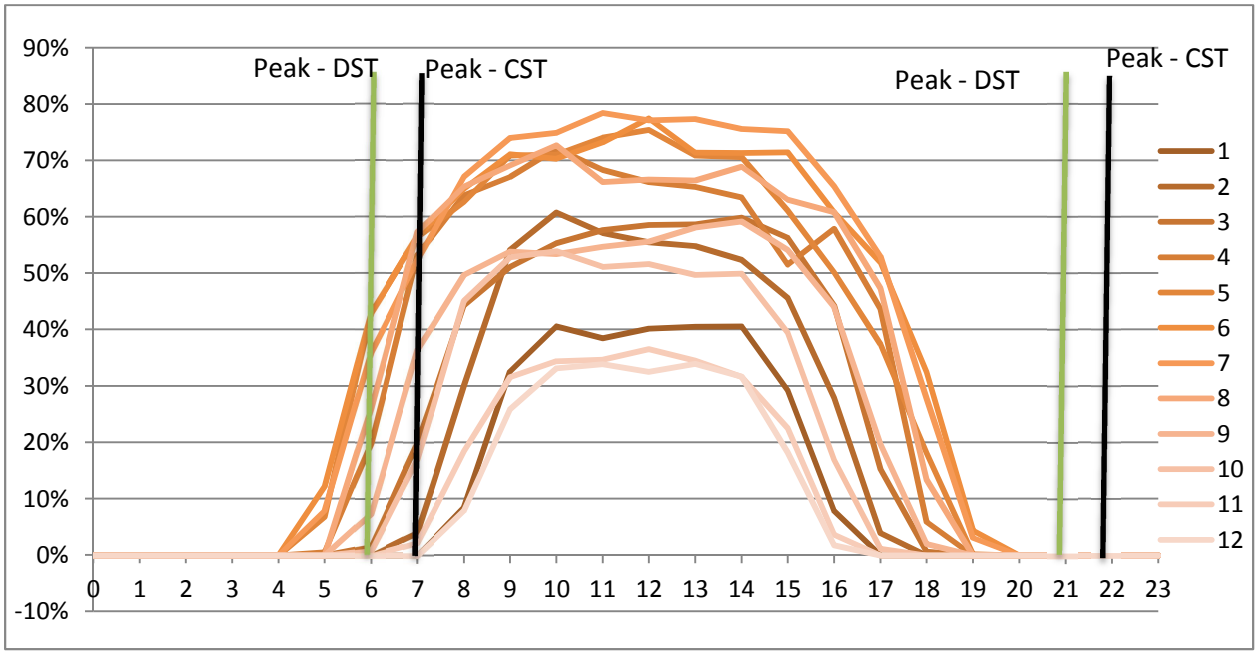
Appendix I - Emissions Displacement Analysis

1 Summary

This analysis estimates the emissions displaced by Geronimo's proposed 100 MW AC Distributed Solar Energy Proposal. The generation from the new solar facilities will result in a net reduction in thermal generation, thus a reduction in the emissions generated by the thermal electrical generators in the region. Emissions from thermal generation impose an additional cost on the environment and the general public, known as an externality cost. This analysis uses the Commission's environmental cost values to estimate the savings achieved by displacing emitting resources with Geronimo's Project. Within Xcel Energy's Minnesota service territory, the Midwest Independent Transmission System Operator, Inc. ("MISO") controls the generation mix on at any given time through price signals and other controls. Solar generation is coincident with MISO's peak hours. Figure 1 provides peak hours along with the expected capacity factors from Geronimo's project. The installation of the Geronimo's solar facilities will change the generation mix MISO uses to serve demand during peak hours by reducing the amount of thermal electrical generation and, thus, emissions generated from these sources.

