Appendix E3

Emissions Worksheets – UPDATED

ESA

POLLUTANT EMISSIONS FROM LOCOMOTIVE DELIVERY OF CONSTRUCTION EQUIPMENT

FUEL CONSUMPTION RATE (TON-MILES/GAL): 400

LINE-HAUL EMISSION FACTORS (g/bhp-hr)				
	PM10	HC	NOx	CO
Uncontrolled	0.32	0.48	13	1.28
Tier 0	0.32	0.48	8.6	1.28
Tier 0+	0.2	0.3	7.2	1.28
Tier 1	0.32	0.47	6.7	1.28
Tier 1+	0.2	0.29	6.7	1.28
Tier 2	0.18	0.26	4.95	1.28
Tier 2+ & Tier 3	0.08	0.13	4.95	1.28
Tier 4	0.015	0.04	1	1.28

CONVERSION FACTOR (bhp-hr/gal)

Large Line-Haul and Passenger: **20.8**

HC to VOC CONVERSTION FACTOR: 1.053

TRANSPORTATION LOAD (tons): 2000

TRANSPORTATION DISTANCE (mi): 180

POLLUTANT EMISSIONS (lbs)

	PM10	**VOC**	**NOx**	**CO**	**PM2.5**[a]
Uncontrolled	13.21	20.86	536.61	52.84	12.15
Tier 0	13.21	20.86	354.99	52.84	12.15
Tier 0+	8.26	13.04	297.20	52.84	7.60
Tier 1	13.21	20.43	276.56	52.84	12.15
Tier 1+	8.26	12.60	276.56	52.84	7.60
Tier 2	7.43	11.30	204.32	52.84	6.84
Tier 2+ & Tier 3	3.30	5.65	204.32	52.84	3.04
Tier 4	0.62	1.74	41.28	52.84	0.57

Source: USEPA, Office of Transportation and Air Quality, EPA-420-F-09-025, *Emission Factors for Locomotives, April 2009.*

[a] PM2.5 emissions for hauling trains were calculated as 92% of PM10 emissions, based on ARB's CEIDARS database for PM2.5 fractions.

DELIVERY TRUCK EMISSIONS DURING CONSTRUCTION

EMISSION FACTORS

Scenario Year: **2012**

All model years in the range 1968 to 2012

Delivery Trucks[a] (pounds/mile)	
CO	0.015457411
NOx	0.017324228
ROG	0.002237757
SOx	2.66688E-05
PM10	0.000649749
PM2.5	0.000549539

TRAVEL DISTANCE (MILES): 320

NUMBER OF TRUCKS DAILY: 10

POLLUTANT EMISSIONS

	pounds/day
CO	49.46371424
NOx	55.43753031
ROG	7.160821076
SOx	0.08534023
PM10	2.079198319
PM2.5	1.758525941

[a] Based on EMFAC 2007 (v2.3) Burden Model Emission Factors compiled by SCAQMD for on-road delivery trucks (>8,500 pounds) in 2012.

SITE ACCESS - FUGITIVE DUST

Conservation and Recovery Component

Unpaved Road Fugitive Dust from Trucks During Construction

VMT [1] (miles/day)	Emission Factors (pounds/VMT) [2]		Emissions Without Dust Control (pounds/day)	
	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
160	1.4	0.1	221.4	22.1
			Emissions With Dust Control [3] (pounds/day)	
			55.8	**5.6**

1 Total VMT from constructon worker trips

2 Based on AP-42 Emission Factor: E (lbs/VMT) =k (s/12)^a (W/3)^b

Where:

E = emission rate in pounds per vehicle mile traveled

k = particle size multiplier (assumed 1.5 lb/VMT for PM10 and 0.15 lb/VMT for PM2.5 per AP-42, Table 13.2.2-2)

a = 0.9

b = 0.45

s = silt content (assumed 8.5% for a construction site per AP-42, Table 13.2.2-1)

W = averge weight (tons) of vehicles (assumed 100% shuttle buses that weight 5 tons)

3 Dust control mesures include limiting maximum speed on unpaved roads to 25 miles per hour and watering of of unpaved roads at least twice daily.

