I. INTRODUCTION

This report presents an analysis of the feasibility and cost effectiveness of cold-ironing ocean-going vessels while docked at California ports. Cold-ironing refers to shutting down auxiliary engines on ships while in port and connecting to electrical power supplied at the dock, thus eliminating virtually all emissions from a ship while it is in port. (Cold-ironing is also referred to as "shore power" and alternative maritime power). The term "cold-ironing" comes from the act of dry-docking a vessel, which involves shutting down all on-board combustion, resulting in the vessel going "cold." Without cold-ironing, auxiliary engines run continuously while a ship is docked, or "hotelled," at a berth to power lighting, ventilation, pumps, communication, and other onboard equipment. Ships can hotel for several hours or several days.

Hotelling emissions from ship auxiliary engines are significant contributors to particulate matter from diesel-fueled engines (diesel PM), California's most significant toxic air contaminant. Diesel PM emissions are estimated to be responsible for about 70 percent of the total ambient air toxics risk in California.

Communities adjacent to the ports are exposed to elevated cancer risk and other health impacts from these hotelling emissions. As indicated in a recent Air Resources Board (ARB or Board) risk analysis conducted for the ports of Los Angeles and Long Beach, "Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach," 20 percent of total diesel PM emissions at these ports comes from hotelling emissions. Other sources of diesel PM include emissions from ship transit and maneuvering, cargo-handling equipment, and rail and truck operations. The analysis concluded that hotelling emissions contribute 34 percent of the total diesel PM population-weighted health risks posed to the residents in the surrounding communities. In fact, of all the sources of diesel PM at the ports, hotelling emissions resulted in the largest area (2,036 acres) where the potential cancer risk levels were greater than 200 in a million in the nearby communities.

In addition to local health risks, hotelling emissions of oxides of nitrogen (NOx) also contribute to regional ozone and fine particulate matter ($PM_{2.5}$) levels. Repeated exposure to ozone can make people more susceptible to respiratory infection and lung inflammation and can aggravate preexisting respiratory diseases, such as asthma. Exposure to fine particulate matter, including diesel PM, can also be linked to premature death and a number of heart and lung diseases.

A. Purpose of Study

The ARB, port operators, and the local air districts have identified several strategies to reduce health impacts posed by hotelling emissions at California ports. The analysis presented in this cold-ironing report will provide information that can be used for further consideration of these strategies.

South Coast SIP

The 2003 revisions to the State Implementation Plan (SIP) for the South Coast Air Basin required the ARB to evaluate the options for requiring cold-ironing of ships that frequently visit South Coast ports. The SIP is sent to the United States Environmental Protection Agency (U.S. EPA), as required by the Federal Clean Air Act, and outlines how the State will reduce emissions for regions not meeting federal ambient air quality standards. The cold-ironing cost-effectiveness analysis discussed in this report fulfills this specific SIP requirement.

Goods Movement

The ARB recently released a draft *Emission Reduction Plan for the Ports and International Goods Movement in California* (December 1, 2005). The plan identifies strategies for reducing emissions created from the movement of goods through California ports and into other regions of the State. The draft Emission Reduction Plan is part of the broader Goods Movement Action Plan being jointly carried out by the California Environmental Protection Agency and the Business, Transportation, and Housing Agency. Phase I of the Goods Movement Action Plan was released in September 2005 and highlighted the air pollution impacts of goods movement and the urgent need to mitigate localized health risk in affected communities.

The draft Emission Reduction Plan identifies numerous strategies for reducing emissions from all significant emission sources involved in the goods movement, including ocean-going vessels, harbor craft, cargo handling equipment, locomotives, and trucks. The draft Plan identifies several strategies for reducing emissions from ocean-going vessels, including cold-ironing ships when in port. The analysis discussed in this cold-ironing report will provide information needed for further consideration of the cold-ironing strategies identified in the draft Emission Reduction Report. Staff anticipates refining the draft Emission Reduction Plan over the next several months, based on public comments and technical input.

Diesel Risk Reduction Plan

The Board has committed to reducing statewide risk posed by diesel PM in its Diesel Risk Reduction Plan. The ARB released the Diesel Risk Reduction Plan in 2000 and established a goal of 85 percent reduction in diesel PM in California by 2020. Because hotelling emissions are significant sources of diesel PM, controlling emissions from this source category could play a significant role in meeting the 85 percent diesel PM emission reduction goal. The information in the cold-ironing analysis presented in this report could help determine if cold-ironing is a cost-effective measure for controlling diesel PM emissions from auxiliary engines on ocean-going vessels while in port.

B. Significance of Ports and their Emissions in California

Ports play a critical role in California's economy. California's location provides a geographic advantage for trade with China and other countries in Asia. In 2003, 73 percent of U.S. imports from Asia entered through California ports, and trade with Asia is expected to significantly increase. Since 2000, container traffic has increased by 40 percent at the ports of Los Angeles and Long Beach and, by 2020, cargo movement at California's ports is expected to triple from 2005 levels.

California is home to three of the largest ports in the nation. The San Pedro Bay ports of Los Angeles and Long Beach comprise the largest container port complex in the nation and the third largest in the world. The Port of Oakland is the seventh largest container port in the nation. The cargo moving through the San Pedro Bay ports is valued at over $200 billion per year. Fifty to sixty percent of the goods passing through these ports are destined for other parts of the region and the country, making the ports a global gateway for the country’s trade.

Port emissions contribute to regional air pollution and impact a region’s ability to meet attainment of health-protective air quality standards. The ports are also significant contributors to local diesel PM emissions. Port air emissions come from ocean-going vessel activities, harbor-craft activities, cargo-handling equipment, and locomotives and trucks used to move the cargo through the terminals and port property. Most of the engines used in these activities are diesel-fueled.

In 1998, the Board identified particulate matter from diesel-fueled engines (diesel PM) as a toxic air contaminant because of its potential to cause cancer and other health problems, including aggravation of respiratory and cardiovascular diseases. The greatest health impacts from exposure to diesel PM from ports occur in the communities adjacent to the ports—in many cases low-income or minority communities—making port emissions an environmental justice concern.

C. Scope of the Cold-Ironing Evaluation Report

As stated earlier, the purpose of this report is to determine the cost effectiveness of cold-ironing ocean-going vessels that visit California ports. There are alternative techniques for reducing emissions from onboard auxiliary engines while hotelling. These include switching to cleaner fuels, using selective catalytic reduction, and installing particulate control devices. These are mentioned briefly in Chapter XII. It was not staff’s intent to discuss these alternatives in detail, but to merely acknowledge them. Staff’s goal was to determine under what circumstances cold-ironing would be cost-effective as a potential air pollution mitigation measure.

The actual infrastructure requirements and costs associated with cold-ironing are site-specific. Where possible, staff has taken into account information at specific ports. Nevertheless, a considerable amount of engineering is required to fully design a cold-ironing project at a port. This level of detail is beyond the scope of this report. Other issues, such as legal jurisdictions, port tenant leases, and worker safety are also beyond the scope of this report.

The results of this cost-effectiveness analysis provide a framework for further consideration of cold-ironing at California ports—what ships and ports are best suited for this technique for reducing air pollutants and protecting public health.

D. Outreach Efforts during Development of the Report

The ARB staff is currently soliciting public comments on this draft report. During the development of this report, staff undertook several outreach measures to gather information and receive public input. ARB's plan for analyzing the cost effectiveness of cold-ironing ocean-going vessels was first discussed at a public consultation meeting on November 9, 2004. Preliminary concepts for the analysis were discussed at the May 14, 2005, Maritime Workgroup meeting. This workgroup is comprised of ARB staff, local air district staff, representatives of the ports, shipping companies and environmental groups, and other interested members of the public.

During the report's development, staff visited four ports in California: Los Angeles, Long Beach, Oakland, and San Diego. Staff also visited three cold-ironing applications in the State: a ship utilizing shore power at the USS POSCO steel plant in Pittsburg, a ship utilizing shore power at the China Shipping Terminal at the Port of Los Angeles, and a Navy ship cold-ironing at the Naval Station in San Diego. During these visits, staff observed the configuration of the ports, terminals, and berths and gained an understanding of the logistics involved in bringing power to the terminals and individual berths.

Staff also held conference calls and/or met with shipping companies, utility companies, environmental groups, and other organizations interested in cold-ironing applications. These meetings gave staff the opportunity to hear from proponents of cold-ironing as well as hear the concerns from those entities that would be involved with bringing power to the terminals and retrofitting ships for cold-ironing. Staff also held conference calls with SCAQMD staff to obtain their input during the development of the report.

E. Future Efforts

As mentioned earlier, a commitment in the 2003 South Coast SIP revisions led to the development of this report. ARB staff worked with South Coast AQMD staff to evaluate cold-ironing as a potential pollution-reduction strategy at the ports of Los Angeles and Long Beach. The SIP commitment further stated that, if cold-ironing was determined to be cost-effective, staff would develop a regulation to include cold-ironing as a pollution-reduction measure for the South Coast ports.

No measures are currently in place requiring cold-ironing. However, cold-ironing has been identified as a strategy for reducing ocean-going vessel emissions in ARB's draft Emission Reduction Plan, which was developed as part of the Good Movement Action Plan. Of all the emission sources involved with the Goods Movement in California, ship emissions are the least controlled. As was mentioned early, activity at the ports is expected to triple by 2020, leading to significant emission increases from ship activities if left uncontrolled. Consequently, cold-ironing may become an effective control measure for significantly reducing hotelling emissions in the future.

II. GENERAL DESCRIPTION OF SHIP CATEGORIES AND CALIFORNIA PORTS

This chapter provides a description of the types of ocean-going vessels that visit California ports. It also provides a general description of the major ports in California.

A. Ship Category Descriptions

Ocean-going vessels are designed to carry specific types of cargo or material. For example, ships transporting automobiles are designed differently than ships carrying perishable food products. The type of cargo entering or leaving a port will determine which types of ships visit that port. There are six general categories of ships that are briefly described below: container, passenger, reefer, tanker, bulk, and vehicle carrier.

<u>Container Ships:</u> Container ships are designed to transport cargo, such as furniture, electronics, and clothes, in standardized containers. These containers have capacities measured in TEUs (twenty-foot equivalent units). The dimensions of a TEU are 20' X 8' X 8.5' and a typical container is 40 feet long or two TEUs.

<u>Passenger Ships:</u> Passenger ships carry passengers on pleasure voyages. These ships typically stop at ports to allow passengers to participate in coordinated activities on shore. These ships also include swimming pools, restaurants, and fitness centers for on-board recreation.

<u>Reefer Ships</u>: Reefer ships are used to transport perishable products, such as fruit and meat. These products are usually palletized and stored in large refrigerated cargo holds.

<u>Tankers:</u> Tankers are designed to carry liquid and gaseous products, such as crude oil, finished petroleum products, and chemicals. These products are pumped into and out of the vessels when in port.

<u>Bulk Ships:</u> Bulk and general cargo ships carry material that is not easily place into containers, such as wood chips, grains, gypsum, and rolls of steel. The cargo is usually shipped in large quantities and does not need to be in packaged form.

<u>Vehicle Carriers:</u> These ships carry wheeled cargo, such as automobiles, trailers, or railway carriages. These ships are also referred to as "RORO's" because the cargo can be rolled on and off the vessels when in port.

B. California Ports

Each of the California ports is unique not only in its physical size but also in the types and amounts of cargo that is handled at the port. Each port can have one to several terminals. Each terminal can have one to several berths. Each terminal is usually dedicated to a certain type of ship, such as a container ship or passenger ship. The Ports of Los Angeles and Long Beach make up the largest port complex in the State. The majority of ship calls in California are made to these two ports. Table II-1 shows the number of ship visits by port based on 2004 data. The Port of Oakland has the third most ship visits in the State. All other ports account for 26 percent of remaining California ship visits.

Table II-1: Port Ranking by Ship Visits

Port	Number of Ship Visits	Percentage of Total Visits to State
Los Angeles/Long Beach	5263	55%
Oakland	1828	19%
Richmond	472	5%
San Diego	454	5%
San Francisco	395	4%
Carquinez	383	4%
Hueneme	329	3%
El Segundo	163	2%
Stockton	135	1%
All Other	191	2%
Total	9613	100%

Table II-2 shows the number of terminals and berths by ship category at each port.

Table II-2: Number of Terminals and Berths per Ship Category for Each California Port

Port	Container		Reefer		Vehicle Carrier		Bulk		Tanker		Passenger		Total	
	T	B	T	B	T	B	T	B	T	B	T	B	T	B
Avalon-Catalina	**no wharf**													
Benicia*														
Carquinez					1	1	1	3	1	2			3	6
Crockett							1	1					1	1
El Segundo									1	2			1	2
Hueneme			1	1	1	1	1	1			1	1	4	4
Humboldt							3	5			1	1	4	6
Long Beach/ Los Angeles	16	48	1	2	3	8	17	32	17	20	2	4	56	114
Monterey	**no wharf**													
Oakland	8	19											8	19
Pittsburg	**bulk ships at port already cold-ironed**													
Redwood City							3	5					4	7
Richmond							1	2	1	2			1	2
Sacramento							6	6					6	6
San Diego			1	1	1	1	1	1			2	4	5	7
San Francisco							2	4	1	2	2	3	5	6
Stockton							9	14	1	1			10	15
Totals	24	67	3	4	6	11	45	74	22	29	8	13	108	198

*According to the State Lands Commission, 2004 data for Benicia was subsumed into other ports' data.

