Appendix M

Additional Cost Effectiveness Summary Tables

Additional Cost Effectiveness Summary Tables

This appendix contains additional tables summarizing the cost-effectiveness analyses, as discussed in Chapter XI. For brevity and clarity, Chapter XI addressed cost-effectiveness for the scenario where only ships making three or more annual visits to the port are cold-ironed and the necessary electrical transformers are located on shore. Furthermore, staff used 0.1 percent sulfur distillate fuel, as required by the recently adopted regulation governing auxiliary engines on ocean-going vessels. Staff believes this to be the most likely approach to implementing cold-ironing.

Tables M-1 through M-3 provide the emissions reductions, by ship category, for all three scenarios discussed throughout this report: 1) all vessels visiting the port are cold-ironed; 2) only vessels that make three or more visits per year to a California port are cold-ironed; and 3) only vessels that make six or more visits per year to a California port are cold-ironed. In all cases, the reductions are based upon the ships using distillate fuel (0.1 percent sulfur). In addition, the reductions take into account the time it takes to connect and disconnect the ship from shore power, and the reductions are discounted for increases in power plant emissions.

Table M-1 provides the emission reductions for the case where all 1,900 vessels visiting California ports during 2004 are cold-ironed.

Table M-1: Emission Reductions from Cold-Ironing by Ship Category Assuming All Ships Are Cold-Ironed

Category	NOx (TPD)	PM (TPD)	HC (TPD)	SOx (TPD)
Container	11.6	0.2	0.32	0.21
Bulk	4.3	0.07	0.1	0.1
Passenger	2.0	0.06	0.05	0.03
Reefer	1.7	0.03	0.05	0.3
Product Tanker	1.1	0.02	0.03	0.02
Vehicle Carrier	1.0	0.02	0.03	0.02
Crude-Oil Tanker	0.7	0.01	0.02	0.01
Total	**22.4**	**0.41**	**0.60**	**0.69**

In general, cold-ironing all the ships would reduce hotelling emissions by between 85 to 95 percent, depending upon the pollutant and ship category. Over 50 percent of the total reduction for NOx, PM and HC comes from the container-ship category. The next highest category, bulk ships, would provide nearly 20 percent of the total reductions.

Table M-2 provides the emission reductions for the case where only the ships that make three or more visits to a California port during 2004 are cold-ironed. About 36 percent of the ships that visit California ports, or 686 ships, made at least three visits to the same California port during 2004.

Table M-2: Emission Reductions from Cold-Ironing by Ship Category Assuming Ships with Three or More Visits to a California Port Are Cold-Ironed

Category	NOx (TPD)	PM (TPD)	HC (TPD)	SOx (TPD)
Container	10.8	0.18	0.34	0.19
Bulk	1.4	0.02	0.04	0.04
Passenger	1.7	0.04	0.05	0.03
Reefer	1.4	0.1	0.04	0.21
Product Tanker	0.7	0.02	0.02	0.05
Vehicle Carrier	0.5	0.01	0.01	0.01
Crude-Oil Tanker	0.6	0.01	0.01	0.01
Total	**17.1**	**0.38**	**0.51**	**0.54**

If the ships that made at least three visits to the same California port are cold-ironed, then the overall hotelling emissions would be reduced by between 70 to 74 percent. For this scenario, the container ship category would provide 50 to 60 percent of the total reduction for NOx, PM, and HC.

Finally, Table M-3 provides the emission reductions for the case where only the ships that make six or more visits to a California port during 2004 are cold-ironed. About 370 ships meet this criterion, or about 20 percent of the total ships.