PIPELINE TRENCHING FUGITIVE DUST EMISSIONS

Worst-Case Daily Grading	10,000	Square Feet[a]
Trenching Duration -	**10**	**days[b]**

Fugitive Dust Stockpiling Parameters

Silt Content[c]	Precipitation Days	Mean Wind Speed Percent[d]	TSP Fraction	Area[e] (acres)
6.9	0	100	0.5	0.02

Fugitive Dust Material Handling

Aerodynamic Particle Size Multiplier[f]	Mean Wind Speed	Moisture Content[c]	Dirt Handled	Dirt Handled[g]
	mph		cy	lb/day
0.35	10	7.9	3704	926,000

Bulldozing Fugitive Dust Parameters

Number of Dozers Daily	Hours of Operation	Overburden Coefficient[h]	Silt Content[i]	PM10 Scaling Factor[j]
1	8	1	6.9	0.75

Incremental Increase in Fugitive Dust Emissions from Construction Operations

Equations:

Storage Piles[k]: PM10 Emissions (lb/day) = 1.7 x (silt content/1.5) x ((365-precipitation days)/235) x wind speed percent/15 x TSP fraction x Area) x (1 - control efficiency)

Material Handling[l] PM10 Emissions (lb/day) = (0.0032 x aerodynamic particle size multiplier x (wind speed (mph)/5)$^{1.3}$/(moisture content/2)$^{1.4}$ x dirt handled (lb/day)/2,000 (lb/ton) (1 - control efficiency)

Bulldzing[m] PM10 Emissions (lb/day) = (overburden coefficient x silt content$^{1.5}$)/moisture content$^{1.4}$ x PM_{10} scaling factor x hours of operation x (1-control efficiency)

	Control Efficiency	PM10[n]	PM2.5[io]
Description	%	lb/day	lb/day
Storage Piles	61	0.32	0.07
Material Handling	61	0.07	0.01
Bulldozing	61	2.35	0.49
Total		**2.74**	**0.56**

Notes:

a) Area to be trenched (100-foot segments).

b) Trenching duration per 100-foot segment.

c) USEPA, AP-42, July 1998, Table 11.9-3 Typical Values for Correction Factors Applicable to the Predictive Emission Factor Equations

d) Mean wind speed percent - percent of time mean wind speed exceeds 12 mph.

e Assumed storage piles are 0.02 acres in size

f) USEPA, AP-42, Jan 1995, Section 13.2.4 Aggregate Handling and Storage Piles, p 13.2.4-3 Aerodynamic particle size multiplier for < 10 µm

g) Assuming 3704 cubic yards of dirt handled [(3704 cyd x 2,500 lb/cyd)/10 days = 926,000 lb/day)

h) USEPA, AP-42, October 1998, Section 11.9 Western Surface Coal Mining, Table 11.9-1, Equation for Overburden Bulldozing.

i) USEPA, AP-42, October 1998, Table 11.9-3 Typical Values for Correction Factors Applicable to the Predictive Emission Factor Equations

j) USEPA, AP-42, October 1998, Section 11.9 Wester Surface Coal Mining, Table 11.9-1 Scaling Factors.

k) USEPA, Fugitive Dust Background Document and Technical Information Document for Best Available Control Measures, Sept 1992, EPA-450/2-92-004, Equation 2-12

l) USEPA, AP-42, Jan 1995, Section 13.2.4 Aggregate Handling and Storage Piles, Equation 1

m) USEPA, AP-42, October 1998, Table 11.9-1, Equation for Overburden Bulldozing.

n) Includes watering at least three times a day (61% control efficiency)

o) ARB's CEIDARS database PM2.5 fractions - construction dust category for fugitive emissions.

