BAY AREA TRANSPORTATION OPTIONS EMISSION REPORT

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Purpose:
This paper is intended as a first step in quantifying the air emissions due to commuter travel in the Bay Area. Three principle modes of travel are compared. The automobile is considered the baseline to which transit buses and ferry boats are compared. We also compared the effects of two different fuel types in transit and ferries, namely diesel and natural gas.

While we recognize that there are a number of other considerations that need to be taken into account in making transit decisions, we believe that the magnitude of the impacts demonstrated here justify further detailed study of the air and water quality impacts of the different transportation modes.

Findings:
Based purely on air quality considerations, transit buses are a much cleaner choice for commuter transit than ferry boats by an order of magnitude. The major factor driving this conclusion is that marine diesel engines are completely unregulated with regard to air emissions. This contrasts sharply with automobiles, which have only six percent of the smog-forming emissions they did in 1973. Buses too, have become much cleaner. Ferry emissions on a grams/horsepower basis are several times the levels permitted in on-road vehicles. The Environmental Protection Agency (EPA) has proposed emission standards for marine diesels scheduled to take effect in 2006 that are nearly twice the current standards for on-road vehicles and more than three times the standards for over the road diesels produced after 2002.

Of further note is that the fleet average emissions for automobiles in the Bay Area are coming down with time as newer, cleaner vehicles enter the fleet and replace older gross emitters. If current trends continue, it is possible that the automobile fleet average emissions will be less than the emissions for diesel buses sometime shortly after 2010.

Methodology:
This study attempts to reduce a substantial amount of data on the different modes of transportation into a form that can be easily compared. The unit chosen was grams/passenger mile. This unit is used to compare modes of travel that are vastly different in scale by quantifying emissions in terms of occupancy rates. We attempted to

use as much publicly available data as possible and to minimize our manipulation of the data. The study only considers Criteria Air Pollutants in the Bay Area, Non-Methane Hydrocarbons (NMHC), Oxides of Nitrogen (NOx), and Particulate Matter (PM).

Future emission projections for diesel in transit and ferry applications are based on proposed emission standards. There is considerable question in the industry as to whether these emission standards are achievable and if so at what cost.

Future emission projection standards for natural gas-fueled transit applications are based on testing currently under way and assume that a significant amount of the technology developed to meet proposed diesel standards is transferable to natural gas engines.

Automobile - These emissions were based on the fleet average emissions for automobiles, hot running, for the years 1999, 2003 and 2010.[1] 1999 was chosen as a baseline. 2003 and 2010 were chosen because they occur after significant changes in diesel emission standards occur. The emission data was divided by 1.15 [2]which is the average number of passengers per vehicle.[3]

Transit Bus - Transit bus emission data is well understood. Data used was prepared by PG&EÕs department of Technical and Ecological services and reviewed by California Air Resources Board staff.[4] The emission data is based on chassis dynamometer tests divided by the 35 which is the current average number passengers in the Bay Area.

Ferry Boats - The fast ferry Del Norte was chosen as a representative ferry configuration for the purposes of this study because it is the newest of the fast catamarans on the bay. The Del Norte currently operates on the Larkspur to San Francisco run for the Golden Gate Bridge, Highway and Transportation District. It operates at nearly twice the speed of other ferries on that run resulting in higher occupancy rates than other ferries, and it would therefore represent a conservative capacity assumption. The vessel is 41.3 Meters in length, has a top speed of 36 Knots, and has seating for 325 passengers.[5] The average

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[1] California Air Resources Board, Average Composite Car Emissions Operating in Calendar Tears 1999, 2003 and 2010. MVE17Gc - 12/01/97 (Summer Planning Inventory).

[2] The average number of vehicle occupants in the Bay Area, Bay Area Air Quality Management District, conversation with Amir Fanai.

[3] Since a majority of mass transit riders use automobiles to commute to and from bus and ferry pick-up points, for the purposes of this study, we assume that auto cold-starts and extra mileage driven by ferry or bus riders roughly correspond to cold-start emissions from that of dedicated automobile riders.

[4] Transit Bus emission data prepared by Sam Altshuler, PG&E's department of Technical and Ecological Services. Mr. Altshuler is also a member of Technical Advisory Committee of BAAQMD.