Table M-3: Emission Reductions from Cold-Ironing by Ship Category Assuming Ships with Six or More Visits to a California Port Are Cold-Ironed

Category	NOx (TPD)	PM (TPD)	HC (TPD)	SOx (TPD)
Container	8.1	0.14	0.22	0.14
Bulk	0.5	0.01	0.01	0.01
Passenger	1.5	0.03	0.04	0.04
Reefer	1.2	0.02	0.03	0.02
Product Tanker	0.4	0.01	0.01	0.03
Vehicle Carrier	0.1	0.002	0.003	0.002
Crude-Oil Tanker	0.5	0.01	0.01	0.01
Total	**12.3**	**0.22**	**0.32**	**0.25**

If the ships that made at least six visits to the same California port are cold-ironed, then the overall hotelling emissions would be reduced by about 50 percent. Again, the container ship category provides most of the reduction, about 60 to 70 percent of the total reduction for NOx, PM, and HC.

Tables M-4 through M-6 provide similar information on the potential emission reductions, but presents the information based on the ports the ships visit. On this basis, 60 to 70 percent of the potential reduction from cold-ironing would occur at Los Angeles/Long Beach and an additional ten percent would occur at Oakland. This result is not unexpected in that Los Angeles, Long Beach, and Oakland are the major ports for container traffic. In addition, the potential reductions from the ports of Los Angeles/Long Beach can come from all seven ship categories (if one counts product tankers and crude-oil tankers as separate categories).

Table M-4: Emission Reductions from Cold Ironing by Port Assuming All Ships Cold-Ironed

Port	NOx (TPD)	PM (TPD)	HC (TPD)	SOx (TPD)
Carquinez	0.57	0.01	0.01	0.01
El Segundo	0.15	0.002	0.004	0.002
Hueneme	0.83	0.01	0.02	0.10
POLA/POLB	**15.0**	**0.27**	**0.4**	**0.40**
Oakland	2.2	0.04	0.06	0.04
Richmond	0.60	0.01	0.02	0.01
San Diego	1.36	0.03	0.04	0.09
San Francisco	0.77	0.02	0.02	0.01
Other	0.88	0.01	0.02	0.02
Total	**22.4**	**0.40**	**0.59**	**0.68**

Table M-5: Emission Reductions from Cold-Ironing by Port Assuming Ships Making 3 or More Visits to One California Port Are Cold-Ironed

Port	NOx (TPD)	PM (TPD)	HC (TPD)	SOx (TPD)
Carquinez	0.28	0.005	0.007	0.01
El Segundo	0.13	0.003	0.003	0.004
Hueneme	0.62	0.04	0.02	0.08
POLA/POLB	**12.0**	**0.24**	**0.37**	**0.30**
Oakland	1.97	0.03	0.06	0.04
Richmond	0.40	0.01	0.01	0.02
San Diego	1.04	0.04	0.02	0.06
San Francisco	0.38	0.008	0.01	0.01
Other	0.23	0.004	0.006	0.007
Total	**17.05**	**0.38**	**0.51**	**0.53**

Table M-6: Emission Reductions from Cold-Ironing by Port Assuming Ships Making 6 or More Visits to One California Port Are Cold-Ironed

Port	NOx (TPD)	PM (TPD)	HC (TPD)	SOx (TPD)
Carquinez	0.22	0.004	0.004	0.005
El Segundo	0.10	0.002	0.002	0.003
Hueneme	0.52	0.009	0.01	0.009
POLA/POLB	**8.63**	**0.15**	**0.23**	**0.17**
Oakland	1.44	0.025	0.04	0.03
Richmond	0.30	0.006	0.007	0.01
San Diego	0.80	0.01	0.02	0.02
San Francisco	0.23	0.004	0.006	0.006
Other	0.08	0.002	0.002	0.003
Total	**12.32**	**0.20**	**0.32**	**0.27**

Table M-7 provides estimate for potential emission reductions for 2010, 2015 and 2020 for the scenario where all ships that make three or more visits to a port are cold-ironed. These estimates assume substantial growth in shipping activities in the container, passenger, and reefer categories. Container ship and reefer ship activities are expected to double from current levels by 2020. Similarly, passenger ship activities are expected to increase by a factor of four. Other ship categories are expected to grow at a more modest rate.