WELLFIELD FUGITIVE DUST EMISSIONS

Worst-Case Daily Grading 125,000 Square Feet[a]

Fugitive Dust Grading Parameters

Vehicle Speed (mph)[b]	Vehicle Miles Traveled[c]
7.1	2.15

Fugitive Dust Material Handling

Aerodynamic Particle Size Multiplier[d]	Mean Wind Speed	Moisture Content[e]	Dirt Handled[f]	Dirt Handled[g]
	mph		cy/day	lb/day
0.35	10	7.9	6130	15,325,000

Bulldozing Fugitive Dust Parameters

Number of Dozers Daily	Hours of Operation	Overburden Coefficient[h]	Silt Content[i]	PM10 Scaling Factor[j]
1	8	1	6.9	0.75

Incremental Increase in Fugitive Dust Emissions from Construction Operations

Equations:

Grading[k]: PM10 Emissions (lb/day) = 0.60 x 0.051 x mean vehicle speed$^{2.0}$ x VMTx (1 - control efficiency)

Material Handling[l] PM10 Emissions (lb/day) = (0.0032 x aerodynamic particle size multiplier x (wind speed (mph)/5)$^{1.3}$/(moisture content/2)$^{1.4}$ x dirt handled (lb/day)/2,000 (lb/ton) (1 - control efficiency)

Bulldzing[m] PM10 Emissions (lb/day) = (overburden coefficient x silt content$^{1.5}$)/moisture content$^{1.4}$ x PM_{10} scaling factor x hours of operation x (1-control efficiency)

Description	Control Efficiency	PM10[n]	PM2.5[o]
	%	lb/day	lb/day
Earthmoving	61	1.29	0.27
Material Handling	61	1.20	0.25
Bulldozing	61	2.35	0.49
Total		**4.84**	**1.02**

Notes:

a) Grading of well pads - one acre/day.

b)The AP-42 default value is 7.1 mph.

c) Assumed 13 foot wide blade with 2 foot overlap (11 foot wide). Vehicle miles traveled (VMT) = (125,000 sq ft/11 foot x mile/5,280 ft) = 2.15220385674931 mile

d) USEPA, AP-42, Jan 1995, Section 13.2.4 Aggregate Handling and Storage Piles, p 13.2.4-3 Aerodynamic particle size multiplier for < 10 µm

e) USEPA, AP-42, July 1998, Table 11.9-3 Typical Values for Correction Factors Applicable to the Predictive Emission Factor Equations

f) Amount of dirt to be handled daily assuming 125,000 sf area graded at a depth of 1 feet.

g) Assuming 6130 cubic yards of dirt handled (6130 cyd x 2,500 lb/cyd) = 15,325,000 lb/day)

h) USEPA, AP-42, October 1998, Section 11.9 Western Surface Coal Mining, Table 11.9-1, Equation for Overburden Bulldozing.

i) USEPA, AP-42, October 1998, Table 11.9-3 Typical Values for Correction Factors Applicable to the Predictive Emission Factor Equations

j) USEPA, AP-42, October 1998, Section 11.9 Wester Surface Coal Mining, Table 11.9-1 Scaling Factors.

k) USEPA, AP-42, July 1998, Table 11.9-1, Equation for Site Grading ≤ 10 µm

l) USEPA, AP-42, Jan 1995, Section 13.2.4 Aggregate Handling and Storage Piles, Equation 1

m) USEPA, AP-42, October 1998, Table 11.9-1, Equation for Overburden Bulldozing.

n) Includes watering at least three times a day (61% control efficiency)

o) ARB's CEIDARS database PM2.5 fractions - construction dust category for fugitive emissions.

DELIVERY TRUCK EMISSIONS DURING PROJECT OPERATIONS
commute to Cadiz
EMISSION FACTORS

Scenario Year: **2013**

All model years in the range 1969 to 2013

Delivery Trucks[a] (pounds/mile)	
CO	0.014077785
NOx	0.015773115
ROG	0.002062954
SOx	2.68223E-05
PM10	0.000599558
PM2.5	0.000501736

TRAVEL DISTANCE (MILES): 320

NUMBER OF TRUCKS DAILY: 2

POLLUTANT EMISSIONS

	pounds/day
CO	9.009782266
NOx	10.09479331
ROG	1.320290312
SOx	0.017166299
PM10	0.383717261
PM2.5	0.32111076

[a] Based on EMFAC 2007 (v2.3) Burden Model Emission Factors compiled by SCAQMD for on-road delivery trucks (>8,500 pounds) in 2013, which is when project operations would commence.