As can be seen in Table II-2, there are 108 terminals at California ports providing services to nearly 200 berths. Some terminals receive ships from more than one category. For example, at Richmond, vehicle carrier ships and bulk cargo ships visit the same berths. For these cases, staff assigned the terminals and berths to the type of ships that utilizes them the most. The Port of Los Angeles and the Port of Long Beach combined (POLA/POLB) handle ships from all categories and have the greatest number of terminals and berths, 56 and 114, respectively. It should be noted that there are other terminals and berths at these ports but they are used primarily for such activities as cargo storage and port services or may not currently be in use. There are very specialized ports, with El Segundo receiving only tankers, and Crockett, Humboldt, Redwood City, Stockton, and Sacramento receiving predominately bulk deliveries. The Ports of Avalon-Catalina and Monterey do not have terminals because they have no wharfs. Passenger ships at these ports anchor offshore, and smaller boats ferry passengers to and from shore. There is only one facility using the port at Pittsburg, USS POSCO, and all four bulk ships that deliver to this facility are cold-ironed.

From a ship perspective, container ships visit three ports: Long Beach, Los Angeles, and Oakland. Reefers also visit only three ports: Hueneme, Los Angeles, and San Diego. Vehicle carriers visit six ports: Carquinez, Hueneme, Long Beach, Los Angeles, Richmond, and San Diego. Passenger ships visit six ports: Hueneme, Humboldt, Long Beach, Los Angeles, San Diego, and San Francisco. Tankers visit Carquinez, El Segundo, Long Beach, Los Angeles, Richmond, San Francisco, and Stockton. Bulk ships visit nearly all of the ports.

In 2004, there were just over 1,900 ships making a total of just over 9,600 visits to California ports. Table II-3 summarizes these ship visits by ship category. For comparison purposes, ship visits are presented for all ships visiting California, ships making three or more visits to one California port, and ships making six or more visits to one California port.

Table II-3: Ship Visits to California Ports in 2004, by Ship Category

Category	Total Ships Visiting California	Total Ship Visits	Number of Ships Making 3 or More Visits to a California Port	Total Visits from Ships Making 3 or More Visits to a California Port	Number of Ships Making 6 or More Visits to a California Port	Total Visits from Ships Making 6 or More Visits to a California Port
Container	592	4,727	426	4,404	247	3,297
Passenger	44	642	22	573	18	549
Reefer	55	270	24	227	16	192
Tanker	370	1,864	86	1,370	37	1,001
Vehicle Carrier	227	748	62	391	14	146
Bulk	618	1,362	66	429	12	147
Total	1,906	9,613	686	7,394	344	5,332

Overall, 39 percent of ships visiting California in 2004 made three or more visits to one port (747 of 1,906) and 19 percent made six or more visits to one port (369 of 1,906). While container ships comprise less than a third of the total ships visiting in 2004 (592 of 1,906), they made nearly 50 percent of the total ship visits (4,727 of 9,613). Container ships dominate in the category of ships visiting a specific port often (six or more times), accounting for 72 percent of these ships (247 of 344). Furthermore, container ships visiting a port six or more times make about 70 percent of the total container ship visits (3,297 of 4,727). Reefers and passenger ships made the least ship visits in 2004. However, about 85 percent of passenger ships' total visits and 70 percent of reefer ships' total visits were made by ships visiting a port six or more times.

III. CURRENT EMISSION REDUCTION AND COLD-IRONING ACTIVITIES AT PORTS ON THE WEST COAST

This chapter discusses emission reduction efforts currently underway at California ports. Some of these efforts include conducting cold-ironing studies and implementing cold-ironing measures. This chapter also discusses cold-ironing applications already operating or planned at ports on the West Coast. Finally, this chapter discusses the challenges involved with adding shore-power installations to ports in California.

A. Current Emission Reduction Efforts at California Ports

Port of Los Angeles

In 2001, then Los Angeles Mayor James Hahn initiated a “No Net Increase” (NNI) policy for the Port of Los Angeles. The purpose of this policy was to roll back and maintain air emissions from the Port’s activities to October 2001 levels. A Task Force was established to develop a plan to meet the NNI policy goals. The Task Force met in 2004-2005, and in June 2005, delivered a report identifying 68 control measures for various port-retailed activities that could reduce and control emissions through 2025. In November 2005, Port staff released a draft report, “NNI Control Measures Evaluation Overview,” as directed by the Los Angeles Board of Harbor Commissioners. The NNI strategy has not yet been adopted.

One of the NNI control measures recommended for implementation, NNI Measure Number OGV16, is the expansion of a program already underway at the Port, referred to as the Alternative Maritime Power (AMP) program. The Port’s current AMP program is a voluntary program intended to reduce hotelling emissions from ships by providing shore power to container and passenger ships. Under this program, a shipping company agrees to utilize shore power at the Port for at least five years as part of its lease agreement. As an incentive for this program, the Port will provide up to $810,000 to defray the cost of adding shore-power equipment to one ship. NNI Measure Number OGV16 would go beyond these voluntary measures and require all passenger ships and all other ships calling at the port five or more times a year to be cold-ironed. It would also require all terminals to utilize shore power on 70 percent of the ship calls within two years of entering a new lease or renewing an existing lease with the Port.

Port of Long Beach

In April 2003, the Port of Long Beach commissioned ENVIRON International to conduct a study on the feasibility of connecting ships to electricity rather than running their auxiliary engines while docked at the Port. The study, “Cold Ironing Cost Effectiveness Study,” was released in March 2004, and it evaluated

12 vessels chosen to represent a cross-section of vessel types, vessel ages, and port calls. Hotelling emissions were calculated based on the hours the ship was in dock, the ship's power requirements at berth, the number of calls per year, and the pollutant emission factors for the auxiliary engines. The study included estimated costs for adding shore-side power to each berth where the 12 vessels docked. Estimated costs were also included for retrofitting the 12 vessels to run on shore power. Fuel cost savings estimates were based on two ships using distillate oil and ten ships using residual oil.

Using a cost-effectiveness threshold of $15,000 per ton of total emissions reduced (NOx, SOx, CO, VOC, and PM—all equally weighed) and a project life of 10 years, the analysis indicated that five out of the 12 vessels studied would be potential candidates for cold-ironing. These vessels included one container ship, two reefers (ships with refrigerated holds), a passenger ship, and a tanker. These five ships had higher hotelling power requirements, longer berth times, and more frequent berth calls than the other ships in the study.

The study indicated that the cost effectiveness of cold-ironing could also be determined by the annual power consumption of a vessel at a specific berth. For a retrofit scenario, where the ship is retrofitted for shore power after it is built and the berth is retrofitted with a shore power infrastructure after it is constructed, the cost-effectiveness threshold appears to correlate with 1.8 million kilowatt-hour (kW-hr) or more of annual power consumption at the berth. For the scenario where shore power is installed during the construction of a berth and the vessel is equipped with shore power capabilities when it is built, the cost-effectiveness threshold is at 1.5 million kW-hr or more of annual power consumption at the berth.

ENVIRON performed a follow-up study in November 2004 to determine which of the frequent callers at the Port (those ships with more than six visits per year) were likely candidates for cold-ironing. Out of 151 frequent callers, 26 ships were identified as being potential candidates. These ships included 22 container ships, two reefers, and two passenger ships.

In January 2005, the Long Beach Board of Harbor Commissioners approved a Green Port Policy which is intended to guide the Port's operations in a "green" manner. The Port has committed to providing shore-side power at new and reconstructed container terminal berths and other berths as appropriate. Through lease language, the Port will require selected vessels to use shore power and all other vessels to use low-sulfur diesel in their auxiliary generators. According to the Third Quarterly Report for the Green Port Program, dated December 13, 2005, cold-ironing projects are being developed at three berths at the Port—one of them a voluntary project with the tenant.

Port of Oakland

The Port has an Air Quality Mitigation Program that targets emission reductions from trucks, local buses, tugboats, and container-terminal equipment. In addition to these activities, the Port has indicated that it is planning on evaluating the feasibility of adding shore power to its terminals in the future.

Port of San Francisco

In October 2004, the Port of San Francisco commissioned ENVIRON to conduct a study on the feasibility of providing shore power at the new passenger ship terminal at Piers 30-32. The new terminal is scheduled for completion in 2008. The feasibility study was required as part of the permit conditions set by the San Francisco Bay Conservation and Development Commission. In this study, four passenger ships that currently visit the Port were evaluated for potential cold-ironing candidates. One of these ships, the Dawn Princess, is already cold-ironed when at port in Juneau, Alaska. The cost estimates used in the report included high- and low-end estimates for ship-side conversions and shore-side infrastructure capital costs. Ship conversion costs ranged from \$500,000 to \$700,000, and shore-side infrastructure costs ranged from \$1.4 million to \$2.8 million, depending on the possible routes for bringing electrical power to the property line. The project life was assumed to be 20 years. Energy cost had a significant impact on the cost of the project. Energy costs were estimated at \$0.22/kW-hr if only one ship was cold-ironed but dropped significantly to \$0.14/kW-hr if all four vessels were cold-ironed.

The hotelling emission reductions used in the cost-effectiveness determination included only tons of NOx reduced plus 10 times the tons of PM reduced (after subtracting power plants emissions). The report considered the cost-effectiveness threshold for tons of NOx plus 10 times PM reduced as being approximately \$14,000, which represented ARB’s Carl Moyer Program requirements at the time the report was developed. The cost effectiveness was determined for four scenarios: one ship cold-ironed; two ships cold-ironed; three ships cold-ironed; and four ships cold-ironed at berths 30-32. As expected, the project became more cost effective as more ships were assumed to cold-iron while hotelling. The analysis indicated that the cost effectiveness would be in the range of \$5,500 to \$7,000 per combined tons of NOx and PM reduced if all four ships analyzed in the study were cold-ironed when docked at the terminal.

After determining that shore power usage at the new passenger ship terminal would be technically feasible, the port will now evaluate the actual implementation of a shore power project. This will include developing more specific cost estimates for designing and building the shore power infrastructure at the terminal, obtaining more definitive cost estimates for power from the electricity providers, and evaluating possible incentives for cruise lines to utilize shore power at the new terminal.

Port of San Diego

The Port of San Diego is developing a conceptual design for including shore power at its B-Street Pier passenger ship terminal, which the Port plans to redevelop. This Pier is the home port for passenger ships that begin their cruises in San Diego.

B. Current Cold-Ironing Applications on the West Coast

The following are descriptions of cold-ironing installations already operating on the West Coast.

China Shipping Terminal at Port of Los Angeles

The Port of Los Angeles retrofitted the China Shipping Terminal to include a shore-power infrastructure as part of a lawsuit settlement with the Natural Resources Defense Council (NRDC), the Coalition for Clean Air, and local community groups. The settlement requires a minimum of 70 percent of ship calls to this berth, on an annual average, to utilize shore power. Two ships began connecting to shore power in June 2004. According to the Port's Stipulated Judgment Quarterly Report for the third quarter of 2005, there are now 15 China Shipping vessels that are equipped with shore power. During the first three quarters of 2005, shore power was used for 28 out of 39 ship calls to Berth 100, or an average shore power use of 72 percent. Although an impressive start, these 28 cold-ironed ship calls still represent a small fraction of overall container ship visits to the Port. In 2004, the Port had 2,940 container ship visits.

At this site, a substation at the edge of the property supplies 14.5 kilovolts (kV) of electricity, which is stepped down by a nearby transformer to 6.6 kV. Underground cables transport the electricity hundreds of yards to the edge of the wharf. A transformer that is housed on a barge next to the ship reduces the power further to 440 volts (V). The barge also contains a crane, cable reels, switching gear, and nine cables. Figure III-1 shows the barge-supported shore power application at the China Shipping Terminal.

Figure III-1: Shore power provided via a barge at China Shipping

When a ship is ready to connect to shore power, a crane lifts the cables from the barge to the ship, where personnel plug them into a panel at the stern of the ship. Figure III-2 shows the cable connections on a China Shipping vessel. The Port has indicated that the barge configuration will no longer be used in future shore-power applications because of the cost and size of the barge.

Figure III-2: Cable Connections on a China Shipping Vessel

Princess Cruises Ships in Juneau, Alaska

Princess Cruises began cold-ironing its ships berthed at the South Franklin St. dock in Juneau in 2001. The shore power operations were installed in response to community concerns over the smoke emissions from passenger ships visiting in the summer. During the summer cruise season, the air is stagnant over Juneau and the emissions from the ships' auxiliary engines significantly reduce visibility.

According to Princess Cruises, there are currently six ships that are equipped to cold-iron when at port in Juneau. If two of these ships are in port at the same time, only one ship is cold-ironed because the South Franklin Street dock has only one berth. According to Juneau's 2005 Cruise Ship Roster, 38 passenger ships visited Juneau last summer, including all six of Princess's shore-power-equipped ships. One of these ships never berthed at the South Franklin Street dock; however, the five Princess Cruises ships that did cold-iron represented 93 out of 586 total ship visits to Juneau in 2005 (or 16 percent).

