Alternative Fuels for Ferries and Other Vessels

Larry Watkins
South Coast Air Quality Management District

November 1-2, 2000

Emission Reducing Technologies

- **Engine Modifications**
- **Exhaust Aftertreatment**
- **Fuel Modifications**

Example of Emission Reducing Technology

- Selective catalytic reduction (SCR)
- NH_4 into exhaust upstream of catalyst
- NOx reduction rxn between NH_4 & NO
- Reduce NOx by > 90%
- High initial cost
- NH_4 storage is drawback
- High maintenance

Emission Reductions by Modifying Operations

- **Reducing Ship Speed**

- **Relocating Shipping Lanes**

Marine Contribution to Emission Inventory (1993 - 2010)

	NOx	SOx
Marine Vessel	41 – 53	25 – 31
Inventory	1194	79

1999-2000 FUNDING
CARL MOYER PROGRAM

- $23 million Statewide
  - —$19 million for vehicles and equipment (ARB)
  - —$2 million clean fuels infrastructure (CEC)
  - —$2 million R&D for heavy-duty engines (CEC)

- **AQMD RFP - $13.5 million**
  - —$8.55 million for vehicles and equipment (ARB)
  - —$900,000 for clean fuels infrastructure (CEC)
  - —$4.05 million match (Clean Fuels Fund)

Available Funding

- Engines, Vehicles, Equipment - $45 million
  - AQMD - $19.5 million
- Fueling Infrastructure - $2.5 million
  - AQMD - $1.1 million

Funding Criteria

- Must Meet $12,000/ton NOx Reduced
  - 1999-2000 AQMD Program - $6,000/ton
- New Vehicle or Repower
- 75% of Operation within AQMD Boundaries

FY1999-00 Carl Moyer Program
Marine

Company	Vessel	Number of Engines	Total NOx Reduction (tons/year)	Total NOx Reduction (tons)*	Calculated Cost Effectiveness ($/ton)**
American	**tug**	**2**	18.25	365	**$578**
American	**work**	**2**	16.25	325	**$649**
American	**work**	**2**	4.98	100	**$657**
American	**work**	**2**	4.98	100	**$802**
American	**work**	**2**	8.98	180	**$861**
Seaboard	**fishing**	**2**	7.71	154	**$954**
Ocean Air	**tug**	**2**	10.14	203	**$1,025**
Ocean Air	**fishing**	**2**	5.31	106	**$1,135**
Ocean Air	**fishing**	**1**	3.91	78	**$1,186**
Ocean Air	**fishing**	**1**	3.66	73	**$1,202**
Ocean Air	**fishing**	**2**	8.40	168	**$1,238**
Harley Marine	**tug**	**2**	17.17	354	**$1,248**
Seaboard	**fishing**	**2**	5.22	104	**$1,294**
Ocean Air	**tug**	**2**	12.02	220	**$1,380**
	TOTAL	**26**	**126.05**	**2,530**	

Table 13-1. Summary of the emissions inventory for marine vessels in the South Coast Air Basin — 1990 (tons per day)

Vessel Category	NO_x	HC	CO	PM	SO_x
Ocean-going, SPBP	28.1	2.5	2.9	2.6	21.6
El Segundo Traffic	0.5	—	—	—	0.5
Transiting Vessels	5.7	0.2	0.5	0.7	4.5
Tugboats (Harbor)	1.7	0.1	0.2	—	0.3
Tugboats (Ocean-going)	0.4	0.1	—	—	0.1
Harbor Vessels	2.1	0.1	0.3	—	0.4
Fishing Vessels	6.3 (5.7)	0.3	0.9 (0.8)	0.1	1.1 (1.0)
U.S. Navy	0.1	—	—	—	0.2
U.S. Coast Guard	0.8	—	0.1	0.1	—
Totals	45.7 (45.1)	3.3	4.9 (4.8)	3.5	28.7 (28.6)

Table 13-2. Summary of the emissions inventory for marine vessels in the South Coast Air Basin — 1993 (tons per day)