- SAE paper 1999-0101469, "Diesel and CNG Transit Bus Emissions Characterization by Two Chassis Dynamometer Laboratories: Results and Issues," May 3-6, 1999, Nigel Clark, et. al.
- SAE paper 981393, "Emissions from Trucks and Buses Powered by Cummins L-10 Natural Gas Engines," May 4-6, 1998, Nigel Clark, et. al.
- SAE Paper 1999-01-0470, "The Latest Developments in Heavy-Duty Vehicle Aftertreatment Testing for Real World Emissions and Fuel Economy," Andrew Eastlake, March 1999.

[5] Janes High-Speed Marine Transportation, 1998-99 Edition.

round trip occupancy rate is 48.5%.[6] Occupancy rate times the seating capacity gives the average number of passengers 157.43 per run which was used for computations.

Comparing the distance a ferry travels to other transit sources as a means of establishing emission levels per passenger mile is a challenge since ferries obviously don't travel the same route as automobiles and buses. However, we do know that the distance a commuter would have traveled by auto of bus had that commuter not boarded a ferry. Therefore, for the purposes of this study, we used the on-road trip distance that a ferry displaces as the denominator in estimating ferry emissions per mile. The numerator represents the total mass emissions of criteria air pollutants. This is then divided by 157 passengers to yield the passenger emissions per mile. Obviously, in the case of the Larkspur high-speed ferry, this is a very conservative assumption since cars and buses travel much farther on the route than do ferries. Other ferry routes provide more similar commute distances compared to on-road vehicles.

Since marine engine manufacturers are currently not required to meet any emission standards, there is a wide range of emissions for marine engines, but most are extremely dirty. Computations of ferry emissions for the years 1999 and 2003 were based on current EPA test data. A Caterpillar 3516 DITA V Type[7] was chosen as a representative engine for this study because it is in widespread use and is of a size and type suitable for use on a fast ferry. Ferry emission computations for 2010 are based on proposed EPA emission standards scheduled to take effect in 2006.[8] It should be noted that the marine engine industry is opposing the proposed standards, characterizing them as impractical given current technology.

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[6] Assumptions regarding marine transit operations, vessel configuration, and passenger occupancy were provided by Pacific Transit Management, Berkeley, CA.