At this site, a dual-voltage transformer supplies power from the utility company. The transformer can step down the voltage to either 6.6 kV or 11 kV. Underground cables carry the power from the transformer to the dock switch, where four 3 ½-inch diameter flexible electrical cables direct the power to the ship. The cables hang in a festooning pattern on a steel gantry located on the dock next to the ship as illustrated in Figure III-3. The gantry system allows the cables to accommodate Juneau's 20-foot tidal range as well as withstand the 100-mph winds during the winter.

Figure III-3: Steel gantry festooning system at Juneau, Alaska

When connecting to shore power, personnel use the festooning system to lower the cables to a side shell door on the ship, where the cables are pulled through the doorway and the 70-pound custom-made plugs are connected to the electrical connection cabinet on the ship. The cable connection is a male/female plug-and-socket system similar to what is used in the American mining industry. Figure III-4 shows cables entering a ship, and Figure III-5 shows the cable connection on a ship. Onboard software allows the shore power and the ship-generator power to automatically synchronize, combine, and transfer. Synchronizing the ship and shore power is mandatory for passenger ships, where any disruption to passenger services is unacceptable.

Figure III-4: Cables entering a Princess Cruises Ship

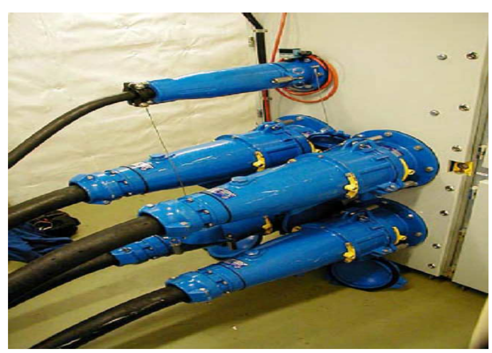


Figure III-5: Cables connected to the electrical connection cabinet on a Princess Cruises Ship

Princess Cruises Ships in Seattle, Washington

Princess Cruises began cold-ironing two of its shore-power-equipped vessels, the Diamond Princess and Sapphire Princess, at the Port of Seattle in the summer of 2005. This project was a collaborative effort among Princess Cruises, the Port of Seattle, Seattle City Light (the local utility), and the U.S EPA to reduce emissions from ships at the Port's new Terminal 30 Cruise Facility, which Princess Cruises shares with the Holland America Line. The Port has two passenger ship terminals serving five passenger ship lines. According to the Port’s 2006 Sailing Schedule, 193 ship visits by 13 vessels are scheduled for 2006. Forty of these ship visits (or 21 percent) will be made by two Princess Cruise Line shore-power-equipped vessels, the Dawn Princess and the Sun Princess.

At this site, existing utility power is brought to a custom-made step-down transformer, which can deliver either 11kV or 6.6 kV, similar to the Juneau site. The specialized transformer provides flexibility to the Princess Cruises fleet to accommodate not only the larger Diamond and Sapphire ships but also the smaller Princess vessels that were originally cold-ironed for Juneau. Similar to Juneau, four cables carry power to the ships’ electrical connection cabinet via a side shell door. The cables are lowered to the ship by a winch connected to a metal support structure located at the edge of the wharf. The structure can be pivoted away from the ship when not in use. Figure III-6 shows the cable management system for a Princess ship at the Port of Seattle.

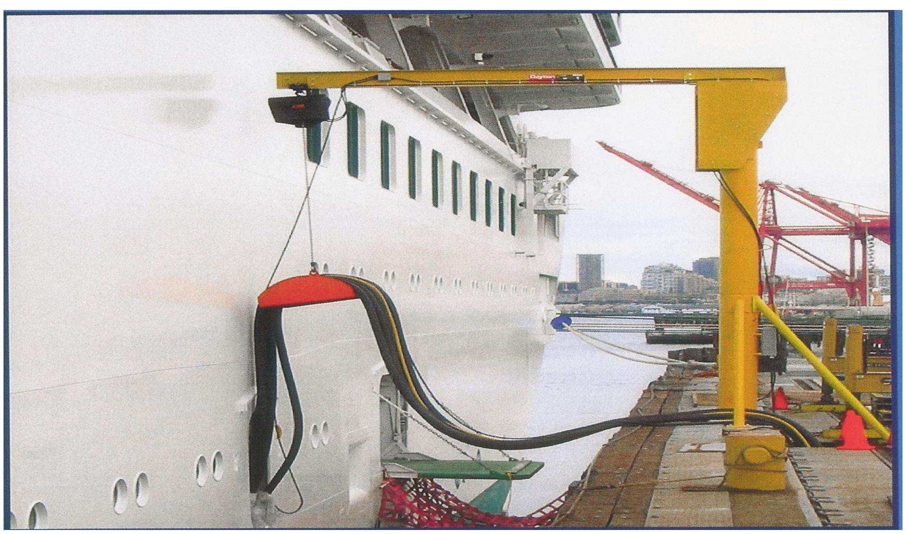


Figure III-6: Power cables at the Princess Cruises Terminal at the Port of Seattle

USS POSCO Industries in Pittsburg, California

Four dry-bulk ships cold-iron while docked at USS POSCO Industries' steel mill in Pittsburg, California. The ships, which are owned by Hyundai, Hanjin, and Korea Line shipping companies, were built between 1989 and 1992 and are equipped with Selective Catalytic Reduction (SCR) technology. Connection to shore power began in 1991 as a means to mitigate emissions from a facility expansion. At this site, two 480-volt cables are stored at the side of the dock. When shore power is provided, the cables are connected to a power box located at the edge of the dock and then pulled up the side of the ship and bolted to an electrical panel in an exterior room on the ship. Figure III-7 shows the cables connected to the dock, and Figure III-8 shows the cables bolted to the shore power connection panel on the ship.

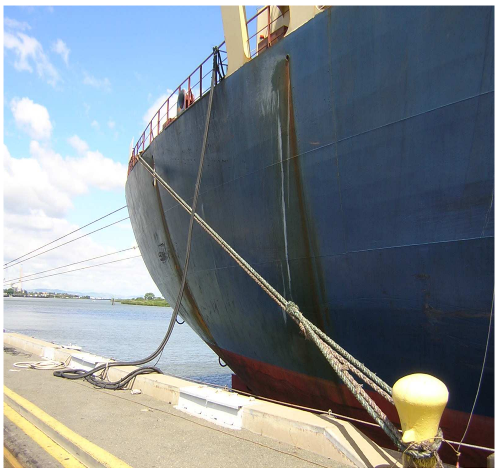


Figure III-7: Shore-side power connection at the USS POSCO facility in Pittsburg, CA.

Figure III-8: Shore power connection on the *Pacific Success* at the USS POSCO facility.

United States Naval Station in San Diego, California

The Navy cold-irons ships while in port at bases all over the world. The Navy connects to shore power as a matter of routine and has done so for several decades. The ships are also hooked up to water, sewer, communication, and steam while docked.

The Navy has developed a unique electrical cable connection system in order to avoid compatibility issues with different ports of call. Figure III-9 shows a schematic of the Navy's shore-power connection system.

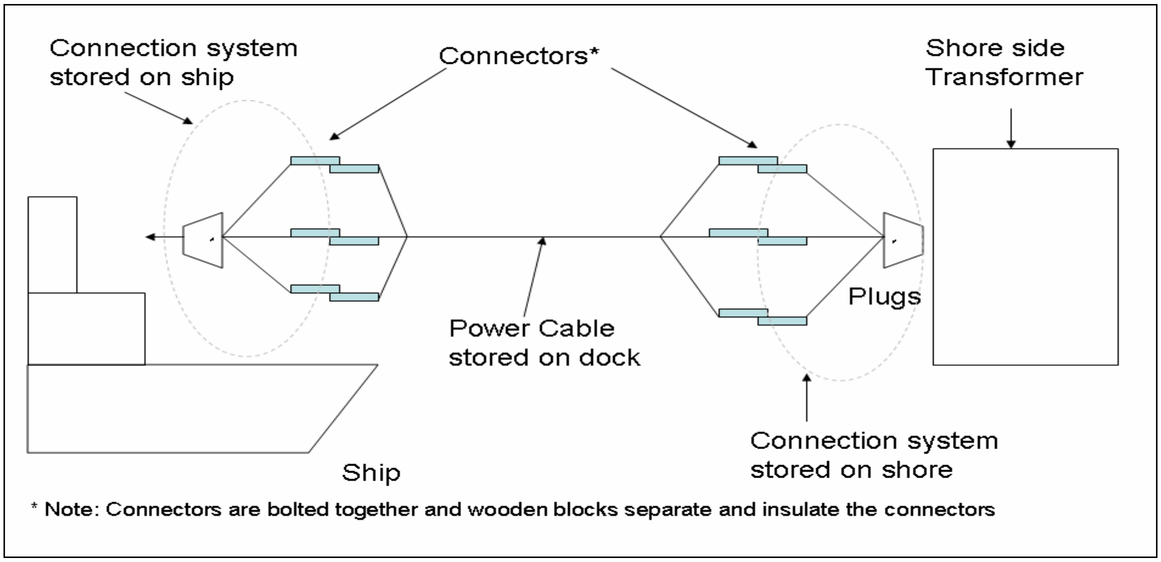


Figure III-9: Navy ships' shore-power connection system

This system consists of power cables that are stored on the docks at the naval stations around the world. On either end of the power cables are "pigtails" of three separate cables that end in metal connection plates. Plugs with similar pigtails of cables and metal connectors are carried on the Navy ship and stored near the transformer/substations on the docks at the naval stations. When a ship docks at the Naval Station in San Diego, a crane lifts a cluster of power cables onto the ship. Navy personnel on the ship bolt the power cable pigtails to the plug pigtails stored onboard. Similarly, Navy personnel on the dock bolt the power cable pigtails to the plug pigtails stored near the substation. Then the plugs are connected to the receptacles on the substation and on the ship. Figure III-10 shows the plugs stored adjacent to a substation at the San Diego Naval Station. Figure III-11 shows cables connected to the receptacles on a Navy ship.

Figure III-10: Plugs stored at a substation at the San Diego Naval Station

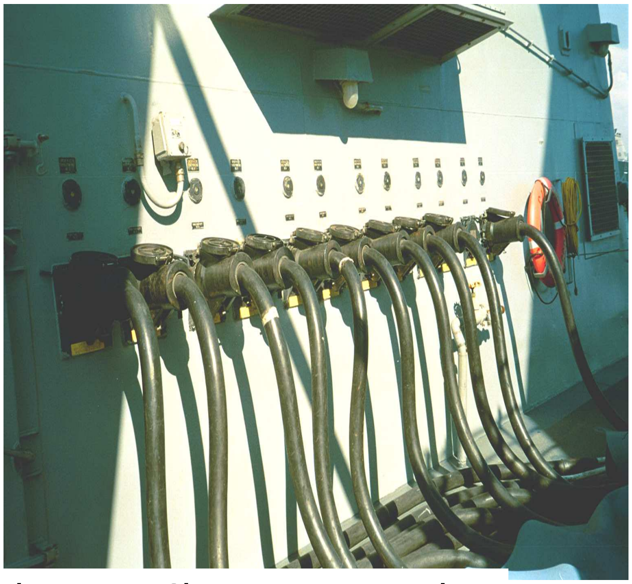


Figure III-11: Shore-Power connection on a Navy ship

Each cable can deliver 480 volts at 400 amps to the ship once the connection is complete. Having to attach plugs to power cables every time a ship cold-irons makes the Navy procedure more labor-intensive; however, since the Navy cold-irons across the globe, by having its own plugs aboard the ships and on the docks, there are no compatibility issues with the different ports of call.

The transfer of power from the ships' auxiliary generators to shore power is synchronized to avoid blackouts. For example, a destroyer-class ship has two auxiliary gas-turbine generators running in parallel when entering the port. One of the generators is turned off when the ship is docked and the second generator is ramped down during the transfer of power. It takes about 60 to 90 minutes after the ship is docked for personnel to connect the ship to electrical and other utility needs.

C. Future Cold-Ironing Installations

The following are descriptions of shore power installations planned for ports in California as well as ships that have already been built with cold-ironing capabilities.

NYK Atlas at Port of Los Angeles

The Port of Los Angeles is currently building a shore-side infrastructure at berths 212-221 (Yusen Terminal) to provide power to a container ship (NYK Atlas) when in port. The NYK Atlas was equipped with shore-power capabilities when built. The ship first arrived at the Port in August 2004 and made a total of five visits that year. The NYK Atlas is one of 36 NYK ships that visited the Port in 2004, with the other 35 vessels making a total of 107 ship visits. Shore-side construction for this installation is expected to be completed by early 2006. At this site, 6.6 kV will be provided at a plug on the wharf (a "wharf box"). Two cables that are housed on a cable reel on the Atlas will be lowered down the side of the ship via a roller guide and connected to the wharf box. Because the Atlas uses 6.6 kV, no transformer will be needed for this cold-ironing application.

Other Sites Planned at the Port of Los Angeles

The Port has indicated that all new shore-side power infrastructures for container ships will include a 6.6 kV plug at the wharf. Transformers, connection cables, cable reels, and plugs will be expected to be included on the ships, not at the wharf. However, the Port is considering an innovative approach of housing a portable power-transfer system, which includes a transformer, cables, and cable reels in a container stored at the dock. When the ship is ready to be cold-ironed and the appropriate space onboard has been made, a crane lifts the container onto the ship, and electricians make the appropriate connections. In this manner, the transformer is not located on the ship or the wharf, but is managed as a container and put into service when needed.