Figure 1: Solar Generation Curve by Month and MISO Peak Hours



To estimate the amount of energy shaving that will likely occur and the resultant reduction in emissions from the Project, Geronimo evaluated the 2012 generation mix in the MISO Minnesota Zone, reviewed data from the U.S. Environmental Protection Agency ("EPA") regarding the emissions specific to Minnesota's energy mix, and compared the solar generation for each month with the generation from thermal plants that could be offset as a result of the project. Geronimo evaluated the MISO model to determine which facilities may be turned on and off and subtracted their generation from the generation of the new solar facilities. Geronimo

was then able to scale the emission data to determine the effect the Project could have when inserted into Minnesota's generation mix.

Geronimo examined the recent results from the Commission's pricing analysis in Docket No. E999/CI-00-1636 and E999/CI-07-1199 for current pricing on the different emissions sources including SOx, NOx, PM10, CO, and CO2. Using this pricing, Geronimo estimated the environmental cost savings that could result from the solar proposal. This analysis provided an overall cost savings ranging between $4.99/MWh and $17.81/MWh.

2 Emission Estimation

2.1 METHODOLOGY

Emissions resulting from electric generation are a function of the pool of generating plants that are being used to generate the electricity, and the demand dispatch of those plants. To estimate emission displacement from the Project, Geronimo used two data sources to approximate these factors: EPA data on Minnesota emissions and Ventyx data on Minnesota generation sources. When combined, these two data sources provide realistic data on generation and emission patterns in the region that will be affected by the Project.

The EPA's National Emission Inventory ("NEI") provides actual emission values on a state level. Geronimo reviewed the NEI 2008 data set-- the most recent available data on emissions for the State of Minnesota. Geronimo then paired this data set with 2008 generation as modeled by Ventyx for the MISO Minnesota Transmission Zone (Ventyx 2013) to determine a per MW value for each of the reported pollutants in the NEI (U.S. Environmental Protection Agency 2013). Table 1 summarizes the NEI data for electrical generation in Minnesota.

Table 1: NEI Data for Electrical Generation in Minnesota, 2008

	Pollutant (Tons)							
	CO	**NOX**	**PM10-FIL**	**PM10-PRI**	**PM25-FIL**	**PM25-PRI**	**SO2**	**VOC**
Biomass	1847.87	1457.65	532.93	552.70	458.43	478.20	401.57	109.35
Coal	6209.45	61184.06	7945.17	8201.26	2945.19	3201.28	77143.46	582.67
Natural Gas	1425.46	684.40	88.32	109.01	8.30	28.99	80.25	30.93
Oil	32.00	293.23	32.23	39.80	23.98	31.55	602.49	3.81
Other	226.80	179.95	0.30	15.87	14.73	14.81	24.55	21.89
Total	9741.59	63799.29	8598.95	8918.63	3450.63	3754.82	78252.32	748.65

By using the NEI, Geronimo is able to capture relative efficiencies as well as pollution variations associated with plant ramping that are unique to the power plants in the Minnesota area and the

way MISO dispatches those plants. Geronimo is also able to capture the variation in emissions associated with different levels of electrical production. Plants burning below their normal output or ramping up and down typically generate more emissions than those burning at a stable rate. The 2008 NEI is limited in that it does not provide quantities of CO2 generated by facilities. To supplement the NEI data, Geronimo used data from the EIA on CO2 emissions using average heat rates for steam electric generators in 2011 (U.S. Energy Information Administration 2013). Table 2 provides the estimations used by the EIA. Recent studies by the National Renewable Energy Laboratory (National Renewable Energy Labrotory 2012) found that integration of renewables, while being intermittent resources, do not increase the amount of emissions generated from plant ramping, so Geronimo did not include this in the analysis.

