Technical Appendix: Measure-Specific Documentation

GHG Reduction Estimate Method:

Priority Measure	GHG Reduction Estimate Method	
EV/Hydrogen Fueling Stations & Fleet Transition	The Guidance for Estimating Emission Benefits of Replacing Diesel Vehicles and Engines with Electric Versions provides information on quantifying and using emission reductions from highway and nonroad diesel vehicles, engines, and equipment that have been replaced with zero-emissions technologies.	
	Fuel Economy is a jointly managed DOE/EPA website that provides calculators and other tools, such as the Fuel Savings Calculator, GHG Emissions Calculator, and My Plug-in Hybrid Calculator.	
Hydrogen Production	Reduction calculations are based on information collected during DEQ's online project idea submission form.	
Asphalt Technology	The National Asphalt Pavement Association (NAPA) described the methodology and assumptions used to calculate the GHG emissions reductions from production of WMA at reduced temperature, with RAP in new asphalt mixes. These calculations are based on publicly available data. The most recent and comprehensive data sources were selected for this purpose.	
Landfill Gas Collection and Control	The Landfill Gas Emissions Model (LandGEM) ● Use to calculate unmitigated emissions Landfill Gas Energy Benefits Calculator (LFGE Benefits Calculator) ● Use output from LandGEM to populate the "standard cubic feet per minute (scfm)" field in the LFGE Benefits Calculator. The LFGE Benefits calculator to estimate Total Equivalent Emissions Reduced.	
Municipal Wastewater Facility Anaerobic Digesters	Use the range of emissions estimated for Anaerobic Digester (AD) systems 162 ± 87 g CH4/(PE · y) to calculate potential emissions reductions for upgrading AD system. Assume that the existing AD system emits at the high end of the range, and the new system would emit at the low end of the range. Source of estimated emission range: J. Tauber, V. Parravicini, K. Svardal, J. Krampe; Quantifying methane emissions from anaerobic digesters. Water Sci Technol 1 November 2019; 80 (9): 1654–1661. doi: https://doi.org/10.2166/wst.2019.415	
Solar Farm Development	Use the EPA AVERT Web Edition to calculate the MWh for the facility: https://www.epa.gov/avert/avert-web-edition Use the EPA eGRID2022 data to find the emission factor for CO_2e/MWh for Oklahoma's region	
Transmission Upgrades	US Energy Information Administration (EIA)	
Green Public Buildings Upgrades	Solar Panel Installation with or without Battery Storage	Use the EPA AVERT Web Edition to calculate the MWh for the facility: https://www.epa.gov/avert/avert-web-edition Use the EPA eGRID2022 data to find the emission factor for CO_2e/MWh for Oklahoma's region Emissions & Generation Resource Integrated Database (eGRID)

	Solar Rooftop	Use the EPA AVERT Web Edition to calculate the MWh for the facility: https://www.epa.gov/avert/avert-web-edition Use the EPA eGRID2022 data to find the emission factor for CO_2e/MWh for Oklahoma's region
	Solar for Heating and Cooling Systems	EPA's eGRID2022 data summary tables
	HVAC and LED Lighting	EPA's eGRID2022 data summary tables
	LED Lighting	EPA's eGRID2022 data summary tables
	HVAC Upgrades	eGRID SPSO Subregion
	Windows Upgrades	Energy.gov
	Chiller, Boiler, and Air Handler Replacement	eGRID2022 data summary tables

Models/Tools Used:

Priority Measure	Tools Used
Hydrogen Fueling Station/ EV Chargers/ Fleet Conversion	EPA's MOtor Vehicle Emission Simulator (MOVES) EPA's Travel Efficiency Assessment Method (TEAM) AVERT
Hydrogen Production	Reduction calculations are based on information provided in DEQ's online project submission website.
Asphalt Technology	These calculations are based on publicly available data
Landfill Gas Collection and Control	The Landfill Gas Emissions Model (LandGEM) Landfill Gas Energy Benefits Calculator (LFGE Benefits Calculator)
Municipal Wastewater Facility Anaerobic Digesters	Use the range of emissions estimated for Anaerobic Digester (AD) systems 162 ± 87 g CH4/(PE · y) to calculate potential emissions reductions for upgrading AD system
Solar Farm Development	Avoided Emissions and Generation Tool (AVERT)
Transmission Upgrades	Avoided Emissions and Generation Tool (AVERT)
Green Public Buildings Upgrades	Avoided Emissions and Generation Tool (AVERT) EPA eGRID2022 data