The Port has already built a shore-side infrastructure at Pier 400, although no ships calling at this terminal are currently equipped to connect to shore power. Shore-side infrastructure will also be built at berths 206-209. The lease for the container terminal's new tenant, P&O Nedlloyd, will require that 70 percent of ships calling there be connected to shore power within three years. According to the Final Environmental Impact Report for this Project, it is expected to take two years out of the five-year lease period to build the shore power infrastructure. At this site, a shore power receptacle fitted with one or two 400-amp, 6.6-kV, 3-phase plug receptacles, will be placed on the wharf.

The port has indicated that they will begin designing a shore-power infrastructure at their passenger ship terminal (berths 91-93) once they receive a firm commitment from a tenant to utilize shore power when in port.

BP terminal at the Port of Long Beach

British Petroleum (BP) will equip two of its new Alaskan-class tankers with shore-power capabilities when they are built in 2006. These 6.6 kV ships will replace ships currently calling at berth T121 at the Port of Long Beach. According to BP, each ship is expected to visit the berth six to 20 times per year. There were 212 total ship visits to berth T121 in 2004. If the two ships visit a total of 40 times per year, they could represent about 20 percent of total ship visits to this berth, based on 2004 numbers.

The Port has committed to developing the shore-side infrastructure at the berth, including bringing the power from the existing substation at the BP terminal to the wharf and providing the equipment needed to connect power cables to the vessels. Because of the size and weight of the cables that will be needed to bring power to the ship, a new wharf must be built to house the cable-management system.

New Evergreen Group Vessels

Evergreen Marine Corporation announced in March 2005 that its new S-class 7,024-TEU container vessels, which will be used by Evergreen’s Hatsu Division, will be equipped with cold-ironing capabilities. Two of the ten S-class ships ordered have been delivered, bringing the Hatsu Division fleet to ten ships. The remaining eight vessels are scheduled to be delivered by 2008. According to a Port of Los Angeles’ news release, one of the new S-class ships, the Hatsu Sigma, made its first visit to the Port of Los Angeles in December 2005. For comparison purposes, in 2004, five Hatsu Division ships made a total of 48 visits (out of a total of 2940 container ship visits) to the Port of Los Angeles. There is currently no shore-side infrastructure at the Evergreen terminals to take advantage of these new ships.

As can be seen in the previous sections, one NYK container ship, 15 China Shipping container ships, and ten new S-class Evergreen container ships have or will soon be equipped with shore-power capabilities (and possibly not all of the new Evergreen S-class ships will come to California). In comparison, there were 595 container ships visiting California ports in 2004, making current and planned shore-power equipped vessels a small fraction of the fleet visiting California (four percent).

D. Challenges to Converting Vessels and Ports to Cold-Ironing

There are several challenges that must be addressed to provide cold-ironing capability on the shore and the ships.

Vessel Voltage Requirements

Ocean-going vessels visit California ports from around the world. These vessels' electrical power and voltage requirements vary between vessel types and the country of manufacture. Most ocean-going vessels are configured for 440-480 V. Larger container ships and passenger ships are configured for 6.6 kV. The larger, newer, passenger ships are configured for 11 kV. The future trend in container-ship design is to build larger ships that use 6.6 kV. However, some manufacturers are still building vessels to operate on 440-480 V. These various voltage requirements present problems when designing a shore-power installation at a berth. Since all ships do not have the same voltage requirements, a transformer will be needed to increase or decrease the voltage to a ship. For example, as described earlier in this chapter, a transformer is used at the China Shipping Terminal at the Port of Los Angles to reduce the 6.6 kV of power supplied to the wharf to the 440 V required for the ships. Deciding where to place transformers, on the wharf or on a ship, is a challenge to designing cold-ironing installations.

Location of Transformers

A transformer can only be added to a wharf or a ship if enough space is available. Many ships do not have the space for a transformer. Future ship designs could include extra space for a transformer; however, it would be much more expensive to equip each new ship with a transformer than it would be to have just one transformer on a wharf for all ships to use. One alternative that is being considered by the Port of Los Angeles is to have the transformer enclosed in a container that is stored on the wharf and loaded onto each ship when it is docked. Although this option would eliminate the need for adding a transformer to every ship, space will still need to be allocated on each ship for the transformer container when used in port. The most cost-effective option is to place the transformer on the wharf; however, there can be many obstacles on a wharf that will limit where a transformer can be located. Containers or other cargo are stored on the wharf while being loaded on or unloaded from a ship.

Trucks are present at the wharf as they move cargo in and out of the terminal. Finally, rail and rubber gantry cranes used to load and unload containers and other cargo from a ship occupy space along the length of the pier—typically with only three feet of clearance from the rail on the pier to the water's edge.

Location of Cable Reels

Cables used for cold-ironing must be stored when ships are not connected to shore power. These cables and the reels that house the extra lengths of cable must be stored either at the dock or on the ship. As with transformers, having enough space on a dock or on a ship for this equipment is an issue. For example, the cable reels for the China Shipping Terminal at the Port of Los Angeles had to be located on a barge next to the ship because of space restrictions on the wharf. (Please refer to Figure III-1 for a picture of the barge shore-power configuration.)

Electrical Connection on Ships

As was illustrated earlier in this chapter, the number of cables used to deliver power to ships at current cold-ironing installations varies, as does the actual connection of the cables to a ship's electrical panel. The China Shipping ships use nine cables to deliver power. The Princess Cruise Line ships use four cables to deliver power to the ships and male/female plug-and-socket connections on the ships. The Navy uses a pigtail-and-plug cable-connection system to ensure shore power can be used at ports worldwide.

In order for cold-ironing to be feasible for a variety of ships, standardizing the number of power cables and the actual electrical connection to ships must be explored by the ports and shipping companies. Because Princess Cruise Line is already cold-ironing at two ports on the West Coast, perhaps its connection system will become the standard for that industry.

Vessel Modifications

Shipping companies will need to decide to use newly converted ships or to retrofit existing ships when considering future shore-power installations. As discussed earlier in this chapter, some ships that currently cold-iron were designed and built with cold-ironing capabilities, and some were retrofitted after they were in service. The NYK Atlas container ship, the new S-10 class Evergreen container ships, the new Alaska-class tanker, and the Diamond and Sapphire Princess passenger ships were all built with the equipment to connect to shore power. The four original Princess Cruise Line ships that cold-iron in Juneau, Alaska, were retrofitted with shore-power capabilities while en route to Alaska. Although Princess Cruise Line was able to retrofit its ships while in service, it may be more difficult to do this for other types of ships. In these cases, modifications may have to take place while the ship is dry-docked.

However, having a ship out of service for an extended period of time may not be economically feasible for some shipping companies.

The companies will also need to commit their converted ships to specific routes for a number of years in order to make shore power cost effective. Shipping companies have typically changed the route of service for their ships frequently, sometimes after only a year or two.

Additional Power Needs at the Terminals

Cold-ironing will increase the power demand for a port. A port's existing power infrastructure may not be sufficient to provide the additional power load. For example, the cold-ironing feasibility reports for the Port of Long Beach and the Port of San Francisco's new passenger ship terminal indicated that more power would have to be brought to these terminals in order to meet the additional power demands from cold-ironing. The ability of electrical utility companies to provide the additional power load with the preexisting substation and power lines at the ports and terminals will vary from site to site. Ports will have to work with the local electrical utilities to design and install power distribution infrastructures to meet additional power demands from cold-ironing ships at their terminals. A summary of power requirements is in Chapter XI.

E. Conclusion

As can be seen in this chapter, cold-ironing is proven and technically feasible. Shore power is currently being used or planned for passenger ships, container ships, bulk ships, and oil tankers, as well as having been practiced routinely for decades at U.S. Navy ports all over the world. Cold-ironing strategies are now part of some ports' efforts to reduce public health impacts to the surrounding communities. The Port of Los Angeles has an active Alternative Maritime Power program and is installing or planning to install several shore power sites. Based on the results of its cold-ironing feasibly study, the Port of Long Beach has committed to adding shore power requirements to future lease conditions and is already planning a shore power site at its BP terminal. Other ports are currently evaluating adding shore power to their terminals. The Port of San Francisco has determined that adding shore power to its new passenger ship terminal is technically feasible and will now conduct a more detailed cost analysis for implementing shore power at the terminal. The Port of San Diego is evaluating the possibility of adding shore power to its passenger ship terminal when it is redeveloped. Additionally, some container-ship, passenger-ship, and tanker companies are now voluntarily adding shore-power-equipped ships to their fleets. Finally, existing shore-power installations and projects have identified a number of challenges that must be addressed when adding cold-ironing capabilities to ships and building shore-power infrastructure at California ports.

IV. COST-EFFECTIVENESS METHODOLOGY

This chapter presents the methodology used to analyze the cost effectiveness of cold-ironing ocean-going vessels at California's ports.

A. Data Collection

Staff chose to collect data for 2004, the most recent year with complete data. Data was obtained from several sources, including:

- The State Lands Commission data for all ships that visited California ports;
- The Marine Exchange database for the San Pedro Port Complex of Los Angeles and Long Beach;
- Berthing data supplied directly by the Port of Oakland;
- Responses to the California Air Resources Board's Ocean-Going Vessel Survey for 2004;
- Published cruise ship schedules for the Ports of San Diego and San Francisco; and
- Extensive web searches for shipping data, port information, and electricity tariffs.

The most extensive source of port and ship data was the database from the State Lands Commission. This database is a compilation of all the Marine Exchange databases in the State. Each port in the State has a Marine Exchange, which keeps track of all ships entering and leaving a port. The State Lands Commission's database includes the name of the ship, the arrival port, the arrival date, and the departure date. Staff identified 18 California ports for consideration of cold-ironing, from San Diego to Eureka. A description of these ports is given in Chapter II.

Unfortunately, the State Lands Commission database had its limitations. For example, the database did not distinguish between the Ports of Los Angeles and Long Beach. Consequently, staff's analysis for cold-ironing considers the impact of cold-ironing for the Ports of Los Angeles and Long Beach together. In addition, the database included the Port of San Francisco, the Port of Carquinez, and the Port of Richmond activities at other ports located in the Bay Area. With little additional data to address this issue, ARB staff used the information as given in the State Lands Commission database. Finally, the State Lands Commission database did not specify actual berthing times, so ARB staff had to estimate berthing times using other data sources, including ARB's Ocean-Going Vessel Survey, discussed below.

To determine length of stay at the Ports of Los Angeles and Long Beach, staff relied on the Marine Exchange database for San Pedro Bay, which divided the traffic into the ships that visited the Port of Los Angeles and the Port of Long Beach and had visiting times for these two ports. The Marine Exchange database included the names of the ships that visited each port, the arrival times, the departure times, and the specific berth that each ship visited. This information can be used to determine, for each visit, the hours each ship spent at each port. The Marine Exchange starts and stops the "clock" for recordkeeping from the time a ship enters the breakwater to the time it leaves the breakwater. These times include maneuvering, anchoring, and hotelling, so staff had to estimate the hotelling times.

During 2004, the ports experienced labor difficulties, which resulted in many ships being anchored near the Port of Los Angeles and the Port of Long Beach prior to tying up at a berth. In this case, the elapsed time would include the time the ship was anchored as well at the time the ship was actually at a berth. Consequently, staff used berthing information provided by shipping companies in response to ARB's Ocean-Going Vessel Survey, discussed below, to supplement the information contained in the Marine Exchange database.

Staff at the Port of Oakland provided ARB staff with berthing data for all ships that visited the Port in 2002, 2003, and 2004. This information was similar to the Marine Exchange data for Los Angeles and Long Beach, except that the actual hotelling times were identified. The berthing data was derived from wharfinger data collected by the port's staff. Wharfinger data documents the time a ship ties its lines at a berth to the time it casts off the lines to depart. The purpose of wharfinger data is to charge fees to each ship that berths, thus generating funds for the port. The Port of Oakland data corroborated well with the State Lands Commission data and the data from responses to ARB's Ocean-Going Vessel Survey, so staff accepted the Oakland data as being the most accurate for ships that visited the Port of Oakland.

ARB staff distributed an Ocean-Going Vessel Survey to gather information about the power consumption of main and auxiliary engines of ships while at sea, maneuvering in port, and hotelling. The Survey also asked for hotelling hours for each visit. Staff used this data to supplement the databases described above.

Finally, ARB staff conducted an extensive web search for shipping and port information. Most of the shipping companies and California ports had their own web sites. These Internet sites provided information on the characteristics of ships operated by the shipping company. For example, shipping companies involved in the container trade typically indicated the number of containers their ships can carry. In addition, the cruise-ship companies listed their cruise schedules, which was valuable in determining what ships were visiting what ports for how long. The main websites accessed by ARB staff are included in Chapter XV.