Table M-7: Potential Emission Reductions from Cold-Ironing Ships That Make Three or More Visits to a California Port

Category	NOx (TPD)	PM (TPD)	HC (TPD)	SOx (TPD)
2010	24.6	0.55	0.74	0.76
2015	30.8	0.69	0.92	0.92
2020	39.6	0.89	1.19	1.15

B. Overall Financial Impact of Cold-Ironing

The total capital costs for the three cold-ironing scenarios are presented in Tables M-8 through M-19. Tables M-8 through M-13 provide the capital costs based on ship category and 2004 ship activity. Two sets of tables are provided for each cold-ironing Scenario. For example, Tables M-8 and M-9 represent the scenario where all ships are cold-ironed. One table provides estimates assuming each ship is equipped with a transformer to supply the appropriate voltage requirements. Alternatively, the other table provides estimates assuming the transformer is added to the shore infrastructure.

For the case where the transformer is placed on each ship, staff assumed that 10 percent of the container ships would not need transformers and therefore the capital cost for modifying these ships would be $500,000 instead of $1,500,000. (As discussed previously, 10 percent of the ships can use the 6.6 kV power directly without a transformer.) For Oakland, the cost is based upon adding infrastructure at the port-side only. As discussed in Chapter V, Oakland is cost-effective to cold-iron when the visiting ships are already equipped to cold-iron. In addition, no infrastructure costs were included for the two container berths that are already equipped to cold-iron ships.

Table M-8: Capital Cost to Implement Cold-Ironing for Each Ship Category Assuming All Ships Are Cold-Ironed —Transformer on Ship Case (Million Dollars)

Category	Shore-Side	Ship-Side	Total
Container	$77	$830	$907
Bulk	$81	$930	$1,011
Passenger	$21	$66	$87
Reefer	$11	$83	$94
Product Tanker	$59	$430	$489
Vehicle Carrier	$21	$340	$361
Crude-Oil Tanker	$28	$130	$158
Total	**$298**	**$2,809**	**$3,107**

Table M-9: Capital Cost to Implement Cold-Ironing for Each Ship Category Assuming All Ships Are Cold-Ironed —Transformer on Shore Case (Million Dollars)

Category	Shore-Side	Ship-Side	Total
Container	$180	$300	$480
Bulk	$150	$310	$460
Passenger	$38	$22	$60
Reefer	$17	$28	$45
Product Tanker	$90	$140	$230
Vehicle Carrier	$39	$43	$82
Crude-Oil Tanker	$40	$130	$170
Total	**$554**	**$973**	**$1,527**

Table M-10: Capital Cost to Implement Cold-Ironing for Each Ship Category Assuming Ships with Three or More Visits to a California Port Are Cold-Ironed —Transformer on Ship Case (Million Dollars)

Category	Shore-Side	Ship-Side	Total
Container	$77	$600	$677
Bulk	$81	$190	$271
Passenger	$21	$33	$54
Reefer	$11	$36	$47
Product Tanker	$56	$66	$122
Vehicle Carrier	$18	$93	$111
Crude-Oil Tanker	$28	$63	$91
Total	**$292**	**$1,081**	**$1,373**

Table M-11: Capital Cost to Implement Cold-Ironing for Each Ship Category Assuming Ships with Three or More Visits to a California Port Are Cold-Ironed —Transformer on Shore Case (Million Dollars)

Category	Shore-Side	Ship-Side	Total
Container	$180	$210	$390
Bulk	$150	$64	$214
Passenger	$38	$11	$49
Reefer	$17	$12	$29
Product Tanker	$90	$22	$112
Vehicle Carrier	$28	$31	$59
Crude-Oil Tanker	$40	$21	$61
Total	**$543**	**$371**	**$914**

Table M-12: Capital Cost to Implement Cold-Ironing for Each Ship Category Assuming Ships with Six or More Visits to a California Port Are Cold-Ironed —Transformer on Ship Case (Million Dollars)

Category	Shore-Side	Ship-Side	Total
Container	$77	$350	$427
Bulk	$25	$56	$81
Passenger	$14	$27	$41
Reefer	$11	$24	$35
Product Tanker	$56	$23	$79
Vehicle Carrier	$11	$21	$32
Crude-Oil Tanker	$28	$33	$61
Total	**$222**	**$534**	**$756**