Assumptions:

Priority Measure	Measure Implementation Assumptions
Hydrogen Fueling /EV/ Fleet Conversion	Assumes 1 fueling station, 4 chargers, and 24 vehicle conversions
Hydrogen Production	MOVES/TEAM/AVERT Assume a new centralized 100MW hydrogen production plant.
Asphalt Technology	• Amount of WMA as a % of total asphalt mix production by 2030 = 75% • Average RAP usage (%) by 2030 = 30% • Expected reduction of production temperature for WMA = 40^{o} F • Estimated energy savings of WMA = 1,100 British thermal units (Btu)/°F per ton • CO_2 emission from production of WMA additive = 5.99 kilograms (kg) CO_2e/kg • CO_2 reduction from replacing virgin binder = 577.9 kg CO_2e /ton • CO_2 emission from aggregate extraction and processing = 1.76 kg CO_2e/ton • Average hauling distance for virgin asphalt binder = 3.9 ton·miles/ton of mix produced • Average hauling distance for virgin aggregate = 21.5 ton·miles/ton of mix produced • CO_2 emission from transportation by diesel truck = 0.185465 kg CO_2e /ton·mile • CO_2 emission from processing RAP = 1.225 kg CO_2e /ton • Current hot mix asphalt (HMA) and WMA production in Oklahoma = 5.1 million tons • Current average RAP usage = 19% • Total tonnage of chemical WMA produced currently = 2.1 million tons • Amount of WMA as a % of total asphalt mix production = 42%
Landfill	LandGEM Annual Waste Acceptance Rate: 34,375 mt Waste/year Landfill Open Year: 1991 Landfill Closure Year: 2026 Assume GCCS installed in 5 landfills.
Anaerobic Digesters	Population of Payne County -82794 Assume 5 municipal wastewater facility anaerobic digesters.
Solar Farm Development	Assume 2 solar farm developments. Battery system emissions -162 kg CO_2/kWh Battery drains and recharges daily Battery Capacity -2 MWh/day Yearly battery usage -730 MWh/year Emission from battery usage -118260 kg CO_2 / yr 118.26 mt CO_2/yr
Transmission Upgrades	Reduction of 5% in transmission losses due to the higher voltage Total Electricity Transmitted was determine by multiplying the per capita electricity usage by the total populations of the 16 cities. Assume 15 distribution system conversions from 4kV to 12kV.

Green Public Buildings Upgrades	Norman Campus - Street Lights	850 -street pole lights 300 -wattage of incandescent streetlights -- estimated based on literature review 75 -wattage of new LED lights -- estimated consume a quarter of the energy of incandescent based on this source https://drawdown.org/solutions/led-lighting 4,380 -hours per year lights are kept on
	Norman Campus - Building Lights	56 -sqft per fixture (source: submittal) 17,850 -fixtures to be replaced (source: submittal) 2 -lamps per fixture 32 -Wattage of current T8 lamp -- assumes a 2' x 4' florescent fixture - https://www.lrc.rpi.edu/programs/NLPIP/lightinganswers/pdf/view/LAT8.pdf 16 -Wattage of new lamp -- estimated based on this source https://drawdown.org/solutions/led-lighting 1460 -hours per year lights are kept on
	Muskogee Cooling	8,500 -sqft building 400 -sqft for per 1 ton of refrigeration https://www.energy.gov/sites/prod/files/guide_to_home_heating_cooling.pdf 6 -months of cooling 5 -months of heating 33% -Percentage of time that the HVAC system is cycled off when it is operating 6.5 -BTU/(W*hr) SEER rating of OLD HVAC system -- assumption based on a HVAC unit built prior to 1980 https://www.tdhca.state.tx.us/community-affairs/wap/docs/WAP-BP-SEERandEERDetermination.pdf 15 -BTU/(W*hr) SEER rating of NEW HVAC system -- assumption based on a HVAC unit built prior to 1980 https://www.tdhca.state.tx.us/community-affairs/wap/docs/WAP-BP-SEERandEERDetermination.pdf
	Muskogee Heating	400.00 -sqft per 1-ton https://www.nrel.gov/docs/fy11osti/51603.pdf 63% -efficiency (old boiler) https://www.energy.gov/energysaver/furnaces-and-boilers 94% -efficiency (new boiler) https://www.energy.gov/energysaver/furnaces-and-boilers 5 -months of heating
	Lawton Recreation Centers & Cemetary Annex	7500 -sqft total space needing lighting - estimated 2,600 -lumens per light fixture 500 -lux lighting 150 -Watts (old incandecent fixtures) 27 -Watts (new fixtures) https://www.voltlighting.com/learn/lumens-to-watts-conversion-led-bulb 2,340 -Operating Hours - source - H.C. King Center open hours
	Library lighting	40,000 -sqft library 500 -lux lighting 2,600 -lumens per light fixture 3,120 -Operating Hours