OPERATIONAL - FUGITIVE DUST

Unpaved Road Fugitive Dust from Trucks During Project Operations

VMT [1] (miles/day)	Emission Factors (pounds/VMT) [2]		Emissions Without Dust Control (pounds/day)	
	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
60	1.1	0.1	66.0	6.6
			Emissions With Dust Control [3] (pounds/day)	
			37.0	**1.7**

1 Total VMT from constructon worker trips for conveyance pipeline.

2 Based on AP-42 Emission Factor: E (lbs/VMT) =k (s/12)^a (W/3)^b

Where:

E = emission rate in pounds per vehicle mile traveled

k = particle size multiplier (assumed 1.5 lb/VMT for PM10 and 0.15 lb/VMT for PM2.5 per AP-42, Table 13.2.2-2)

a = 0.9

b = 0.45

s = silt content (assumed 8.5% for a construction site per AP-42, Table 13.2.2-1)

W = averge weight (tons) of vehicles (assumed 3 tons)

3 Dust control mesures include limiting maximum speed on unpaved roads to 25 miles per hour

CH2MHILL

JOB NO.	425035
Calc#	
SHEET NO.	1 of 1
DATE	8-May-12
	Rev. 2
COMPUTED BY	RE Menze
CHECKED BY	

JOB NAME Cadiz Water Project

SUBJECT Heat rate and emission data screen test for gas recip engines

PURPOSE: List the various heat rate, output power, and annual emission totals for different RE's and CTG's

REFERENCES:
1. CAT - MWM Spec sheet from CAT - MWM email of 30-April-2012
2. GE-Western Energy - Tech Data Sheets
3. GE-Jenbacher email of 01-May-2012 with emission data plus spec data sheet of 23-July-2010 for the J624
4. Table 4.3-6 from the project EIR, page 4.3.14

ASSUMPTIONS:
1. Ambient air temperature is **95** ° F
2. Site elevation is **790** ft ASL
3. Fuel consumption at LHV
4. Data given for single units only, except for daily emissions shown for all units
5. Annual hours of operation for each RE is 8760 , though unrealistic due to maintenance requirements.
6. UHC Emissions are generally considered to include VOC's, and other Unburned Hydrocarbon compounds
7. Output power shown at **100% load**
8. Post combustion treatment reductions are: Nox = 85% CO = 90% VOC = 70%
9. The project output capacity will be: 2 x 4MW = 8 MW plus 2 x 2 MW units = Total capacity of - 12 MW

INPUT DATA:

Engine - Make & Model #		Caterpillar - MWM TCG 2020	Caterpillar - MWM TCG 2032	GE - Jenbacher J612	GE - Jenbacher J624
Electrical output	(kW)	2,000	4,000	1,951	4,002
Mechanical output	(bhp)	2,790	5,507	2,760	5,521
Engine speed	(rpm)	1,500	900	1,500	1,500
No. of cylinders / engine		20	16	12	24
Number of cylinders all engines		72		72	

MDAQMD Thresholds of Significance	
lb/day	Pollutant
137	NOX
548	CO
137	VOC

CALCULATIONS:

			TCG 2020	TGC 2032	J612	J624		
	Fuel Use	(MM Btu/hr)	15.801	31.366	15.71	31.245		
	Power Output	(kW)	2,000	4,000	1,951	4,002		
	Heat Rate	(Btu/kW-hr)	7,901	7,842	8,052	7,807		
	Efficiency	(%)	43.20	43.52	42.39	43.72		
Emission rates	Nox	(gm / bhp)	1.20	1.20	1.10	0.60		
	CO	(gm / bhp)	1.90	2.30	2.50	2.50		
	VOC	(gm / bhp)	?	?	0.60	0.40		
Before SCR	Nox Emissions	(lb / hr)	7.37	14.56	6.69	7.30		
Mass flow rate	CO Emissions	(lb / hr)	11.68	27.90	15.20	30.40		
	VOC Emissions	(lb / hr)	?	?	3.65	4.86		
After SCR	Nox	(gm / bhp)	0.18	0.18	0.17	0.09		
	CO	(gm / bhp)	0.19	0.23	0.24	0.25		
	VOC	(gm / bhp)	?	?	0.18	0.12		
After SCR	Nox Emissions	(lb / hr)	1.11	2.18	1.00	1.09	GEJenbacher	CAT - MWM
Mass flow rate	CO Emissions	(lb / hr)	1.17	2.79	1.46	3.04	**Project Daily Total**	Project Daily Total
	VOC Emissions	(lb / hr)	?	?	1.09	1.46		
Daily flow	Daily Nox - 4 units	(lb / day)	53.10	104.80	48.15	52.53	**100.68**	157.90
	Daily CO - 4 units	(lb / day)	56.05	133.91	70.03	145.93	**215.96**	189.96
	Daily VOC - 4 units	(lb / day)	?	?	52.53	70.05	**122.57**	