Table 2: EIA CO2 Emissions Estimates

Fuel	Lbs of CO_2 per Million Btu	Heat Rate (Million Btu per kWh)	Lbs CO_2 per kWh
Coal			
Bituminous	205.300	0.010128	2.03
Sub-bituminous	212.700	0.010128	2.10
Lignite	215.400	0.010128	2.13
Natural gas	117.080	0.010414	1.12
Distillate Oil (No. 2)	161.386	0.010414	1.55
Residual Oil (No. 6)	173.906	0.010414	1.67

Geronimo then used the per MW emission number to scale to the 2012 generation patterns. Geronimo rescaled the data to 2012 patterns so as to accommodate for the slight changes in generation since 2008. In particular, the increase in wind energy has shifted MISO to rely on gas generation more than other generation sources to accommodate for wind variability. Because of the granularity of the rescaling, Geronimo limited its analysis of this data to monthly MISO on-peak (7am to 10pm) operations

A PVsyst model developed by Westwood Professional Services was used to estimate the generation profile on a monthly basis for the proposed Project. PVsyst is an internationally recognized modeling tool for solar photovoltaic generation design. The results of the PVsyst modeling were applied to the monthly generation data, targeting the most expensive electrical generation source, petroleum, first and natural gas second because of its ability to ramp easily. Coal and biomass were assumed to be dispatched last because they cannot be easily ramped up and down. The revised emissions data was then subtracted from the initial scaled data to provide total tons of each emission reduced by Geronimo's solar project.

2.2 RESULTS

Table 3 details the emissions estimates for 2012 generation mix. This generation is the result of the recalculation of the 2008 output by source and emission level.

Table 3: 2012 Emissions Estimates by Month

Fuel	Year-Month	Sum Net Generation (MWh)	CO2 (tons)	CO (tons)	NOX (tons)	PM10-FIL (tons)	PM10-PRI (tons)	PM25-FIL (tons)	PM25-PRI (tons)	SO2 (tons)	VOC (tons)
Coal	2012-01	1529408.84	1784661.37	214.38	2112.34	274.30	283.14	101.68	110.52	2663.33	20.12