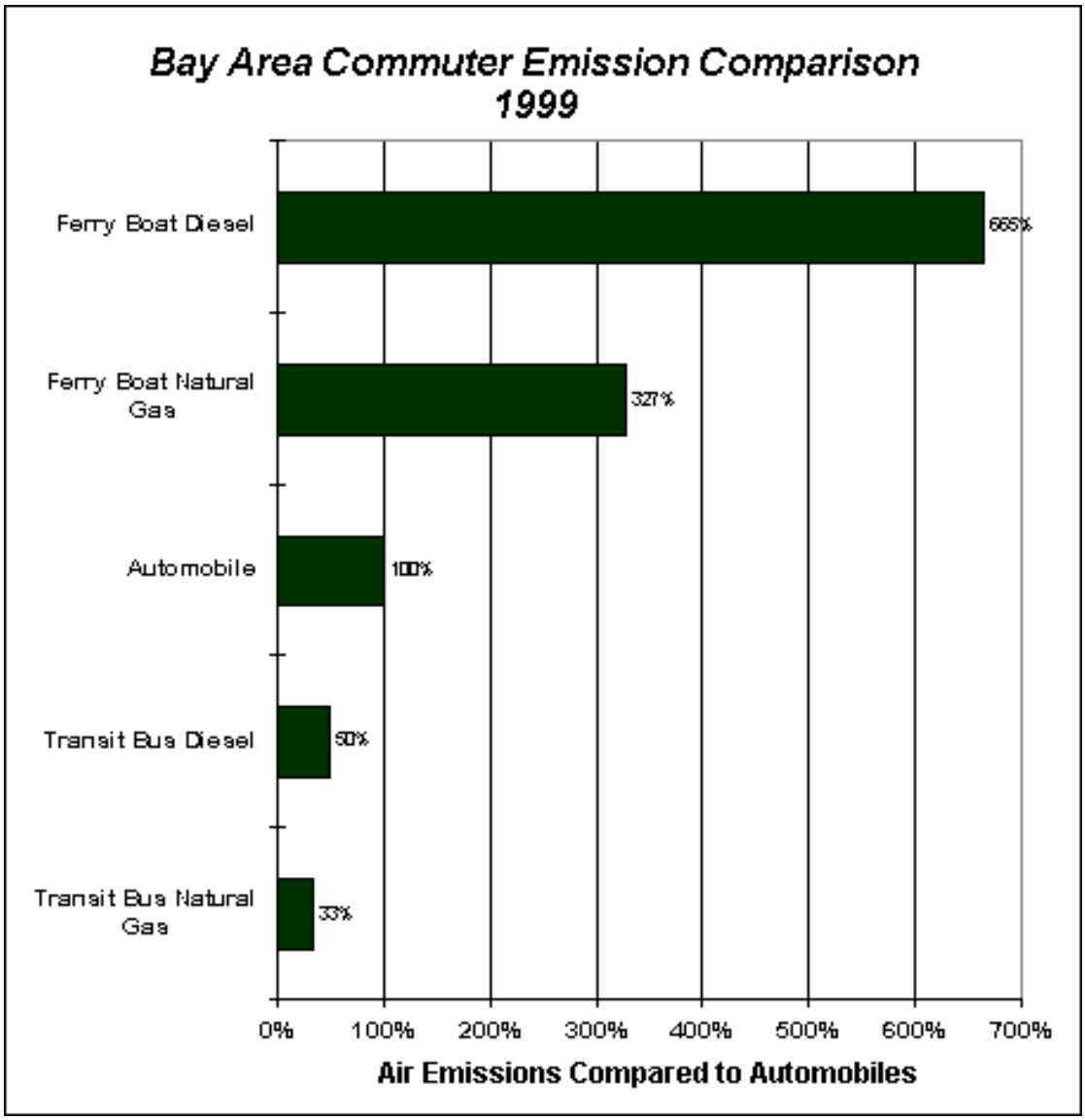
[7] "Shipboard Marine Engine's Emission Testing for the United States Coast GuardÓ by Environment Transportation Consultants. Study funded by EPA.

[8] EPA, Draft Regulatory Analysis: control of Emissions from Compression Ignition Engines, November 1998.