Vessel Category	NO_x	HC	CO	PM	SO_x
Ocean-going, SPBP	24.0	2.2	2.4	2.3	18.5
El Segundo Traffic	0.5	—	—	—	0.5
Transiting Vessels	5.7	0.2	0.5	0.7	4.5
Tugboats (Harbor)	1.4	0.1	0.2	—	0.2
Tugboats (Ocean-going)	0.2	—	—	—	—
Harbor Vessels	2.1	0.1	0.3	—	0.4
Fishing Vessels	6.3 (5.7)	0.3	0.9 (0.8)	0.1	1.1 (1.0)
U.S. Navy	0.1	—	—	—	0.2
U.S. Coast Guard	0.8	—	0.1	0.1	—
Totals	41.1 (40.5)	2.9	4.4 (4.3)	3.2	25.4 (25.3)

Table 4-1. Summary of the emission inventory for marine vessels in the South Coast Air Basin — 1997 (tons per day)

Vessel Category	NO_x	HC	CO	PM	SO_x
Oceangoing, Ports	29.8	3.2	3.5	2.7	21.7
El Segundo Traffic	0.5	—	—	—	0.5
Transiting Vessels	1.9	0.1	0.2	0.2	1.5
Tugboats (Harbor)	1.1	0.1	0.2	—	—
Tugboats (Oceangoing)	0.4	—	—	—	—
Harbor Vessels	2.3	0.1	0.3	—	—
Fishing Vessels	6.3 (5.7)	0.3	0.9 (0.8)	0.1	0.1
U.S. Navy	0.1	—	—	—	—
U.S. Coast Guard	0.8	—	0.1	0.1	—
Totals	43.2 (42.6)	3.8	5.2 (5.1)	3.1	23.8

Table 13-3. Summary of the emissions inventory for marine vessels in the South Coast Air Basin — 2000 (tons per day)

Vessel Category	NO_x	HC	CO	PM	SO_x
Ocean-going, SPBP	26.8	2.5	2.8	2.3	19.6
El Segundo Traffic	0.5	—	—	—	0.5
Transiting Vessels	5.7	0.2	0.5	0.7	4.5
Tugboats (Harbor)	1.5	0.1	0.2	—	0.3
Tugboats (Ocean-going)	0.4	0.1	—	—	0.1
Harbor Vessels	2.1	0.1	0.3	—	0.4
Fishing Vessels	6.3 (5.7)	0.3	0.9 (0.8)	0.1	1.1 (1.0)
U.S. Navy	0.1	—	—	—	0.2
U.S. Coast Guard	0.8	—	0.1	0.1	—
Totals	44.2 (43.6)	3.3	4.8 (4.7)	3.2	26.7 (26.6)

Table 13-4. Summary of the emissions inventory for marine vessels in the South Coast Air Basin — 2010 (tons per day)

Vessel Category	NO_x	HC	CO	PM	SO_x
Ocean-going, SPBP	34.7	3.4	3.7	2.7	23.4
El Segundo Traffic	0.5	—	—	—	0.5
Transiting Vessels	5.7	0.2	0.5	0.7	4.5
Tugboats (Harbor)	1.9	0.1	0.3	—	0.3
Tugboats (Ocean-going)	0.4	0.1	—	—	0.1
Harbor Vessels	2.1	0.1	0.3	—	0.4
Fishing Vessels	6.3 (5.7)	0.3	0.9 (0.8)	0.1	1.1 (1.0)
U.S. Navy	0.1	—	—	—	0.2
U.S. Coast Guard	0.8	—	0.1	0.1	—
Totals	52.5 (51.9)	4.2	5.8 (5.7)	3.6	30.5 (30.4)

MARINE EMISSIONS INVENTORY
Ocean going VesselsCalling on SFBP; Main Engine Fuel Consumption Calculations and Time in Operating Mode