Fuel	Year-Month	Sum Net Generation (MWh)	CO2 (tons)	CO (tons)	NOX (tons)	PM10-FIL (tons)	PM10-PRI (tons)	PM25-FIL (tons)	PM25-PRI (tons)	SO2 (tons)	VOC (tons)
	2012-02	1467573.07	1718754.87	205.71	2026.94	263.21	271.70	97.57	106.05	2555.65	19.30
	2012-03	1222731.6	1463257.71	171.39	1688.78	219.30	226.37	81.29	88.36	2129.28	16.08
	2012-04	1135514.89	1351948.60	159.17	1568.32	203.66	210.22	75.49	82.06	1977.40	14.94
	2012-05	956655.73	1177325.23	134.09	1321.29	171.58	177.11	63.60	69.13	1665.93	12.58
	2012-06	1240170.35	1474134.84	173.84	1712.86	222.43	229.60	82.45	89.62	2159.65	16.31
	2012-07	1614627.15	1898954.15	226.32	2230.04	289.59	298.92	107.35	116.68	2811.73	21.24
	2012-08	1737413.17	2025168.04	243.53	2399.63	311.61	321.65	115.51	125.55	3025.55	22.85
	2012-09	1334301.99	1551740.60	187.03	1842.87	239.31	247.02	88.71	96.42	2323.57	17.55
	2012-10	1563681.12	1799819.07	219.18	2159.68	280.45	289.49	103.96	113.00	2723.01	20.57
	2012-11	1459931.62	1686248.12	204.64	2016.39	261.84	270.28	97.06	105.50	2542.34	19.20
	2012-12	1604531.59	1860577.52	224.91	2216.10	287.78	297.05	106.68	115.95	2794.15	21.10
	2012-01	153175.02	66146.58	77.72	37.32	4.82	5.94	0.45	1.58	4.38	1.69
	2012-02	257926.02	111422.27	130.88	62.84	8.11	10.01	0.76	2.66	7.37	2.84
	2012-03	279399.83	118121.49	141.77	68.07	8.78	10.84	0.83	2.88	7.98	3.08
	2012-04	369343.11	159495.75	187.41	89.98	11.61	14.33	1.09	3.81	10.55	4.07
	2012-05	475072.47	225010.05	241.06	115.74	14.94	18.43	1.40	4.90	13.57	5.23
	2012-06	581009.52	289578.46	294.82	141.55	18.27	22.55	1.72	6.00	16.60	6.40
	2012-07	968511.03	507672.41	491.45	235.96	30.45	37.58	2.86	9.99	27.67	10.66
	2012-08	552867.44	264955.38	280.54	134.69	17.38	21.45	1.63	5.70	15.79	6.09
Gas	2012-09	202622.03	93233.41	102.82	49.36	6.37	7.86	0.60	2.09	5.79	2.23
	2012-10	162024.4	73146.33	82.22	39.47	5.09	6.29	0.48	1.67	4.63	1.78
	2012-11	271751.8	123939.92	137.89	66.21	8.54	10.54	0.80	2.80	7.76	2.99
	2012-12	380759.91	166444.60	193.21	92.76	11.97	14.77	1.12	3.93	10.88	4.19
	2012-01	68.49	39.57	0.24	0.19	0.07	0.07	0.06	0.06	0.05	0.01
	2012-02	32.37	18.70	0.11	0.09	0.03	0.03	0.03	0.03	0.02	0.01
	2012-03	254.59	147.10	0.89	0.70	0.26	0.27	0.22	0.23	0.19	0.05
	2012-04	74.3	42.93	0.26	0.21	0.08	0.08	0.06	0.07	0.06	0.02
	2012-05	67.56	39.04	0.24	0.19	0.07	0.07	0.06	0.06	0.05	0.01
	2012-06	686.53	396.67	2.41	1.90	0.69	0.72	0.60	0.62	0.52	0.14
Oil	2012-07	4673.33	2700.20	16.40	12.94	4.73	4.91	4.07	4.24	3.56	0.97
	2012-08	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2012-09	238.81	137.98	0.84	0.66	0.24	0.25	0.21	0.22	0.18	0.05
	2012-10	186.09	107.52	0.65	0.52	0.19	0.20	0.16	0.17	0.14	0.04
	2012-11	711.13	410.88	2.50	1.97	0.72	0.75	0.62	0.65	0.54	0.15
	2012-12	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2012-01	34469.8	72056.45	120.98	95.44	34.89	36.19	30.01	31.31	26.29	7.16
	2012-02	34881.06	70540.65	122.43	96.58	35.31	36.62	30.37	31.68	26.61	7.24
	2012-03	37788.73	75143.89	132.63	104.63	38.25	39.67	32.90	34.32	28.82	7.85
	2012-04	34389.98	67971.68	120.70	95.22	34.81	36.10	29.95	31.24	26.23	7.14
	2012-05	22995.48	49710.63	80.71	63.67	23.28	24.14	20.02	20.89	17.54	4.78
Biomass	2012-06	36557.41	67042.60	128.31	101.22	37.01	38.38	31.83	33.21	27.88	7.59
	2012-07	37989.68	82204.84	133.34	105.18	38.46	39.88	33.08	34.51	28.98	7.89
	2012-08	39322.26	79634.16	138.02	108.87	39.80	41.28	34.24	35.72	29.99	8.17
	2012-09	30662.03	58051.55	107.62	84.89	31.04	32.19	26.70	27.85	23.39	6.37
	2012-10	38388.99	70439.83	134.74	106.29	38.86	40.30	33.43	34.87	29.28	7.97
	2012-11	32639.78	60425.86	114.56	90.37	33.04	34.27	28.42	29.65	24.90	6.78
	2012-12	33217.25	72040.57	116.59	91.97	33.62	34.87	28.92	30.17	25.34	6.90

Geronimo applied the estimated output to the energy estimates and found that the oil-based generation sources were completely supplanted and that a portion of the gas-based peaking sources were also supplanted with the new solar facility. The replacement of generation results in the reduction of emissions as provided in Table 4.