BAY AREA TRANSPORTATION
OPTIONS EMISSION REPORT DATA

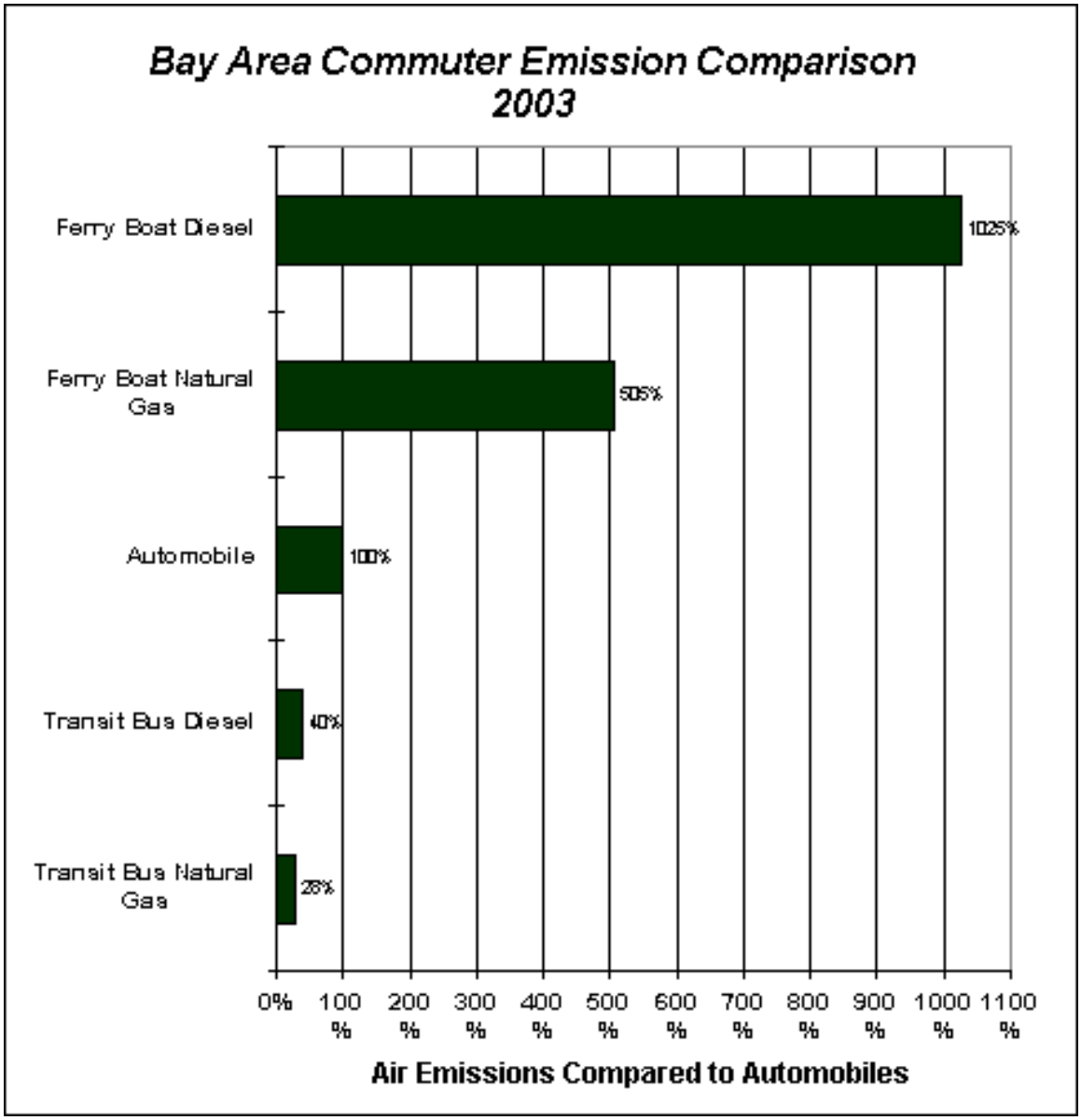
1999 Commuter Emissions

	Percentage of	Emission (Units - Grams / Passenger Mile			
	Auto Emissions	NMHC	NOx	PM	Total
Mode of Travel					
Transit Bus Natural Gas	33%	0.041	0.371	0.001	0.414
Transit Bus Diesel	50%	0.016	0.594	0.020	0.631
Automobile	100%	0.443	0.817	0.000	1.261
Ferry Boat Natural Gas	327%	0.014	4.112	0.001	4.127
Ferry Boat Diesel	665%	0.014	8.224	0.143	8.382