Staff also downloaded electrical tariff schedules from utility company web pages, namely: Pacific Gas & Electric, Southern California Edison, Los Angeles Department of Water and Power, and San Diego Gas & Electric. Staff calculated the cost of electricity for specific cold-ironing applications based on these tariff schedules. Included in the electrical rates were power charges for peak, mid-peak, and off-peak times; customer charges; facility demand charges; and time-demand charges for peak, mid-peak, and off-peak times. These charges and the various tariff schedules for each electrical utility company are discussed in more detail in Appendix D.

B. Cost-Effectiveness Methodology

According to the State Lands Commission database, 1,906 ocean-going vessels visited California ports in 2004. Staff divided the ships into six categories: container ships, passenger ships, refrigerated cargo ships (reefers), tankers, vehicle carriers, and bulk/cargo ships. Some ships do not easily fall into one category. For example, some bulk ships can also carry containers. For these cases, staff categorized the ship based on the State Lands Commission designation. In the example given, the bulk ship also carrying containers was treated as a bulk ship.

Staff conducted cost-effectiveness analyses for each of these ship categories. For each ship category, the cost-effectiveness analysis consisted of two parts: an analysis where both the shore-side infrastructure and ship retrofits are considered, and an analysis considering the incremental cost for cold-ironing a ship if the ports have already installed the necessary shore-side infrastructure. For the infrastructure/ship analysis, staff analyzed the following three scenarios: 1) all ships being cold-ironed at all California ports; 2) cold-ironing ships that made at least three visits per year to a California port; and 3) cold-ironing ships that made at least six visits per year to a California port.

Cost-Effectiveness Scenarios for Cold-Ironing Projects

ARB staff calculated cost effectiveness using three major sets of variables: ship categories, ship electrical requirements, and pollutants reduced.

As described in the previous section of this chapter, staff divided the ocean-going vessels into six categories: container ships, passenger ships, refrigerated ships (reefers), tankers, vehicle carriers, and bulk/cargo ships. Staff determined cost effectiveness for each of these categories.

A second major variable was the electrical requirements of the ships. Ocean-going vessels typically fall into two categories: low-voltage and high-voltage. Except for passenger ships, high-voltage is nominally 6.6 kV, and low-voltage is around 440 V. For passenger ships, high-voltage is 11.0 kV, while low-voltage is 6.6 kV. Due to these varying power requirements, transformers are needed to supply the proper voltage to nearly all of the ships. These transformers either have to be located within the port infrastructure or on the ships. ARB looked at both of these scenarios.

ARB staff calculated cost effectiveness using three approaches for air pollutants reduced: (1) “all pollutants” emissions reductions (NOx, PM, VOC, and SOx); (2) NOx emissions reductions only; and (3) PM emissions reductions only.

The all-pollutants case recognizes that cold-ironing reduces multiple pollutants. For the all-pollutants case, the cost effectiveness was determined by dividing the total annualized costs for cold-ironing by the total annual emissions reduced for the four major pollutants (NOx, PM, VOC, and SOx).

The NOx-only case allows for comparison to other NOx measures adopted in the State. NOx is a precursor to ozone, which can damage the tissues of the respiratory tract, causing inflammation and irritation, and result in symptoms such as coughing, chest tightness and worsening of asthma symptoms. For the NOx-only case, the cost effectiveness was determined by dividing the total annualized cold-ironing costs by the annual NOx emissions reduced.

The diesel-PM-only case recognizes the importance of reducing diesel PM in California. Overall, diesel engine emissions are responsible for the majority of California's potential airborne cancer risk from combustion sources. For the diesel-PM-only case, the cost effectiveness was determined by dividing the total annualized cold-ironing costs by the annual diesel-PM emissions reduced.

Currently, most ocean-going vessels use residual fuel. The Board adopted an Ocean-Going Vessel Auxiliary Engine Fuel regulation in December 2005. The regulation requires that most of these ships use cleaner distillate fuel when in California waters beginning in January 2007. Because of this requirement, ARB staff calculated cost-effectiveness values based on the use of distillate fuel only.

For all cost-effectiveness analyses, ARB staff used 2005 dollars. Total annualized cold-ironing costs included both capital-recovery costs and recurring operating costs. Capital costs for equipment were amortized over a ten-year period at an annual real interest rate of five percent.

<u>Capital Costs</u>

Capital costs included both the cost for retrofitting the ships and the cost for infrastructure improvements necessary on the port side.

Ship Retrofits

The most important consideration for determining ship retrofit costs is whether an onboard transformer is required to supply the proper voltage to the ship's electrical system. For example, 90 percent of all container ships that visited California in 2004 used low-voltage (~ 440 V) electrical power. The newer, larger container ships use high-voltage (6.6 kV) power. Currently, the Port of Los Angeles (POLA) and the Port of Long Beach (POLB) are planning to provide only 6.6 kV at their container-ship berths for these new ships. The low-voltage ships, if they were to cold-iron, would have to provide their own onboard transformers.

Currently, there are no onboard transformers on cold-ironed ships. The only low-voltage ships that are cold-ironed are 15 container ships operated by China Shipping at POLA, where a shore-side transformer is located on a barge adjacent to the wharf. (See a full description in Chapter III.) Since there were no transformers required on the ships, the cost of each ship retrofit averaged about $320,000. The total cost for the barge was estimated at $2 million, of which $1 million was for the transformer and associated electrical gear for cold-ironing.

For the purposes of this report, the estimated cost to retrofit a ship is based on information available from the China Shipping project mentioned above, Princess Cruises cold-ironing projects in Juneau, Alaska, and Seattle, Washington, a new cold-ironed NYK container-ship, and a retrofit analysis conducted in the ENVIRON Cold Ironing Cost Effectiveness Study for the Port of Long Beach (2004).

According to Princess Cruises, the cold-ironing projects for both Juneau and Seattle averaged about $500,000 per ship. This cost includes the electrical equipment necessary to synchronize the ship electrical system with the shore system so that there is no interruption of power to the passenger ships. The ships do not "go dark," even for fractions of a second. With other ships, such as container ships, it may not be necessary to avoid the brief "dark" period as the power is being transferred.

NYK constructed a cold-ironing-ready container ship in 2004, although it has not yet been cold-ironed. The Port of Los Angeles is putting in the infrastructure for this ship to cold-iron. The estimated construction cost for the cold-ironing equipment built on this ship was $830,000.

ENVIRON International Corporation estimated ship-retrofit costs in their Cold Ironing Cost Effectiveness Study for the Port of Long Beach (2004). For high-voltage applications, the ship retrofit costs ranged between $200,000 to $574,000, with an average cost of $400,000. For low-voltage applications, the ship retrofit costs ranged between $240,000 to $1,100,000, with an average cost of $588,000. The report assumed that these low-voltage ships would use transformers mounted on barges. A barge was estimated to cost $2 million, with the transformer and associated electrical equipment on the barge estimated to be between $300,000 to $500,000.

Therefore, based on these projects and analyses, ARB staff estimates that the average cost for retrofitting ocean-going vessels is $500,000 per ship without an onboard transformer and $1.5 million per ship with an onboard transformer. For the purpose of this report, staff assumed that cost increases due to inflation would be offset by cost decreases due to more efficiently retrofitting ships as cold-ironing experiences increase.

Construction is underway for two diesel-electric crude oil tankers that will visit the Port of Long Beach. Because the construction will not be completed until later this year, the average retrofit costs discussed above did not include the estimated cost for modifying the two tankers. While the initial costs were originally estimated as $440,000 per ship, the projected cost is now expected to be $1.1 million per ship. Staff believes the costs for this project is unique to diesel-electric tankers and not generally applicable to other tankers or other types of ships.

Many ships visit multiple ports, so there is a certain degree of synergism among these ports. Where a ship visited multiple ports, staff allocated the cost of retrofitting the ship to the port at which it visited most often. Therefore, the other ports did not have to pay for retrofitting the ship; they received it “for free.” For the few times a ship visited two ports the same number of times, staff allocated that ship to the port with the fewest number of visiting ships. Because of the dominance of container-ship activity at POLA/POLB, this procedure for assigning ship costs was not applied to the container-ship category.

Shore-Side Infrastructure

Shore-side infrastructure costs are site-specific and can vary widely. The largest portion of overall shore-side infrastructure costs is usually the modifications required to the existing electrical infrastructure to bring adequate power to specific terminals. The availability and proximity of adequate electrical power varies from port to port. For example, available power supplies are generally located closer to the Port of Los Angeles than they are at the Port of Long Beach, and adequate power for the passenger-ship terminal at the Port of San Diego would have to be brought in through downtown San Diego at additional construction costs.

As mentioned in the discussion of ship retrofit costs, transformers are required for most ships to be cold-ironed. If these transformers are located on the ships, the retrofit costs for the ships increase significantly. If these transformers are installed on shore, the shore-side infrastructure costs increase. Based on existing cold-ironing projects, shore-side infrastructure costs have run between $1 million and $7 million.

The $1 million case represents a scenario at POLA where the existing electrical power at the terminal was adequate to support cold-ironing. POLA upgraded the infrastructure by adding a transformer for more efficient use of available power. The $7 million case was also at POLA: the China Shipping project. Ninety percent of the new China Shipping terminal was already constructed when, due to litigation, the Port of Los Angeles was forced to provide cold-ironing capabilities to the new terminal. To retrofit the terminal, POLA had to build new infrastructure to supply adequate power—including cutting concrete trenches for electrical cable to the wharf—and construct the barge on which the necessary transformer and associated electrical equipment were located. Ultimately, the project was overbuilt for its current use, so the China Shipping case—a last-minute retrofit case—can be considered the high end of the shore-side infrastructure costs.

The shore infrastructure for the Juneau, Alaska, passenger-ship cold-ironing project has been estimated at $5.5 million; however, this figure includes providing shore-side steam needs as well as electrical needs. The cost for the electrical portion of the shore infrastructure is estimated to be about half of the total costs, or $2.75 million. The shore-side infrastructure costs for the Princess Cruise Lines cold-ironing project in Seattle has been estimated at $1.8 million, which does not include steam needs.

Finally, the ENVIRON Cold Ironing Cost Effectiveness Study for the Port of Long Beach estimated shore-side infrastructure costs for 12 different terminals, ranging from $1 million to $4 million, the average being about $2 million. The cost to bring utility power to the terminal was estimated to be about half of the total retrofit costs.

ARB staff estimates that the average cost for providing shore-side infrastructure—without additional shore-side transformers—to be $3.5 million per terminal. Staff estimates the cost for a shore-side transformer and associated equipment to be an additional $1.5 million per berth. For example, if a terminal consists of three berths, the total cost for the shore-side infrastructure would be $8 million ($3.5 million for general terminal costs and $4.5 million for three transformers).

Construction of a cold-ironing project for diesel-electric crude oil tankers at the Port of Long Beach has not yet started and is not expected to be completed until 2007; therefore, staff did not include the estimated costs for this project when establishing a representative shore-side infrastructure cost. The initial estimate for modifying the terminal was $1.6 million based upon the facility already having adequate power. A more-detailed engineering analysis has now estimated the shore-side infrastructure to be closer to $7.5 million. Most of the added cost is associated with the need to drive additional pilings to support the new platform for the electrical cables. It is unclear if this additional cost would be unique to this specific terminal or would be a necessary cost to include for all crude-oil tanker terminals.

Operating Costs

Recurring operating costs include energy costs (electricity or fuel), labor, and routine equipment maintenance.

Energy Costs

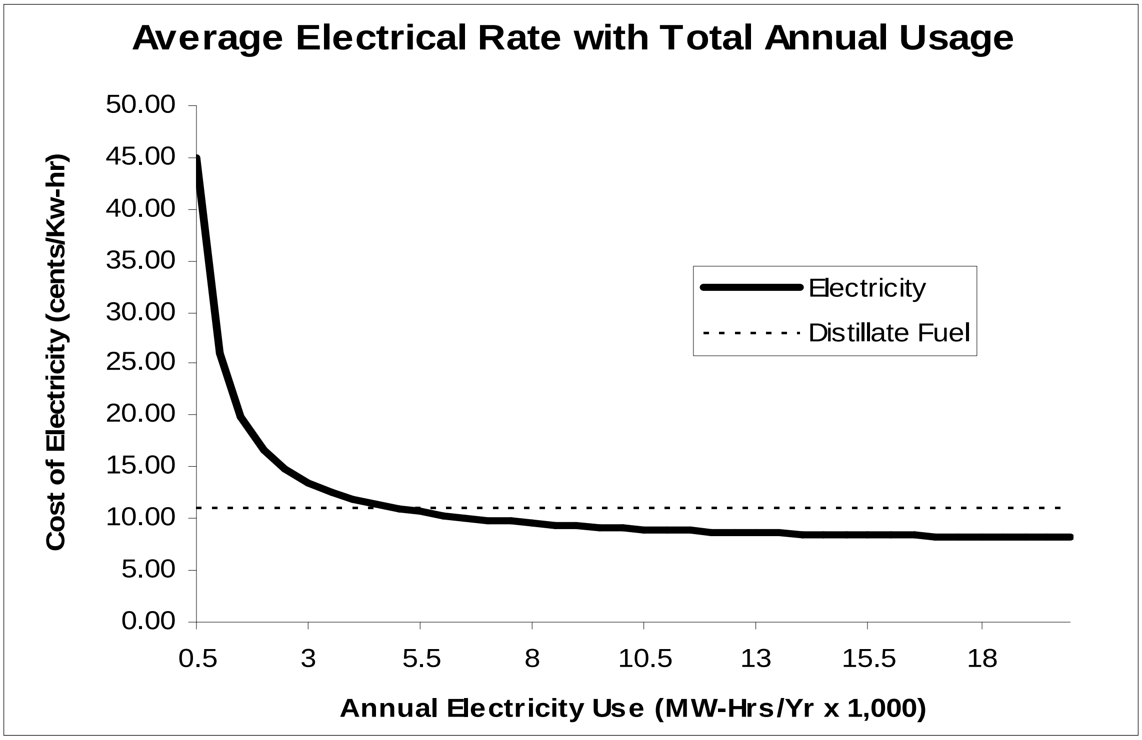
Staff used actual utility tariff schedules to estimate electrical costs for cold-ironing. Although Pacific Gas and Electric (PG&E) does not sell power to either the Port of Oakland or Port of San Francisco, its tariff rate schedule (E-20) was used as a surrogate. Likewise, staff used a Southern California Edison (SCE) tariff rate schedule (TOU-8) for POLA/POLB and Port of Hueneme. POLA is actually served by the Los Angeles Department of Water and Power (LADWP), but since, as mentioned previously, the State Lands Commission database did not distinguish between POLA and POLB, staff used SCE for its analysis. (The average electrical rates for LADWP users are less than SCE's, but since electrical infrastructure requirements are site-specific and electrical rates will ultimately be negotiated between the users and the utilities, staff believed that this difference is not significant.) Staff used a San Diego Gas and Electric tariff schedule (AL-TOU) for the Port of San Diego. All of these tariff schedules apply to large industrial users.