PROJECT OPERATIONAL PM EMISSIONS - NATURAL GAS-FIRED RECIPRICATING ENGINES

Project: Cadiz

	Caterpillar - MWM		GE - Jenbacher	
Unit	TCG 2020	TCG 2032	J612	J624
(MMBTU/hr)[a]	15.801	31.366	15.71	31.245
(MMBTU/day)	379.224	752.784	377.04	749.88

AT 75,000 AFY[b]

	Emission Factor[c]	Emissions per day	Emissions per year
Pollutant	lb/MMBTU	lbs/day	tons/year
PM10	0.0000771	0.173771064	0.031713219
PM2.5	0.0000771	0.173771064	0.031713219

AT 50,000 AFY[d]

	Emission Factor[c]	Emissions per day	Emissions per year
Pollutant	lb/MMBTU	lbs/day	tons/year
PM10	0.0000771	0.115955316	0.021161845
PM2.5	0.0000771	0.115955316	0.021161845

[a] CH2MHILL, Heat rate and emission data screen test for gas receip engines, May 3, 2012.

[b] For 75,000 AFY, two J612 engines and two J624 engines would be used for a total output capacity of 12 MW.

[c] AP-42, Chapter 3.2 Natural Gas-Fired Recipricating Engines, August 2000.

[d] For 50,000 AFY, two J612 engines and one J624 engine would be used for a toal output capacity of 8 MW.

EMISSIONS OF GREENHOUSE GAS EMISSIONS FROM CONSTRUCTION

Project Name:	Cadiz
Analysis Year:	2012
Analysis Scenario:	Proposed Project

EMISSION FACTORS[a]

	Carbon Dioxide Emission Factors (kg/gal):	Methane Emission Factors (kg/gal):	Nitrous Oxide Emission Factors (kg/gal):
Diesel Fuel :	10.21	0.00058	0.00026
Gasoline:	8.78	0.0005	0.00022

Offroad and Onroad Diesel Construction Equipment Emissions

Carbon Dioxide (metric tons)[b]:	10577.23
Gallons of Diesel Fuel Consumed:	1036897.44

Onroad Gasoline Emissions (Worker Trips)

Carbon Dioxide (metric tons)[c]:	1702.31
Gallons of Gasoline Consumed:	194058.97

Methane and Nitrous Oxide Emissions

	Diesel Fuel Consumption Emissions	Gasoline Consumption Emissions
Methane (metric tons):	0.59663	0.09626
Nitrous Oxide (metric tons):	0.26746	0.04235

GREENHOUSE GAS EMISSIONS

	Emissions (metric tons)	CO_2 Equivalency Factors	CO_2 Equivalent Emissions (metric tons)
Carbon Dioxide	12,279.54	1	12,279.54
Methane	0.693	21	14.55
Nitrous Oxide	0.310	310	96.04
Total Emissions:	**12,280.54**		**12,390.13**

[a] 2012 Climate Registry Default Emisison Factors, Table 13.1 and Table 13.7.

[b] From URBEMIS outputs.

[c] From calculations based on EMFAC2007 emission factors.