2003 Commuter Emissions

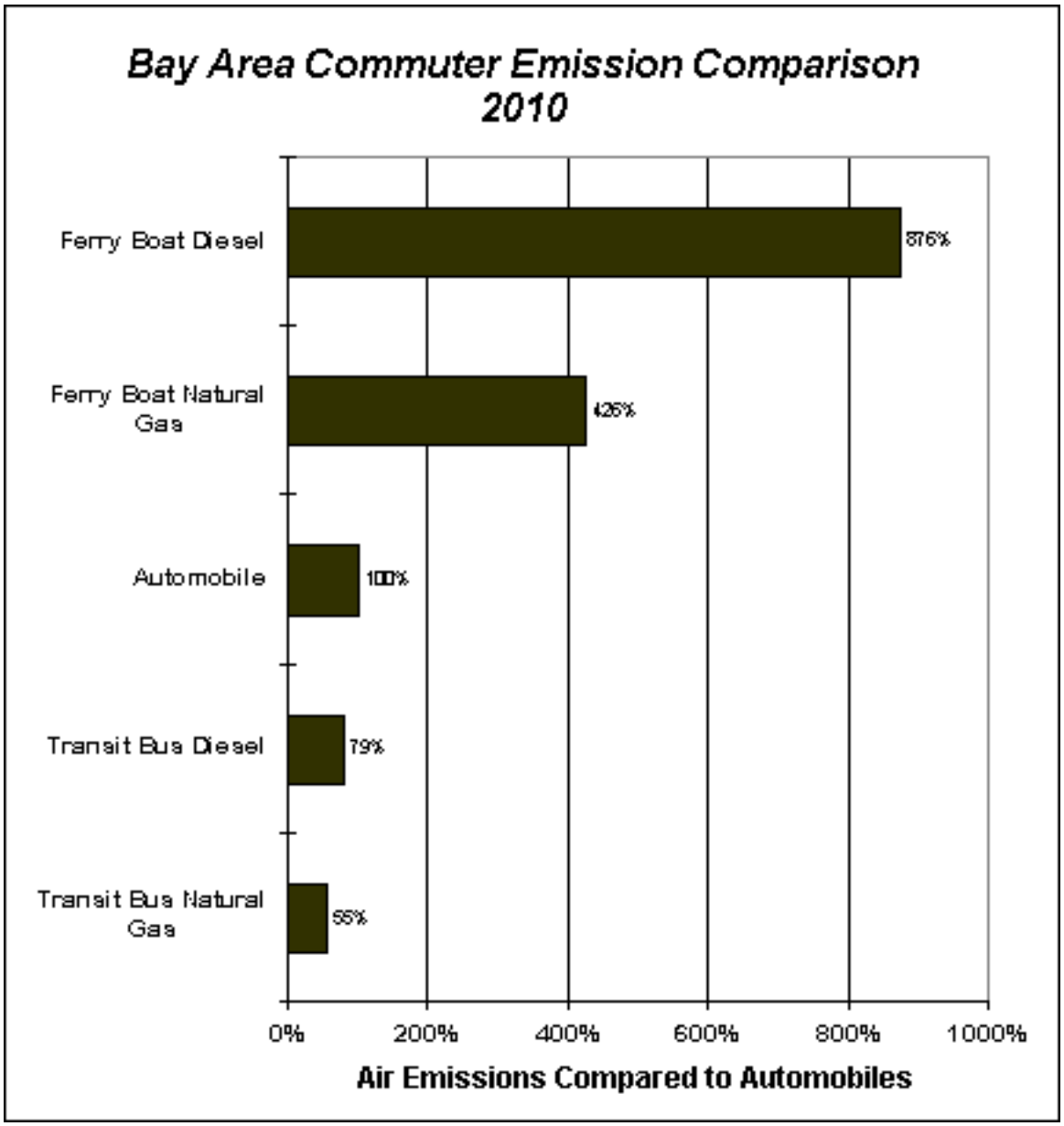
	Percentage of	Emission	(Units - Grams / Passenger Mile		
	Auto Emissions	NMHC	NOx	PM	Total
Mode of Travel					
Transit Bus Natural Gas	28%	0.041	0.189	0.001	0.231
Transit Bus Diesel	40%	0.016	0.293	0.020	0.329
Automobile	100%	0.261	0.557	0.000	0.817
Ferry Boat Natural Gas	505%	0.014	4.112	0.001	4.127
Ferry Boat Diesel	1025%	0.014	8.224	0.143	8.382



2010 Commuter Emissions

	Percentage of	Emission	(Units - Grams / Passenger Mile		
	Auto Emissions	NMHC	NOx	PM	Total
Mode of Travel					
Transit Bus Natural Gas	55%	0.041	0.189	0.001	0.231
Transit Bus Diesel	79%	0.016	0.293	0.020	0.329
Automobile	100%	0.087	0.330	0.000	0.417
Ferry Boat Natural Gas	426%	0.000	1.776	0.001	1.777
Ferry Boat Diesel	876%	0.000	3.557	0.099	3.656

2006 EPA Standard Combines HC and Nox



Average Composite Car Operating Criteria Emissions for Calender Years 1999, 2003, and 2010

Number of Occupants **1.15**

Model Year 1999	**g/mi**	**g/pass-mile**
ROG	0.510	0.443
NOx	0.940	0.817
PM	0.000	0.000
	Total	**1.261**

Model Year 2003	**g/mi**	**g/pass-mile**
ROG	0.300	0.261
NOx	0.640	0.557
PM	0.000	0.000
	Total	**0.817**

Model Year 2010	**g/mi**	**g/pass-mile**
ROG	0.100	0.087
NOx	0.380	0.330
PM	0.000	0.000
	Total	**0.417**