Electrical tariff schedules vary among utilities, but they all typically include monthly fees, demand charges, time-of-use charges, and seasonal adjustments. (An example of a utility tariff schedule can be found in Appendix D). Overall, the cost of electricity from the grid depends upon how much capacity is needed (i.e., the "demand," the maximum number of megawatts needed at any one time) and how much electricity is used annually.

The most expensive average electrical rates occur if the electrical demand is high (a lot of megawatts are needed, as with passenger ships), but the actual usage is low (few ships being cold-ironed). In this case, the demand charges, which can be substantial and are paid whether one is using electricity or not, dominate the total electricity costs.

Conversely, for most tariff schedules, the more electricity one uses, the lower the average electrical rate. In this case, the monthly fees and the demand charges are diluted by the energy costs, which can be relatively low (e.g., $0.08 per kW-hour). Figure IV -1 illustrates this phenomenon.

FIGURE IV - 1



Based on SCE Tariff Schedule TOU-8 at 1.5 MW load.

ARB staff used a spreadsheet to estimate electrical costs based on the various utility tariff schedules. (Two examples of the spreadsheet can be found in Appendix D.) The spreadsheets estimate annual percentages of off-peak, mid-peak, and peak rates for winter and summer months.

Passenger-ship rates are higher because passenger ships berth mostly during peak hours—they arrive in the morning and sail in the evening. Other ships, such as container ships, may be in berth for several days, using nighttime (i.e., off-peak) electricity rates for a significant portion of their visits.

For the various ship categories and specific scenarios reviewed, the average electrical costs varied from about nine cents per kilowatt-hr to over 60 cents per kilowatt-hour. Except for diesel-electric ships, the cost for the electricity was not a major portion of the overall cost.

Because of the large power needs for cold-ironing projects, the utility rates will probably be negotiated between the utility companies and the ports when more cold-ironing projects are proposed. Since consideration may be given to interruptible-rate schedules, or cold-ironing-specific tariff schedules, ARB staff considers current tariff schedules sufficient for the purposes of this report.

Currently, electrical energy costs are higher than fuel energy costs when bunker fuel is used, so a cold-ironing project will incur a net cost for energy consumption. However, by the time cold-ironing could be widely deployed in California, virtually all ships will be required to use higher cost but less polluting distillate fuels to generate onboard electricity. For this report, ARB staff assessed an electricity charge for cold-ironing, then subtracted the distillate fuel cost savings for shutting down the auxiliary engines. Due to world events and high demand for petroleum products, the cost of fuel has been volatile in recent months. Based on published costs for fuels in the spot-fuel market in mid-summer 2005, staff estimated distillate fuel to cost $485 per metric ton. Using the energy content of these fuels, and an average internal-combustion-engine efficiency of 35 percent, these market values correspond to eleven cents per kilowatt-hour for average energy use (see Attachment E-1 in Appendix E). In areas where cold-ironing is used extensively, shore power costs would likely represent a cost savings over the use of distillate fuel to generate onboard power.

Labor Costs

For all ship categories but the tanker category, staff included the cost of using union electricians to both connect and disconnect electrical power for these ships. Staff estimates that it would take one hour to connect a ship and one hour to disconnect a ship from shore power. Staff assumed that three electricians are necessary to both connect and disconnect the electrical power, and that the direct cost of this labor is about $600. If, however, electricians are not already on duty, costs could be much higher, as labor contracts require that workers, once called, be paid for an entire shift. In the case of passenger ships, staff assumed that two electricians would connect and disconnect electrical power—all other assumptions regarding labor costs are the same. For the tanker category, it was assumed that the additional labor would be met with existing resources; thus, there would be no additional cost.

Routine Maintenance Costs

ARB staff assumed that additional maintenance costs incurred with cold-ironing—mostly associated with shore-side electrical equipment—would be offset by reduced maintenance costs for the ships' auxiliary engines, which would accrue fewer hours of operation. Therefore, routine equipment maintenance costs were not considered in this report.

An example spreadsheet, which contains the elements discussed above, and was used by staff to perform the cost-effectiveness analysis can be found in Appendix E. This appendix also presents information on the data inputs used in the spreadsheet.

Cost-Effectiveness Considerations for Incremental Analysis

The *incremental* cost-effectiveness analysis is similar to the *average* cost-effectiveness analysis, except that the cost for shore-side infrastructure is not included in the incremental analysis: the infrastructure is assumed to already be in place. Additionally, staff assumed that the berths had sufficient cold-ironing activity to warrant the lower average electrical rates.

V. CONTAINER SHIPS

This chapter provides background on container ships, a discussion of staff's cost-effectiveness analysis for cold-ironing container ships, and a discussion of the expected growth in container ship traffic to California.

A. Background

Container ships are designed to carry cargo stored in standardized containers. Container ships can also carry some refrigerated containers, with the ship's electrical power plant providing the necessary electricity for these containers. The size of these ships is based upon how many twenty-foot-equivalent units (TEUs) can be carried by the ship. The dimensions of a TEU are 20' x 8' x 8.5' and a typical container is 40 feet long, or two TEUs. Because most ocean-going containers are 40' or 45' long, the number of containers equals the number of TEUs divided by about 1.8. A 40- or 45- foot container fits on the back of an 18-wheeler, so it is common to see these containers being transported on the highway. Ships visiting California typically have a carrying capacity ranging between 1,000 to over 8,000 TEUs, with the "average" ship being able to carry nearly 4,000 TEUs. In general, container ships have increased in size over the last few years, and this trend is expected to continue in the future.

Typically, container ships are propelled by a large low-speed diesel engine, and electrical power is provided by three to five auxiliary diesel engines when the ship is moving. In some cases, a shaft generator provides the electrical power. The auxiliary engines range in size from 500 kW to 3 MW each, with the largest engines used on the largest container ships. In port, the electrical power is provided by the auxiliary engines.

Several older ships use steam-based power plants to both propel the ship and provide electrical power. Unlike diesel engines that can be shut down very quickly, steam-based power plants take several hours to shutdown and to restart. For the short duration that a ship is in port, it would be impractical to shut down the ship's steam-based power plant. Consequently, the steam-based power plant would continue to operate and emit air pollutants even if the ship is cold-ironed. Cold-ironing these types of ships would result in minimal emission reductions.

In 2004, 592 container ships visited California ports and accounted for nearly 50 percent of the total ship visits to California. That is, container ships visited California ports as much as the combined visits of the other five ship categories, with no other ship category representing more than 20 percent of the total ship visits. If significant emission reductions are to be achieved from cold-ironing, container ships must represent a significant portion of that effort.

Table V-1 provides a frequency distribution for container ships visiting California ports in 2004. This table shows that 178 container ships made only one visit to a California port that year. Ships making three or more visits accounted for 92 percent of the total visits, while those visiting six or more times still accounted for two-thirds of the total visits.

Table V-1: Container Ship Visits to a California Port During 2004

Annual Visits During 2004	Ships Making "N" Visits*	Total Visits by All Ships Making "N" visits	Cumulative Percentage For Total Ship Visits
1	178	178	100
2	113	226	96
3	117	351	92
4	116	464	84
5	74	370	74
6	68	408	66
7	43	301	58
8	58	464	51
9	57	513	42
10	77	770	31
11	22	242	14
12	9	108	9
13	3	39	7
14	2	28	6
16	1	16	6
19	1	19	5
21	1	21	5
22	3	66	4
23	2	46	3
24	3	72	2
25	1	25	1
Totals		4,727	

* Note: The number of ships is based on ships visiting a specific port. Since some ships visited multiple ports, they have been counted more than once in this table. These ships were identified during the cost-effectiveness analysis and counted only once. In fact, the economic synergism created by these ships was taken into account.

Container ships often make their first West Coast call at the Port of Los Angles or the Port of Long Beach (POLA/POLB). Many will then stop at the Port of Oakland. About 60 percent of the ships that visit POLA/POLB also visit Oakland. POLA/ POLB receive more container ship visits than Oakland, and the ships tend to stay much longer, unloading more containers. In 2004, POLA/POLB processed over six times the amount of container traffic than Oakland: nine million loaded TEUs versus 1.4 million TEUs.

The most important shipping routes for container ships visiting California ports are the routes from Asia to North America. Ships that frequent this route average 8 - 9 visits annually to the ports in the Los Angeles area and six visits annually to the Port of Oakland. Many ships also bring goods from South and Central America. Another important shipping route is between Hawaii and California ports. Fewer ships travel these routes but, because of the shorter distance, call more often at California ports.

Power needs for a container ship varies between 1 MW to 4 MW, with the high end of the range based upon a ship carrying a substantial number of refrigerated containers. Hotelling times for container ships vary between 20 to 200 hours per visit (average hotelling time is 65 hours per visit) to ports in the Los Angeles area and 10 to 40 hours per visit (average hotelling time is 22 hours per visit) to the Port of Oakland.

B. Cost-Effectiveness Results

Because the container-ship category was so large, staff sought to find an appropriate subset of the data to illustrate the cost effectiveness of the entire container-ship category. In this manner, the cost-effectiveness calculation method for container ships varied from the calculation methods used for the other ship categories.

Specific berth information in the 2004 Marine Exchange database suggested that at the three major container ports in California—POLA, POLB, and Oakland—the ships of the same shipping company nearly always visited the same terminals at these ports. Therefore, for the container-ship category, ARB staff selected three shipping companies, identified the specific terminals to where these companies sent their ships and then analyzed these *terminals* for cost effectiveness. Staff then considered the results of the cost-effectiveness analysis for these specific terminals to be illustrative of the container-ship category as a whole. A complete discussion of the selection of the shipping companies, their associated terminals, and the cost-effectiveness calculations can be found in Appendix F.

Of the three shipping companies that staff selected, two of them had several ships that visited POLA/POLB and Oakland. The third company had only one ship that visited POLA/POLB and Oakland. Staff selected the three companies based on the number of ships that made several (six or more) visits to each terminal, the average number of visits by these ships, and the average hotelling times while in port. Ultimately, staff analyzed three container terminals at POLA/POLB and two container terminals at Oakland.

A review of the activity at these terminals indicated that, in addition to the three companies discussed above, several other shipping companies also had ships frequenting the three POLA/POLB and the two Oakland terminals. Overall, ships from 19 different container shipping companies visited these five terminals during

2004. Container ships made from 240 - 425 visits to the three POLA/POLB terminals studied and 140 - 220 visits to the two Oakland terminals.

These ships visited anywhere from one to 25 times apiece in 2004, with berthing times that varied between 40 and 100 hours per visit. For Oakland's two terminals, staff analyzed the container ships that visited both the POLA/POLB complex and Oakland. The average berthing time in Oakland varied from 15 to 30 hours. The average berthing times are based upon responses to ARB's Ocean-Going Vessel Survey. As part of this response, shipping companies provided berthing times for ships that visited California at least five times. From this information, ARB staff developed a relationship between berthing times and the size of the ship, in terms of TEU carrying capacity. Consequently, ARB staff could either establish the berthing times based on the responses to the Survey or estimate the berthing times based on the ship's TEU capacity.

At each port, cost-effectiveness values were determined for three scenarios: 1) all ships visiting the port are cold-ironed; 2) only ships that make three or more visits per year to a port are cold-ironed; and 3) only ships that make six or more visits per year to a port are cold-ironed. In addition, the cost-effectiveness scenarios consider whether the necessary electrical transformers are constructed at the port (shore-side) or on the ships (ship-side).