DELIVERY TRUCK GHG EMISSIONS DURING CONSTRUCTION

EMISSION FACTORS

Scenario Year: **2012**

All model years in the range 1968 to 2012

Delivery Trucks[a] (pounds/mile)	
CO2	2.766284144
CH4	0.000106675

TRAVEL DISTANCE (MILES): 320

NUMBER OF TRUCKS DAILY: 10

TOTAL PROJECT CONSTRUCTION DAYS: 264

ANNUAL CO2 and CH4 POLLUTANT EMISSIONS

	pounds/day	metric tons/year	CO2e factors	CO2e emissions (metric tons/year)
CO2	8852.109261	1051.63058	1	1051.63058
CH4	0.341360918	0.040553677	21	0.851627218

ANNUAL N2O POLLUTANT EMISSIONS

	CH4 Factors (kg/gal):	N2O Factors (kg/gal):
Diesel Fuel [b]:	0.00058	0.00026

	pounds/day	metric tons/year	CO2e factors	CO2e emissions (metric tons/year)
N2O	0.153159806	0.018195385	310	5.640569343

GREENHOUSE GAS EMISSIONS

Total Emissions (metric tons/year): **1058.12**

[a] Based on EMFAC 2007 (v2.3) Burden Model Emission Factors compiled by SCAQMD for on-road delivery trucks (>8,500 pounds).

[b] 2012 Climate Registry Default Emisson Factors, Table 13.7

DELIVERY TRUCK GHG EMISSIONS DURING PROJECT OPERATIONS

EMISSION FACTORS

Scenario Year: **2013**

All model years in the range 1968 to 2012

Delivery Trucks[a] (pounds/mile)	
CO2	2.781634585
CH4	9.70338E-05

TRAVEL DISTANCE (MILES):	320
NUMBER OF TRUCKS DAILY:	2
TOTAL PROJECT OPERATION DAYS:	365

ANNUAL CO2 and CH4 POLLUTANT EMISSIONS

	pounds/day	metric tons/year	CO2e factors	CO2e emissions (metric tons/year)
CO2	1780.246134	292.4054276	1	292.4054276
CH4	0.062101609	0.010200189	21	0.214203976

ANNUAL N2O POLLUTANT EMISSIONS

	CH4 Factors (kg/gal):	N2O Factors (kg/gal):
Diesel Fuel [b]:	0.00058	0.00026

	pounds/day	metric tons/year	CO2e factors	CO2e emissions (metric tons/year)
N2O	0.027863384	0.004576561	310	1.418733871

GREENHOUSE GAS EMISSIONS

Total Emissions (metric tons/year): **294.04**

[a] Based on EMFAC 2007 (v2.3) Burden Model Emission Factors compiled by SCAQMD for on-road delivery trucks (>8,500 pounds) in 2013, which is the year project operations would commence.

[b] 2012 Climate Registry Default Emisson Factors, Table 13.7

PROJECT OPERATIONAL GHG EMISSIONS - METROPOLITAN CRA CONVEYANCE

Project: Cadiz

Conversion Factors:	Acre-Foot	Gallons (Water)	Million Gallons
	1	325,851	0.325851

Metropolitan CRA Conveyance Rate (kWh/MG): 3886

Project Extraction Values (Acre-Feet Per Year): 50000, 75000

Project Energy Demand (kWh/Year):

AFY	(kWh/Year)	(MWh/Year)
50000	63312849.30	63312.8493
75000	94969273.95	94969.27395

GREENHOUSE GAS EMISSIONS (50,000 AFY)

Emissions	Emission Factors[a] (lbs/MWh)	Emissions (metric tons/year)	CO_2 Equivalency Factors	CO_2 Equivalent Emissions (tons per year)
Carbon Dioxide	681.01	19,557.42	1	19,557.42
Methane	0.028	0.804	21	16.89
Nitrous Oxide	0.006	0.172	310	53.42
Total Emissions:		19,558.40		19,627.72

GREENHOUSE GAS EMISSIONS (75,000 AFY)

Emissions	Emission Factors[a] (lbs/MWh)	Emissions (metric tons/year)	CO_2 Equivalency Factors	CO_2 Equivalent Emissions (tons per year)
Carbon Dioxide	681.01	29,336.13	1	29,336.13
Methane	0.028	1.206	21	25.33
Nitrous Oxide	0.006	0.258	310	80.12
Total Emissions:		29,337.60		29,441.59

[a] Emission factors from The Climate Registry, Table 14.1 US Emission Factors by eGRID Subregion: http://www.theclimateregistry.org/downloads/2009/05/2011-Emission-Factors.pdf