	Library cooling	6 -months of cooling 5 -months of heating 33% -Percentage of time that the HVAC system is cycled off when it is operating 6.5 -BTU/(W*hr) SEER rating of OLD HVAC system -- assumption based on a HVAC unit built prior to 1980 15 -BTU/(W*hr) SEER rating of NEW HVAC system -- assumption based on a HVAC unit built prior to 1980
	Library Heating	27.1 -MBTU/year of natural gas consumption per sqft -- for building built in 1970s region 25.4 -MBTU/year of natural gas consumption per sqft -- for building built after 2010 region 63% -efficiency (old boiler) 94% -efficiency (new boiler)
	Miami Library Windows	12000 -sqft building 400 -sqft for per 1 ton of heating/cooling 6 -months of cooling 5 -months of heating 33% -% of time that the HVAC system is cycled off when operating 6.5 -BTU/(W*hr) SEER rating of HVAC system -- assumption based on a HVAC unit built prior to 1980 23% -energy from HVAC saved by upgrading windows
	Miami Baseball Lights	309 -Bulbs counted at 5 baseball fields (per Allen's estimates) 52 -bulbs per field 3 -fields (from submittal) 1500 -Watts (Old bulbs) 375 -Watts (New bulbs) 156 -Operating Hours (3 hrs/night, 4 nights/week, 13 weeks)
	Forgan Cooling	4,135 -sqft city hall 400 -sqft for per 1 ton of heating/cooling 6 -months of cooling5 -months of heating 33% -% of time that the HVAC system is cycled off when it is operating 6.5 -BTU/(W*hr) SEER rating of OLD HVAC 15 -BTU/(W*hr) SEER rating of NEW HVAC system
	Forgan Heating	27.1 -MBTU/year of natural gas consumption per sqft -- for building built in 1970s region 25.4 -MBTU/year of natural gas consumption per sqft -- for building built after 2010 region 63% -efficiency (old boiler) 94% -efficiency (new boiler)
	Texhoma Windows	4,000 -sqft floor space estimated for museum 1,850 -sqft floor space estimated for public works building 2,000 -sqft floor space estimated for public works library 400 -sqft for per 1 ton of heating/cooling 6 -months of cooling 5 -months of heating 33% -Percentage of time that the HVAC system is cycled off when it is operating 6.5 -BTU/(W*hr) SEER rating of HVAC system 23% -energy from HVAC saved by upgrading windows
	Solar	Energy from solar would be used primarily to power HVAC systems3.50E+06-sqft of building area (73 buildings owned by

		OK govt) 400 -sqft for per 1 ton of heating/cooling 6 -months of cooling 5 -months of heating 33% -Percentage of time that the HVAC system is cycled off when it is operating 10 -BTU/(W*hr) SEER rating of HVAC system

Measure-Specific Activity Data:

Site Specific Data		
Landfill	Landfill Name	Redacted
	Landfill Open Year	1991
	Estimated Landfill Closure	2026*
	Waste Design Capacity	1,209,507 Metric Tons

**This estimation was used for GHG calculation purposes. If awarded, DEQ would focus on landfills with the longest lifespan.*

Reference Case Scenario:

The DEQ has developed near-term (2030) and long-term (2050) projections of GHG emissions that would occur in a "business-as-usual" (BAU) scenario where the PAP measures are not implemented and under a scenario where the measures in the PAP are fully implemented (PAP scenario). Base year data downloaded from EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks by State, for Oklahoma for 2019.