The cost-effectiveness scenarios also consider whether the auxiliary engines on the ships are burning two types of distillate fuel, as would be mandated by a recently adopted statewide regulation. This regulation requires, by January 1, 2007, the use of distillate fuel in a ship's auxiliary engines when the ship is within 24 nautical miles of California's coastline. Currently, distillate fuel has an average sulfur content of 0.5 percent by weight. By January 1, 2010, these auxiliary engines will be required to use distillate fuel with a maximum sulfur content of 0.1 percent. Because the auxiliary engine regulation requires the use of distillate fuel by 2007, the fuel mix currently used by ships (mostly residual fuel) was not considered in the cost-effectiveness scenarios.

Finally, staff calculated the cost-effectiveness values on the basis of pollutants reduced: 1) "all pollutants" (NOx, PM, hydrocarbons, and oxides of sulfur [SOx]); 2) NOx-only reductions; and 3) PM-only reductions. For purposes of this chapter, staff chose to present cost-effectiveness values for NOx reductions only because the majority of emission reductions from cold-ironing will be NOx. A discussion of staff's cost-effectiveness results for all other pollutants and scenarios analyzed, and the corresponding cost-effectiveness tables, are included in Appendix G.

The cost-effectiveness values presented below are based on using shore-side transformers and 0.1 percent sulfur distillate fuel. The shore-side transformer scenario was presented here because staff believes this to be the most likely approach to implementing cold-ironing. The 0.1 percent sulfur distillate fuel was used because the recently adopted fuel regulation requires its use statewide by 2010.

Table V-2 provides the NOx cost-effectiveness values for container ships visiting POLA/POLB and Oakland.

Table V-2: NOx Reduction Cost Effectiveness for Cold-Ironing Container Ships* (Dollars/ton)

Port	All ship visits	Ships with 3 plus visits to the port	Ships with 6 plus visits to the port
POLA/POLB	$18,500	$14,500	$15,500
Oakland	$56,000	$50,500	$48,500
Oakland without ship costs	$25,500	$24,000	$26,000

* Assumes shore-side transformer and 0.1 percent sulfur distillate fuel.

The average cost-effectiveness values are highest when all ships are cold-ironed because ships with only one or two visits are included. These infrequent visitors have high cost-effectiveness values that drive up the average values. The average cost-effectiveness values for POLA/POLB are the lowest for ships making three or more visits. The values go up slightly for ships with six or more visits because there are fewer ship visits in this category, which reduces berth utilization.

The average cost-effectiveness values at Oakland are substantially higher than those at POLA/POLA—about three to four times higher—due to the lower hotelling times for ships that visit Oakland: 22 hours per visit versus 65 hours per visit for POLA/POLB. However, if retrofitted container ships visiting cold-ironing applications at POLA/POLB were to visit Oakland as well, Oakland would have to only add the required infrastructure to service these retrofit ships and would have no additional shipside investment cost. In 2004**,** 65 container ships that visited the three terminals analyzed at POLA/POLB also visited Oakland. If these ships were retrofitted for POLA/POLB, the cost-effectiveness values for Oakland would then decrease by about 50 percent (the “Oakland without ship costs” scenario). For this scenario, the average cost-effectiveness values are similar for all three categories because the only capital cost considered is the infrastructure cost.

The prior analyses addressed *average* cost effectiveness. These average values include many ships that visit a few times and a few ships that visit many times. The following analysis addresses the cost effectiveness of cold-ironing a ship if the shore-side infrastructure is already in place, as a function of the number of ship visits.

Table V-3 provides incremental cost-effectiveness values for NOx reductions. These values are based on a 3,900 TEU container ship (a moderate size) visiting POLA/POLB, berthing at the port for 40 hours per visit—typical for this size ship. The average electrical rate assumes that there is already sufficient cold-ironing activity at the berth to minimize the effect of demand charges.

Table V-3: Incremental Cost Effectiveness to Retrofit a Typical Container Ship* (Dollars/ton)

Visits	NOx
1	$96,000
2	$50,000
3	$35,000
4	$27,000
5	$23,000

* Assumes shore-side transformer and 0.1 percent sulfur distillate fuel.

Not surprisingly, the cost-effectiveness values decrease with the increasing number of trips. What is important to note is that while the *average* cost effectiveness for cold-ironing all ships on a NOx-only basis is $18,500 per ton (see Table V-2), the incremental cost of cold-ironing one ship is $96,000 per ton. It is not until a ship makes about five visits until the incremental cost effectiveness approaches the average cost effectiveness.

As discussed before, average cost-effectiveness values are higher if all ships are cold-ironed because the one-time visitors are included. These ships represent the "$96,000" incremental ships. So while the *average* cost effectiveness may look reasonable for all ships, there are ships within that group that have much higher than average costs.

Table V-4 provides the cost-effectiveness values for a large container ship, (6,000-7,000 TEUs), berthing at the port for 75 hours per visit. The incremental cost-effectiveness values are substantially lower for larger container ships because they use more power and therefore emit more pollutants, and the larger ships tend to stay in port longer than smaller ships.

Table V-4: Incremental Cost Effectiveness to Retrofit a Large Container Ship* (Dollars/ton)

Visits	NOx
1	$32,000
2	$18,000
3	$13,000

* Assumes shore-side transformer and 0.1 percent sulfur distillate fuel.

Table V-4 suggests that a large container ship may be cost effective to cold-iron for only one trip if the shore-side infrastructure is in place and the berth is sufficiently active to have lower electrical rates.

C. Summary

Container ships make nearly half of the ship visits to California, so if significant emission reductions are to be achieved from cold-ironing, container ships must represent a significant portion of that effort.

While cold-ironing at the Port of Oakland is not as cost effective as it is at the Ports of Los Angeles and Long Beach, due to shorter berthing times, if Oakland takes advantage of retrofitted ships coming from POLA/POLB and installs cold-ironing infrastructure, the economics look more promising.

Throughout our assessment, staff concluded that it is more cost effective to locate the necessary electrical transformers on the shore instead of the ships. The obvious reason for this is that fewer transformers are needed on shore for the same level of service. The only exception is if Oakland installs the shore-side infrastructure to service retrofit ships. In this case, it would be cheaper not to install a shore-side transformer, assuming the ships had their own transformers.

Finally, to determine if cold-ironing is cost effective, both an overall assessment and an incremental cost-effectiveness assessment need to be considered. For container ships, one-time visitors have cost-effectiveness values that are quite high, unless they are large ships that stay in berth for long periods of time.

D. Future Trends

Since 2000, container traffic has increased by 40 percent at the ports of Los Angeles and Long Beach and by 2020, cargo movement at California's ports is expected to triple from 2005 levels. Much of this growth is based upon the expected increase in imported products from Asia. Container traffic at the Port of Los Angeles and Port of Long Beach will continue to see the highest levels of overall growth.

This growth is not expected to cause a proportional growth in ship traffic to California ports because container ships are being built to carry more containers. Orders for large container ships—ships that can carry in excess of 6,000 TEUs—have dramatically increased. Some shipping companies have already placed orders for ships that can carry nearly 10,000 TEUs. These very large ships will require larger auxiliary engines to handle the increased power demands of the ships and will also require longer berthing times to load and unload the containerized cargo. Both of these factors will lead to significantly improved cost effectiveness for cold-ironing container ships in California. (See Chapter XI).

On the other hand, the expected growth in container-ship activity and subsequent cold-ironing requirements will create additional electrical demands. Utility companies and ports will have to invest in additional infrastructure to bring more power to the container-ship terminals.

VI. PASSENGER SHIPS

This chapter provides background on passenger ships, a discussion of staff's cost-effectiveness analysis for cold-ironing passenger ships, and a discussion of the expected growth trend of the cruise-line industry in California.

A. Background

The passenger-ship category is one of the smallest, with only 44 ships visiting California in 2004. The vast majority of the passenger ships visit the ports of San Francisco, Los Angeles, Long Beach, and San Diego. A few passenger ships visit Monterey and Catalina, but they moor offshore and do not actually berth.

Pleasure cruises have become increasingly popular and significant growth in the cruise-line industry is expected to continue. As with other types of ocean-going vessels, the physical size and carrying capacity of passenger ships have increased steadily over the years.

Unlike most ship categories, passenger ships are diesel-electric. Propulsion is typically provided by several diesel engines coupled to generators. These generators produce electrical power that drives electric motors coupled to the vessel's propellers. This arrangement provides the option to run the vessel at a slower speed, while operating fewer engines at their peak efficiency, as opposed to a single engine at low, relatively inefficient loads. The same engines that are used for propulsion are also used to generate auxiliary power onboard the vessel for lights, refrigeration, etc.

Passenger ships typically dock in the morning and set sail in the evening. The average time in dock ranges from nine to eleven hours. Passenger ships have the highest power consumption while hotelling of any vessel type: five to eleven megawatts. Since the short docking time occurs only during the day, utility rates are usually at peak or near-peak rates.

As described in Chapter III, passenger ships have the most cold-ironing experience, aside from U.S. Navy ships. Princess Cruises has constructed cold-ironing facilities in Juneau, Alaska and Seattle, Washington.

A distribution of the number of times passenger ships visited California Ports is provided in Table VI-1.

Table VI-1: Passenger Ship Visits to a California Port in 2004

Annual Visits During 2004	Total Ships Making "N" Visits	Total Visits by All Ships Making "N" visits	Cumulative Percentage For Total Ship Visits
1	35	35	100
2	17	34	94
3	5	15	89
4	1	4	87
5	1	5	86
6	2	12	85
7	2	14	84
8	2	16	81
11	1	11	79
12	1	12	77
13	3	39	75
14	1	14	69
17	1	17	67
23	1	23	64
26	2	52	61
28	1	28	52
33	1	33	48
49	1	49	43
51	1	51	36
75	1	75	27
103	1	103	16
Totals		642	

* Note: The number of ships in this table is based on ships visiting a specific port. Since some ships visited multiple ports, they have been counted more than once here. These ships were identified during the cost-effectiveness analysis and counted only once. In fact, the economic synergism created by these ships was taken into account.

Table VI-1 shows that a considerable number of passenger ships make only one stop to a California port, although several ships make numerous visits. Passenger ships visiting three times or more accounted for 89 percent of the total visits, and passenger ships visiting six times or more still accounted for 85 percent of the total visits. The Monarch of the Seas itself made 103 visits to the Port of Los Angeles and 49 visits to the Port of San Diego, accounting for 22 percent of all passenger ship calls to California ports.

B. Cost-Effectiveness Results

For passenger ships, staff only considered shore-side transformers. The shore-side costs include a special dual-voltage transformer (6.6 or 11 kV), as most passenger ships use either of these voltages. This is the configuration used at both Juneau and Seattle for the Princess Cruises passenger terminals.

Furthermore, staff assumed labor costs for this category would be the same as that for container ships with one exception: only two electricians, instead of three, would be used to hook-up and unplug passenger ships. Two electricians are currently being used for the ports in Juneau and Seattle. Staff assumed the same union rates for the electricians as with the container ships.

As with the other ship categories, for each port, cost-effectiveness values were determined for three scenarios: 1) all ships visiting the port are cold-ironed; 2) only ships that make three or more visits per year to a port are cold-ironed; and 3) only ships that make six or more visits per year to a port are cold-ironed. For the passenger ship category, staff also considered one-berth and two-berth scenarios for the “six or more visits” case. Electrifying one passenger-ship berth may capture most of the ships making six or more visits; however, occasionally two frequent visitors are docked at the same time. The two-berth electrification includes the additional costs and emissions reductions for addressing these situations. The exception is the Port of Long Beach, which has only one berth for passenger ships.

Finally, staff calculated the cost-effectiveness values on the basis of pollutants reduced: 1) “all pollutants” (NOx, PM, hydrocarbons, and oxides of sulfur [SOx]); 2) NOx-only reductions; and 3) PM-only reductions. For purposes of this chapter, staff chose to present cost-effectiveness values for NOx reductions only because the majority of emission reductions from cold-ironing will be NOx. A discussion of staff’s cost-effectiveness results for all other pollutants and scenarios analyzed, and the corresponding cost-effectiveness tables, are included in Appendix H.

The cost-effectiveness values presented below are based on using 0.1 percent sulfur distillate fuel because the recently adopted fuel regulation requires its use statewide by 2010.

Tables VI-2 shows the NOx cost-effectiveness values for passenger ships visiting Los Angeles, Long Beach, San Diego, and San Francisco, respectively. At the Port of Long Beach, the group of ships that made three or more visits in 2004 also made six or more visits. Consequently, the cost-effectiveness values in Table VI-2 for ships making six or more visits would also be the same for the ships making three or more visits. The “all ship visits” case for Long Beach shows that it is more cost effective than the six or more visits. There are three factors that contribute to this unique trend: first, Long Beach has one berth so more visits to one berth spreads the shore-side infrastructure cost over more ship; second, the retrofit costs of two of the ships were charged to other ports where these ships visited more often; and third, the electrical demand cost is lower with more ships utilizing one berth.

Table VI-2: NOx Reduction Cost Effectiveness for Cold-Ironing Passenger Ships* (Dollar/ton)

Port	All ship visits	Ships with 3 plus visits to the port	Ships with 6 plus visits to the port
POLA	$44,000	$24,000	$17,000
POLB	$16,000	$17,000	$17,000
San Diego	$58,000	$45,000	$21,000
San Francisco	$36,000	$34,000	$24,000

* Assumes shore-side transformer and 0.1 percent sulfur distillate fuel.