Table M-13: Capital Cost to Implement Cold-Ironing for Each Ship Category Assuming Ships with Six or More Visits to a California Port Are Cold-Ironed —Transformer on Shore Case (Million Dollars)

Category	Shore-Side	Ship-Side	Total
Container	$180	$120	$300
Bulk	$38	$19	$57
Passenger	$20	$9	$29
Reefer	$15	$8	$23
Product Tanker	$90	$7	$97
Vehicle Carrier	$17	$7	$24
Crude-Oil Tanker	$40	$11	$51
Total	**$400**	**$181**	**$581**

As shown above, constructing electrical transformers at the ports instead of on the ships reduces the overall capital investment by 33 to 50 percent. Fewer transformers are required. The container and bulk ship categories account for two-thirds of the total capital costs.

Tables M-14 through M-19 provide the same capital costs information, but on a port basis instead of ship category basis.

Table M-14: Capital Cost to Implement Cold-Ironing for Each Port Assuming All Ships Are Cold-Ironed —Transformer on Ship Case (Million Dollars)

Category	Shore-Side	Ship-Side	Total
Carquinez	$14		
El Segundo	$7	$2,900 for all	$3,199
Hueneme	$7	1,906 ships	
POLA/POLB	$190		
Oakland	$35		
Richmond	$11		
San Diego	$14		
San Francisco	$21		

Table M-15: Capital Cost to Implement Cold-Ironing for Each Port Assuming All Ships Are Cold-Ironed —Transformer on Shore Case (Million Dollars)

Category	Shore-Side	Ship-Side	Total
Carquinez	$23		
El Segundo	$10	$953 for all 1,906 ships	$1,503
Hueneme	$10		
POLA/POLB	$360		
Oakland	$70		
Richmond	$17		
San Diego	$25		
San Francisco	$35		

Table M-16: Capital Cost to Implement Cold-Ironing for Each Port Assuming Ships with Three or More Visits to a California Port Are Cold-Ironed —Transformer on Ship Case (Million Dollars)

Category	Shore-Side	Ship-Side	Total
Carquinez	$14		
El Segundo	$7	$1,100 for 747 ships	$1,389
Hueneme	$7		
POLA/POLB	$180		
Oakland	$35		
Richmond	$11		
San Diego	$14		
San Francisco	$21		

Table M-17: Capital Cost to Implement Cold-Ironing for Port Assuming Ships with Three or More Visits to a California Port Are Cold-Ironed —Transformer on Shore Case (Million Dollars)

Category	Shore-Side	Ship-Side	Total
Carquinez	$23		
El Segundo	$10	$370 for 747 ships	$910
Hueneme	$10		
POLA/POLB	$350		
Oakland	$70		
Richmond	$17		
San Diego	$25		
San Francisco	$35		

Table M-18: Capital Cost to Implement Cold-Ironing for Each Port Assuming Ships with Six or More Visits to a California Port Are Cold-Ironed —Transformer on Ship Case (Million Dollars)

Category	Shore-Side	Ship-Side	Total
Carquinez	$11		
El Segundo	$7	$550 for 369 ships	$773
Hueneme	$7		
POLA/POLB	$130		
Oakland	$32		
Richmond	$11		
San Diego	$11		
San Francisco	$14		

Table M-19: Capital Cost to Implement Cold-Ironing for Each Port Assuming Ships with Six or More Visits to a California Port Are Cold-Ironed —Transformer on Shore Case (Million Dollars)

Category	Shore-Side	Ship-Side	Total
Carquinez	$15		
El Segundo	$10	$180 for 369 ships	$579
Hueneme	$10		
POLA/POLB	$250		
Oakland	$62		
Richmond	$15		
San Diego	$17		
San Francisco	$20		

The above tables show that the majority of the capital cost will need to be spent at POLA/POLB. For any of the three scenarios, about 60 percent of the shore-side costs would be born by POLA/POLB.