030	\$22	\$57	\$35	\$79	\$43
2031	\$43	\$57	\$36	\$100	\$64
2032	-	\$57	\$36	\$57	\$20
2033	\$22	\$57	\$36	\$79	\$43
2034	-	\$57	\$36	\$57	\$21
2035	-	\$57	\$36	\$57	\$21

Note: Totals may not sum due to independent rounding

As seen in Table A.11, below, in years where capital costs are not incurred, the total avoided costs accounting for product recovery in the OTR are negative. That means the value of forgone product recovery is greater than the avoided costs. This is a function of the estimated annual O&M costs, the estimated amount of natural gas that could be recovered, and the value of that natural gas over time. All else equal, the price of natural gas would have to be \$2.45/Mcf in order for avoided total costs in the OTR to be positive in every year. In the total updated analysis, and in the Moderate or higher NA areas, the avoided total costs with forgone product recovery are positive for all years.

Table A.11 Undiscounted Stream of Avoided Costs for the OTR (millions, 2016\$)

Year	Avoided Capital Cost	Avoided Annual O&M	Value of Forgone Product Recovery	Total Avoided Cost w/o Product Recovery	Total Avoided Cost w/Product Recovery
2021	\$51	\$8.6	\$14	\$59	\$45
2022	-	\$8.6	\$14	\$8.6	-\$5.6
2023	-	\$8.6	\$14	\$8.6	-\$5.7
2024	\$8.2	\$8.6	\$15	\$17	\$2.2
2025	-	\$8.6	\$15	\$8.6	-\$6.1
2026	-	\$8.6	\$15	\$8.6	-\$6.3
2027	\$8.2	\$8.6	\$15	\$17	\$1.8
2028	-	\$8.6	\$15	\$8.6	-\$6.7
2029	\$1.8	\$8.6	\$16	\$10.4	-\$5.2
2030	\$8.2	\$8.6	\$16	\$17	\$1.00
2031	\$26	\$8.6	\$16	\$35	\$18
2032	-	\$8.6	\$16	\$8.6	-\$7.7
2033	\$8.2	\$8.6	\$16	\$17	\$0.61
2034	-	\$8.6	\$16	\$8.6	-\$7.4
2035	-	\$8.6	\$16	\$8.6	-\$7.5

Note: Totals may not sum due to independent rounding

The stream of avoided total costs (accounting for forgone product recovery) discounted back to 2016 at both a 7 percent and 3 percent discount rate for the updated analysis, Moderate or higher NA areas and for the OTR are shown in Table A.12 through Table A.14. These tables also include the PV and the EAV of those avoided costs. The value of forgone product recovery is included in the calculation of the PV of avoided costs, and is therefore reflected in the EAV

Table A.12 Discounted Stream of Avoided Costs, PV and EAV for the Oil and Natural Gas Sector for the Proposed Withdrawal of the CTG, All Areas (millions, 2016\$)

Year	Discounted Total Avoided Costs (Millions \$)	
	3%	7%
2021	\$309	\$255
2022	\$16	\$13
2023	\$15	\$12
2024	\$38	\$28
2025	\$14	\$10
2026	\$13	\$9
2027	\$34	\$22
2028	\$11	\$7
2029	\$17	\$10
2030	\$29	\$17
2031	\$53	\$30
2032	\$8	\$4
2033	\$26	\$14
2034	\$8	\$4
2035	\$8	\$4
NPV	\$599	\$4439
EAV	\$49	\$45

Note: Totals may not sum due to independent rounding

Table A.13 Discounted Stream of Avoided Costs, PV and EAV for NA Areas Classifies as Moderate or higher (millions, 2016\$)

Year	Discounted Total Avoided Costs (Millions \$)	
	3%	7%
2021	\$270	\$223
2022	\$21	\$17
2023	\$20	\$15
2024	\$36	\$27
2025	\$18	\$13
2026	\$17	\$12
2027	\$33	\$21
2028	\$16	\$10
2029	\$21	\$13
2030	\$29	\$17
2031	\$41	\$23
2032	\$13	\$7
2033	\$26	\$13
2034	\$12	\$6
2035	\$12	\$6
NPV	\$585	\$423
EAV	\$48	\$43

Note: Totals may not sum due to independent rounding

Table A.14. Stream of Avoided Total Costs for the OTR Discounted to 2016, NPV and EAV (millions 2016\$)

Year	Discounted Total Avoided Costs (Millions \$)	
	3%	7%
2021	\$39	\$32
2022	-\$4.7	-\$3.7
2023	-\$4.6	-\$3.5
2024	\$1.8	\$1.3
2025	-\$4.6	-\$3.3
2026	-\$4.7	-\$3.2
2027	\$1.3	\$0.86
2028	-\$4.7	-\$3.0
2029	-\$3.6	-\$2.2
2030	\$0.66	\$0.39
2031	\$12	\$6.6
2032	-\$4.8	-\$2.6
2033	\$0.37	\$0.19
2034	-\$4.3	-\$2.2
2035	-\$4.3	-\$2.1
NPV	\$14	\$16
EAV	\$1.2	\$1.6

Note: Totals may not sum due to independent rounding