Shiptype	Propulsion Type	Design Categories	NB / B[1] Calls in 1993	Fuel Consumption (gal/hour)			Time in Mode (hours/call)			Fuel Consumption (gal/call)			Fuel Consumption (gal/year)		
				Cruise	P-zone Cruise	Maneuvering	Cruise	P-zone Cruise	Maneuvering	Cruise	P-zone Cruise	Maneuvering	Cruise	P-zone Cruise	Maneuvering
Auto Carrier	*(% MCR)*		NB calls	*80%*	*22%*	*15%*									
	Motorships	0-200	0	0	0	0	4.2	1.0	1.5	0	0	0	0	0	0
		200-400	191	446	123	100	4.2	1.0	1.5	1868	118	150	356760	22538	28732
		400-600	75	526	145	118	4.2	1.0	1.5	2206	139	178	165428	10450	13323
		>600	1	592	163	133	4.2	1.0	1.5	2481	157	200	2481	157	200
Auto Carrier	*(% MCR)*		B calls	*80%*	*22%*	*15%*									
	Motorships	0-200	0	0	0	0	4.2	1.0	1.3	0	0	0	0	0	0
		200-400	33	446	123	100	4.2	1.0	1.3	1868	118	133	61640	3894	4387
		400-600	2	526	145	118	4.2	1.0	1.3	2206	139	157	4411	279	314
		>600	3	592	163	133	4.2	1.0	1.3	2481	157	177	7443	470	530
Bulk Carrier	*(% MCR)*		NB calls	*80%*	*40%*	*20%*									
	Motorships	0-240	9	262	131	65	5.0	1.1	2.5	1319	130	164	11872	1241	1473
		200-400	166	325	162	81	5.0	1.1	2.5	1637	171	203	271673	28389	33713
		400-600	105	402	201	101	5.0	1.1	2.5	2026	212	251	212748	22231	26401
		600-800	30	503	251	126	5.0	1.1	2.5	2531	265	314	75938	7935	9424
		800-1000	1	764	382	191	5.0	1.1	2.5	3849	402	478	3849	402	478
		>1000	1	1,004	502	251	5.0	1.1	2.5	5054	528	627	5054	528	627
	Steamships	600-800	1	918	459	229	5.0	1.1	2.5	4622	483	574	4622	483	574
		800-1000	0	1,335	667	334	5.0	1.1	2.5	6723	703	834	0	0	0
		1000-1200	0	1,530	765	382	5.0	1.1	2.5	7704	805	956	0	0	0
Bulk Carrier	*(% MCR)*		B calls	*80%*	*40%*	*20%*									
	Motorships	0-200	12	262	131	65	5.0	1.1	1.1	1319	130	74	15829	1654	888
		200-400	211	325	162	81	5.0	1.1	1.1	1637	171	92	345319	36085	19396
		400-600	142	402	201	101	5.0	1.1	1.1	2026	212	114	287716	30085	16186
		600-800	44	503	251	126	5.0	1.1	1.1	2531	265	142	111375	11638	6246
		800-1000	19	764	382	191	5.0	1.1	1.1	3849	402	216	73131	7643	4102
		>1000	2	1,004	502	251	5.0	1.1	1.1	5054	528	283	10108	1056	567
	Steamships	600-800	5	918	459	229	5.0	1.1	1.1	4622	483	259	23111	2415	1296
		800-1000	0	1,335	667	334	5.0	1.1	1.1	6723	703	377	0	0	0
		1000-1200	12	1,530	765	382	5.0	1.1	1.1	7704	805	432	92444	9660	5184

ALAMAR EMISSIONS INVENTORY
Updating Vessels Calling on the SFBP: NOx Inventory Calculations