Table 4: Calculation of Emission Reductions from New Solar (2012 Levels)

	Pollutants (Tons)								
	CO2	CO	NOX	PM10-FIL	PM10-PRI	PM25-FIL	PM25-PRI	SO2	VOC
Totals Pre Solar	22,123,862.01	9,827,605,214.85	3,517.50	23,448.64	3,213.00	3,142.39	1,175.73	1,357.15	29,424.32
Totals Post Solar	22,029,729.01	9,827,605,098.88	3,454.24	23,435.90	3,198.66	3,135.77	1,167.52	1,346.67	29,420.88
DELTA	(94,133.00)	(115.98)	(63.26)	(12.74)	(14.33)	(6.62)	(8.21)	(10.48)	(3.44)

The installation of the Project produces notable reductions in generation levels for all pollutants measured in the NEI.

3 Cost Savings Estimation

3.1 METHODOLOGY

The Commission has per statute quantified the costs of carbon and other emissions. These values are provided by the Commission in dockets E999/CI-00-1636 for all pollutants and Docket No. E999/CI-07-1199 for CO_2. Docket No. E999/CI-00-1636 provides a calculation of the externality costs associated with different emissions in different regions of Minnesota. Geronimo applied the costs calculated for the Metropolitan Fringe since that is the location of a majority of the resources that would be affected by the addition of the Project. Geronimo applied the carbon costs calculated in Docket No. E999/CI-07-1199 because they represent the market rate for carbon emissions reduction and will most closely approximate any control technology that would be required as a result of the pending EPA rules on greenhouse gasses. All of these savings were aggregated and divided by the annual project output in PVsyst to generate a per MWh savings.

3.2 RESULTS

Table 5 provides the results of the cost calculation.

Table 5: Cost Savings Associated with Geronimo's Solar Project

Emission	Tons	Cost/Ton		Total Cost
CO2	(94,133.00)	$ 34.00	High	$ (3,200,522.08)
		$ 21.50	Mid	$ (2,023,859.55)
		$ 9.00	Low	$ (847,197.02)
CO	(115.98)	$ 1.86	High	$ (215.71)
		$ 1.46	Mid	$ (169.32)
		$ 1.06	Low	$ (122.93)
NOX	(63.26)	$ 370.00	High	$ (23,406.18)
		$ 282.50	Mid	$ (17,870.93)

Emission	Tons	Cost/Ton		Total Cost
		$ 195.00	Low	$ (12,335.69)
PM10	(27.08)	$ 4,012.00	High	$ (108,632.65)
		$ 3,387.00	Mid	$ (91,709.57)
		$ 2,762.00	Low	$ (74,786.48)

Total		High	**$ (3,332,776.62)**
		Mid	**$ (2,133,609.37)**
		Low	**$ (934,442.13)**

$/MWH		High	**$ (17.81)**
		Mid	**$ (11.40)**
		Low	**$ (4.99)**

Geronimo estimates that by offsetting risks associated with carbon pricing and reducing externalities from other generation sources, the Project will save Minnesota ratepayers between $4.99 and $17.88 per MWh generated by the Project.

4 Conclusion

Based on our analysis, the Geronimo Distributed Solar Proposal will result in a reduction in environmental costs of between $4.99 and $17.88 per MWh of solar generation. This result is significant, as it can be used as a direct reduction of the cost of solar generation when the Commission is considering, pursuant to Minnesota Statutes, section 216B.243, subdivision 3a, whether alternatives to the Project are less expensive.

References

National Bureau of Economic Research, Inc. *US Business Cycle Expansions and Contractions.* Cambridge MA, September 20, 2010.

National Renewable Energy Labrotory. *The Western Wind and Solar Integration Study.* Golden, CO, September 2012.

U.S. Energy Information Administration. *FAQ: How much carbon dioxide (CO2) is produced per kilowatt-hour when generating electricity with fossil fuels?* February 12, 2013. http://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11 (accessed 4 11, 2013).

U.S. Environmental Protection Agency. *2008 National Emission Inventory.* March 1, 2013. http://www.epa.gov/ttn/chief/net/2008inventory.html (accessed 4 11, 2013).

Ventyx. *Velocity Suite.* May 1, 2013.

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