Sector/Source	**2019**	**BAU**		**PAP**	
		2030	**2050**	**2030**	**2050**
Transportation	30.88	32.85	36.05	32.7	35.96
Electric Power Industry	28.28	22.73	23.05	22.64	22.99
Industry	52	52.15	58.27	49.79	56.32
Agriculture	20.26	16.52	14.77	16.33	14.42
Commercial, Residential & Municipal	9.09	7.69	8.04	7.56	7.95
Waste, Water, and Sustainable Material Management	2.95	3.63	3.59	3.06	3.33
Total Emissions (Sources)	143.13	135.57	143.77	132.08	140.95
LULUCF Sector Net Total	-5.87	0.57	12.13	0.57	12.13
Net Emissions (Sources and Sinks)	137.26	136.14	155.9	132.65	153.08

GHG Emissions Reduced:

Projects	5-year $mtCO_2e$ estimates	25-year $mtCO_2e$ estimates
36 MW Solar Farm	241,423.75	1,207,118.75
9.9 MW Solar Facility	66,107.50	330,536.50
Asphalt	237,000	1,188,000
Hydrogen Production	530,000.00	2,650,000.00
Promote Medium-and Heavy-Duty Zero Emissions Truck Fueling Stations	250,000.00	1,000,000.00
Chiller, Boiler, and Air Handler Replacement	311.8	1,559.00
Boiler at Universities	9,500.00	47,500.00
Boiler Upgrades at a Military Base	7,250.00	36,250.00
1MW with 1 MW/2MWh Battery Storage	239,877.26	1,207,000.47
Rooftop Solar	28,908.50	144,543.00
Solar for Heating and Cooling Systems in Government Building	124,333	621,667
Lighting at Sports Complexes and Window Replacement at Public Library	208	1,038
HVAC and LED Lighting – Library	1,300	6,502
LED Lighting – University Buildings	1,845	9,223
LED Lighting – Street Poles	1,853	9,264
LED Lighting – Recreation Centers and Cemetery	85.31	426.53
HVAC Upgrades	71.72	358.59
Control Ventilation System	3,773.83	16,353.26
Windows Upgrades	96.53	482.65
Landfill Gas Collection & Control	567,652	1,838,399
Anaerobic Digesters	2,016.85	10,084.25

The cumulative GHG emissions reductions in the near-term, 2025-2030, and long-term, 2025-2050, as well as the relative cost-effectiveness of those reductions are detailed in the table below:

Priority Measure	Requested CPRG Funding	GHG Emissions Reductions ($mtCO_2e$)		Cost Effectiveness
		Near-term 2025-2030	Long-term 2025-2050	
EV/Hydrogen Fueling Hubs & Fleet Transition	$37,600,000.00	250,000.00	1,000,000.00	150.40
Hydrogen Production	$40,000,000.00	530,000.00	2,650,000.00	75.47
Asphalt Technology	$1,000,000.00	237,000.00	1,188,000.00	4.22
Landfill Gas Collection and Control	$25,000,000.00	2,838,260.00	9,191,995.00	8.81
Municipal Wastewater Facility Anaerobic Digesters	$15,000,000.00	10,084.00	50,421.00	1,487.50
Green Public Buildings	$22,500,000.00	614,937.44	3,074,687.22	36.59
Solar Farm Development	$10,000,000.00	307,531.25	1,537,655.25	32.52
Transmission Upgrades	$37,500,000.00	125,614.42	628,072.12	298.53
TOTAL	**$ 188,600,000.00**	**4,913,427.11**	**19,320,830.59**	**-**

Implementation of all reduction measure is anticipated to reduce 4,913,427.11 cumulative $mtCO_2e$ for the period between 2025 – 2030, and 19,320,830.59 cumulative $mtCO_2e$ for the period between 2025 – 2050.

Estimated Reductions of Co-Pollutants (tons)						
Sector	**NOx**	**PM2.5**	**SO2**	**VOCs**	**HAPs**	**Total**
Transportation	77,304.65	25,728.06	452.18	40,879.67	10,430.57	**154,795.13**
Electric Power	16,601.11	1,462.54	7,503.11	486.07	178.1	**26,230.93**
Industry	98,938.55	12,651.47	20,565.29	227,336.03	17,263.08	**376,754.42**
Buildings	6,247.84	6,928.76	162.65	44,410.71	6,705.92	**64,455.88**
Waste	1,222.20	3,586.76	252.95	2,053.03	671.11	**7,786.05**
Total	**200,314.35**	**50,357.59**	**28,936.18**	**315,165.51**	**35,248.78**	**630,022.41**