Shiptype	Propulsion Type	Design Category	NO of Calls in 2000	Time in Mode (hours/year)				Main Engine/Boiler Fuel Consumption (gallons/year)			Main Engine/Boiler NOx Emissions (tons/year)				Auxiliary Engine NOx (tpy)			Auxiliary Boiler NOx (tpy)	
				Cruise	Precruise	Maneuvering	Hotelling	Cruise	Precruise	Maneuvering	Cruise	Precruise	Maneuvering	Hotelling	At Berth	Maneuvering	Hotelling	Maneuvering	Hotelling
															1.5	2.5	2	1	1
Auto Carrier	Motorships	0-200	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0
		200-400	239	1052	230	359	6047	307930	29407	31194	113.6	7.2	9.2	0	13.6	5.8	35.9	0.5	0.1
		400-600	95	388	81	143	2404	101800	11486	14642	53.3	3.4	4.3	0	5.4	2.6	15.4	0.2	0.2
		>600	1	4	1	2	26	2153	196	173	0.6	0.0	0.1	0	0.1	0.0	0.4	0.0	0.0
			11 calls												1.5	2.5	2	1	1
Auto Carrier	Motorships	0-200	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0
		200-400	42	376	40	55	403	88868	4080	4751	20.0	1.3	1.4	0	2.4	1.0	7.1	0.1	0.0
		400-600	2	8	2	3	23	3020	242	207	1.1	0.1	0.1	0	0.1	0.0	0.3	0.0	0.0
		>600	4	17	4	5	46	6010	544	601	2.5	0.2	0.2	0	0.2	0.1	0.7	0.0	0.0
															1.5	2.5	2	1	1
Bulk Carrier	Motorships	0-200	9	45	8	23	259	10533	1101	1007	3.4	0.4	0.4	0	0.6	0.4	0.7	0.0	0.0
		200-400	167	824	177	405	11940	230077	24702	29071	75.0	7.9	9.4	0	11.0	7.5	175.8	0.5	10.0
		400-600	122	644	128	305	8944	219014	22940	27240	70.0	7.3	8.7	0	9.2	5.8	131.5	0.4	11.8
		600-800	77	388	81	193	5641	172924	18070	21458	55.4	5.8	6.9	0	5.2	3.5	83.0	0.3	7.5
		800-1000	1	5	1	3	73	3415	357	424	1.1	0.1	0.1	0	0.1	0.0	1.1	0.0	0.1
		>1000	1	5	1	3	73	4484	469	556	1.4	0.2	0.2	0	0.1	0.0	1.1	0.0	0.1
	Steamships	600-800	1	5	1	3	73	4677	493	574	0.1	0.0	0.0	0.7	0	0	0	0	0
		800-1000	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0	0
		1000-1200	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0	0
			11 calls												1.5	2.5	2	1	1
Bulk Carrier	Motorships	0-200	17	80	15	13	171	14041	1468	767	4.5	0.5	0.2	0	0.8	0.2	1.0	0.0	0.2
		200-400	307	1510	218	275	2201	300565	31400	16111	96.3	10.1	5.3	0	13.0	4.2	30.0	0.3	2.6
		400-600	161	826	173	100	1656	284815	30807	16096	91.5	9.9	5.2	0	11.8	3.3	24.4	0.2	2.2
		600-800	113	589	123	129	1182	262755	27457	14347	84.2	8.8	4.6	0	7.9	2.4	17.4	0.2	1.6
		800-1000	33	166	35	36	333	119707	11777	6154	38.1	3.8	2.0	0	2.2	0.7	4.9	0.0	0.4
		>1000	19	96	20	21	192	85197	8993	4652	27.3	2.9	1.5	0	1.3	0.4	2.8	0.0	0.3
	Steamships	600-800	5	25	5	6	51	29111	3415	1262	0.7	0.1	0.0	0.5	0	0	0	0	0
		800-1000	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0	0
		1000-1200	11	56	12	12	111	84740	8935	4697	27	0.3	0.1	1.1	0	0	0	0	0

Note: Right-justified numbers at top of "Auxiliary" columns indicate a multiplier to adjust the TAC average load (about 500 kW) to the expected hotelling load for each shiptype. Expected hotelling loads are based on data for over 80 ships taken from a survey of ship operators conducted by the Ports (Reference 7) and on average port load data for the ships tested by MEC (Reference 8).