See Footnote #1 of Report for Citations and Sources

Transit Bus Emissions

Average # of Passengers 35

Model Year 1999		**Diesel Bus g/mile**	**CNG Bus g/mile**	**Diesel Bus g/pass mile**	**CNG Bus g/pass mile**
	NMHC	0.560	1.450	0.016	0.041
	NOx	20.800	13.000	0.594	0.371
	PM	0.710	0.025	0.020	0.001
			Total	**0.631**	**0.414**

Model Year 2002		**Diesel Bus g/mile**	**CNG Bus g/mile**	**Diesel Bus g/pass mile**	**CNG Bus g/pass mile**
	NMHC	0.560	1.450	0.016	0.041
	NOx	10.250	6.600	0.293	0.189
	PM	0.710	0.025	0.020	0.001
			Total	**0.329**	**0.231**

See Footnote #3 of Report for Citations and Sources

Ferry Emissions 2010

2006 Proposed EPA Marine Emission Standards

	Starboard				Port				Total	Average Emissions			
% Pwr	Power kW	HC g/kw-hr	NOx g/kw-hr	PM g/kw-hr	Power kW	HC g/kw-hr	NOx g/kw-hr	PM g/kw-hr	Power KW	HC g/kw-hr	NOx g/kw-hr	PM g/kw-hr	% Pwr
75%	1431	0.0	7.2	0.2	1416	0	7.2	0.2	2847	0.00	7.20	0.20	75%
50%	954	0.0	7.2	0.2	944	0	7.2	0.2	1898	0.00	7.20	0.20	50%
25%	477	0.0	7.2	0.2	472	0	7.2	0.2	949	0.00	7.20	0.20	25%
Idle	48.1	0.0	7.2	0.2	44	0	7.2	0.2	92.1	0.00	7.20	0.20	Idle

Emissions / Passenger Trip = # of Passengers x Load Factor x Trip Emissions

Note: Operating Profile and Overland distance assume Larkspur to San Francisco run.

Trip Emission Computation (Grams)

Power Level	Time @ Power	KW	HC	NOx	PM
85%	20	3227	0	7,744	215
25%	10	949.00	0	1,139	32
Idle	7	92.10	0	77	2
			0	8,960	249
					9,209

Overland Trip Distance 16 Miles

Emissions / Passenger Trip

Average Passenger Load = Passenger Capacity x Load Factor

157.43	325	0.4844

	HC	NOx	PM	Total
Total Criteria Emissions / Passenger Trip	0.000	56.914	1.581	58.495
Total Criteria Emissions / Passenger Mile	0.000	3.557	0.099	3.656

See Footnote #7 of Report for Citations and Sources

Ferry Emissions 1999 & 2003

Caterpillar 3516 DITA V Type Long Island

% Pwr	Starboard Power kW	HC g/kw-hr	NOx g/kw-hr	PM g/kw-hr	Port Power kW	HC g/kw-hr	NOx g/kw-hr	PM g/kw-hr	Total Power KW	Average Emissions HC g/kw-hr	NOx g/kw-hr	PM g/kw-hr	% Pwr
75%	1431	0.028	16.878	0.257	1416	0.0128	15.228	0.23	2847	0.02	16.05	0.25	75%
50%	954	0.02	21.02	0.31	944	0.0306	21.153	0.24	1898	0.02	21.09	0.27	50%
25%	477	0.04	21.38	0.52	472	0.0545	21.206	0.34	949	0.05	21.29	0.43	25%
Idle	48.1	0.42	7.64	3.22	44	0.88	7.68	2.22	92.1	0.65	7.66	2.72	Idle

Emissions / Passenger Trip = # of Passengers x Load Factor x Trip Emissions

Note: Operating Profile and Overland distance assume Larkspur to San Francisco run.

Trip Emission Computation (Grams)

Power Level	Time @ Pwr	KW	HC	NOx	PM
85%	20	3227	22	17,266	264
25%	10	949.00	7	3,368	68
Idle	7	92.10	7	82	29
			36	20,716	361
					21,113

Overland Trip Distance 16 Miles

Emissions / Passenger Trip

Average Passenger Load = Passenger Capacity x Load Factor

157.43 325 0.4844

	HC	NOx	PM	Total
Total Criteria Emissions / Passenger Trip	0.230	131.587	2.294	134.112
Total Criteria Emissions / Passenger Mile	0.014	8.224	0.143	8.382

See Footnote #7 of Report for Citations and Sources