Overall, as a ship category, passenger ships exhibit relatively low average cost-effective values, comparable to container ships and reefer ships.

For Los Angeles and San Diego, the cost-effectiveness values decrease as fewer ships are cold-ironed. For the “all ships” scenario, four berths at both ports are cold-ironed. For the three or more visits scenarios, only two berths are cold-ironed, reducing the shore-side infrastructure costs, while eliminating the passenger ships that make one or two calls. Finally, the one-berth cost-effectiveness value for the six ships or more case assumes that the most attractive candidates will frequent that one berth. As with all other ship categories, high berth utilization is a strong influence on cost effectiveness.

For San Francisco, the cost-effective values are relatively flat until the one-berth, frequent-visitor scenario. For the “all ships” case, three berths are cold-ironed, while two berths are cold-ironed for the three or more visits scenario, and one berth was cold-ironed for the six or more visits scenario. San Francisco receives the fewest number of passenger ships among the four California ports analyzed, but the electrical rates are the lowest. Furthermore, there are more one-time visitors to San Francisco than to the other ports. All of these factors produce cost-effectiveness values that are relatively constant for the scenarios examined.

The prior analyses have all addressed *average* cost effectiveness. As mentioned before, when cold-ironing all ships, these average values include many ships that visit a few times and a few ships that visit many times. The following analysis addresses the cost effectiveness of cold-ironing a ship if the shore-side infrastructure is already in place, as a function of the number of ship visits.

Table VI-3 provides the incremental cost-effectiveness values for NOx reductions for passenger ships. The electrical rate used in the analysis assumed that cold-ironing activity was already occurring at the berth, reducing the impact of demand charges. In this case, staff used $0.22 per kW-hour.

Table VI-3: Incremental Cost Effectiveness to Retrofit a Typical Passenger Ship* (Dollars/Ton)

Visits	NOx
1	$72,000
3	$29,000
7	$19,000

* Assumes shore-side transformer and 0.1 percent sulfur distillate fuel.

Not surprisingly, the incremental cost-effectiveness values drop significantly with more visits made by a ship. At about three visits, the *incremental* cost-effectiveness values are similar to the *average* cost-effectiveness values discussed earlier, which are some of the lowest of any ship category. Although the passenger ships stay briefly in port—about 10 hours—their emissions are significant, making cold-ironing an attractive emissions reduction strategy.

C. Summary

As a category, passenger ships are one of the more attractive candidates for cold-ironing. The passenger ship category has relatively few ships that visit California (44 passenger ships, as compared to 592 container ships and 618 bulk cargo ships), but there are a high percentage of frequent visitors within this category. Furthermore, although the berthing times are the shortest of all ship categories, the electrical power needs of the passenger ships—and therefore the air pollutant emissions rates—are much greater. Because passenger ships use a considerable amount of electricity, the availability of electrical power at reasonable rates is essential to keeping cold-ironing economically viable.

D. Future Trends

The cruise industry in California and nationwide has grown tremendously. California-based cruises tend to either go down to Mexico or up to Alaska, with a few going to Hawaii. According to the “The Cruise Industry 2004 Economic Summary,” in 2004, the national increase in cruise passengers was ten percent from 2003. For California, the combined increase in cruise passengers for 2004 was 35 percent from 2003, or an increase of 288,000 passengers. Table VI-4 summarizes the growth from 2003 to 2004 for the four major passenger ports in the State.

According to a press release by the International Council of Cruise Lines, the two ports that expect the most growth in the future are San Francisco and San Diego. San Francisco expects nearly 250,000 cruise passengers in 2006—a 194 percent increase in passengers from 2004. The Port of San Diego is also projecting increases in cruise-ship visits in the future. The increase in passengers would increase the number of visits in passenger ships either by more visits by the existing fleet or an increase in the passenger ship fleet to California. In either case, more visits increase berth utilization at the ports, which makes cold-ironing even more cost effective.

Table VI-4: Growth in Passenger Travel in Cruise Ships in California

Ports	Passengers (2003)	Passengers (2004)	Percent Change
San Francisco	51,000	85,000	67%
Los Angeles	403,000	470,000	17%
Long Beach	272,000	367,000	35%
San Diego	81,000	173,000	114%

VII. REEFER SHIPS

This chapter provides background on refrigerated cargo (reefer) ships, a discussion of staff's cost-effectiveness analysis for cold-ironing reefer ships, and a discussion of the expected growth of reefer ship traffic to California.

A. Background

Reefer ships carry perishable products, such as fruit and meat, to and from California. The products, usually palletized, are stored in large cold-storage cargo holds. Additionally, containers can be stored on the deck of some reefer ships. Unlike container ships, most of these types of ships are equipped with cranes.

Similar to container ships, a reefer ship is propelled by a large low-speed diesel engine and electrical power is provided by two to three auxiliary diesel engines. A reefer ship's electrical load can be considerable due to refrigerating the cargo, supplying power to the cranes, and providing power for lights and ballast pumps.

Fifty-five reefer ships visited California ports in 2004, representing only three percent of the total ship visits to California. A distribution of the number of times reefers visited California Ports is provided in Table VII-1.

Table VII-1: Reefer Ship Visits to a California Port During 2004

Annual Visits During 2004	Total Ships Making "N" Visits*	Total Visits by All Ships Making "N" Visits	Cumulative Percentage For Total Ship Visits
1	34	34	100
2	8	16	87
3	4	12	82
4	4	16	77
5	1	5	71
6	6	36	69
7	1	7	56
8	1	8	53
11	1	11	50
15	1	15	46
16	2	32	41
17	2	34	29
22	2	44	16
Totals		270	

* Note: The number of ships in this table is based on ships visiting a specific port. Since some ships visited multiple ports, they have been counted more than once here. These ships were identified during the cost-effectiveness analysis and counted only once. In fact, the economic synergism created by these ships was taken into account.

Table VII -1 shows that a large number of reefer ships visiting California in 2004 made only one visit. Nevertheless, these one-time port visits accounted for only 12 percent of the total visits. Reefers visiting three times or more accounted for 83 percent of the total visits, and reefers visiting six times or more accounted for 69 percent of the total visits. This is largely due to the frequent visitors; two ships made 17 port visits apiece, and two ships made 22 visits apiece.

Reefer ships can use between 1-3 MW when hotelling; the high end of the range includes the use of the on-board cranes. Reefers have hotelling times that are similar to container ships, about 60 hours per visit.

B. Cost-Effectiveness Results

Reefer ships visited the Ports of Hueneme, POLA/POLB, and San Diego. The cost-effectiveness analysis for cold-ironing reefers is based on the activity of reefer ships at these three ports. Because of the special needs for the cargo that is delivered (bananas, other fruit, meat), reefers generally go to the same ports and to the same terminals at these ports. During 2004, 14 reefer ships visited the Port of Hueneme, 43 other reefers ships visited POLA/POLB (two ships have since relocated to the Port of Hueneme), and another 11 ships visited the Port of San Diego. Because reefers no longer call at the Port of Long Beach, an analysis of the activity at the Port of Long Beach was not included.

Staff analyzed two electrical loads for reefer ships: 1-MW and 2-MW. Staff believes that the 2-MW case is probably more representative of the reefer fleet; however, the Ocean-Going-Ship Survey response received for reefers suggested a lower power requirement. It is unclear if the request for “hotelling” data on the survey was fully understood by the respondents. According to the ENVIRON study conducted for Long Beach, the Chiquita Joy, a reefer ship, uses 3.5 MW while berthed.

As was done previously for other ship categories, for each port, cost-effectiveness values were determined for three scenarios: 1) all ships visiting the port are cold-ironed; 2) only ships that make three or more visits per year to a port are cold-ironed; and 3) only ships that make six or more visits per year to a port are cold-ironed. In addition, the cost-effectiveness scenarios consider whether the necessary electrical transformers are constructed at the port (shore-side) or on the ships (ship-side).

Staff calculated the cost-effectiveness values on the basis of pollutants reduced: 1) “all pollutants” (NOx, PM, hydrocarbons, and oxides of sulfur [SOx]); 2) NOx-only reductions; and 3) PM-only reductions. For purposes of this chapter, staff chose to present cost-effectiveness values for NOx reductions only because the majority of emission reductions from cold-ironing will be NOx. A discussion of staff’s cost-effectiveness results for all other pollutants and scenarios analyzed, and the corresponding cost-effectiveness tables, are included in Appendix I.

The cost-effectiveness values presented below are based on using shore-side transformers and 0.1 percent sulfur distillate fuel. The shore-side transformer scenario was presented here because staff believes this to be the most likely approach to implementing cold-ironing. The 0.1 percent sulfur distillate fuel was used because the recently adopted fuel regulation requires its use statewide by 2010.

Table VII-2 shows the NOx cost-effectiveness values for reefer ships visiting POLA, San Diego, and Hueneme. Staff used a 2 MW electrical load for this analysis—a typical load for reefer ships.

Table VII-2: NOx Reduction Cost Effectiveness for Cold-Ironing Reefer Ships* (Dollars/ton)

Port	All ship visits	Ships with 3 plus visits to the port	Ships with 6 plus visits to the port
POLA	$25,000	$29,000	$32,000
San Diego	$13,000	$15,000	$15,000
Hueneme	$8,800	$8,800	$8,100

* Assumes shore-side transformer and 0.1 percent sulfur distillate fuel.

As can be seen in Table VII-2, the average cost-effectiveness values for Hueneme are the lowest, followed by San Diego, then POLA, whose average cost-effectiveness values are three to four times greater than those for Hueneme. Hueneme has the lowest cost-effectiveness values because it has three times the number of ships that visited often (six visits or more) than the other two ports. POLA has the highest average cost-effective values because most of the reefers that made only one visit to California went to POLA. It is interested to note that cold-ironing reefers at Hueneme or San Diego is more cost effective than cold-ironing *container* ships at POLA/POLB (see Table V-2 in Chapter V).

The prior analyses have all addressed *average* cost effectiveness. As mentioned before, when cold-ironing all ships, these average values include many ships that visit a few times and a few ships that visit many times. The following analysis addresses the cost effectiveness of cold-ironing a ship if the shore-side infrastructure is already in place, as a function of the number of ship visits.

Table VII-3 provides incremental cost-effectiveness values for NOx reductions only for the three ports visited by reefer ships. The average electrical rate assumes that there is already sufficient cold-ironing activity at the berth to minimize the effect of demand charges.

Table VII-3: Incremental Cost Effectiveness to Retrofit a Reefer Ship* (Dollars/Ton)

Visits/Port	NOx
San Diego	
1	$41,000
2	$23,000
3	$17,000
Hueneme	
1	$32,000
2	$17,000
3	$12,000
POLA	
1	$32,000
2	$16,000
3	$11,000

* Assumes shore-side transformer and 0.1 percent sulfur distillate fuel.

Not surprisingly, the incremental cost-effectiveness values improve significantly with more visits made by a ship. In general, by the third visit, the incremental cost-effectiveness value is less than half of that for one visit. Note that the cost-effectiveness values for Hueneme and POLA are lower than those for San Diego. This is due to the smaller ships visiting San Diego and the higher electricity rates for the San Diego area.

C. Summary

As with other ship categories, both the *average* cost-effectiveness and the *incremental* cost-effectiveness need to be considered when determining what reefer ships and associated ports should be cold-ironed. As a category, however, reefers have some of the most attractive cost-effectiveness values among all ship categories. For example, cold-ironing reefer ships and their respective berths at the Port of San Diego and the Port of Hueneme may be the most cost-effective ship category/port combination in California, based on the 2-MW power level.

D. Future Trends

Products shipped in reefer ships are typically designated at ports as general cargo. Overall, the amount of general cargo shipped through America's ports is expected to grow, but at a more modest rate than the expected increase in container traffic. The National Dredging Needs Study, which discusses the growth in goods movement through our nation's ports in relationship to needed port improvements, estimates that ship visits for ships carrying general cargo will increase at half the rate expected for ships carrying containers. Unlike container ships, where much of the expected growth will be addressed by new, very large ships, the growth for general cargo will more likely be addressed through increased ship traffic, resulting in more reefers making more visits. This greater berth utilization will make reefers even more cost effective.

VIII. TANKERS

This chapter provides background on tankers, a discussion of staff's cost-effectiveness analysis for cold-ironing tankers, and a discussion of the expected growth of tanker traffic to California.

A. Background

Tankers are designed to carry liquid and gaseous products. The major products transported include crude oil, finished petroleum products, and chemicals. There are two types of tankers: crude-oil tankers and product tankers. Tankers visiting California ports range in size from 15,000 dead weight tons (DWT) to over 200,000 DWT. Tankers larger than 70,000 DWT typically carry only crude oil. The smaller tankers, or product tankers, carry various types of finished petroleum products and chemicals. In 2004, 370 tankers visited California ports, accounting for almost 20 percent of the total ship calls to California.

Most of this activity supports the operation of California's refineries. Tankers bring crude oil from Alaska and the Middle East to refineries in the Bay Area and Los Angeles. In addition, product tankers transport needed materials from Northern California to Southern California and vice versa, as well as transfer material into and out of the State. The major ports that tankers frequent in California include Benicia, Carquinez, El Segundo, POLA/POLB, Martinez, and Richmond.

Crude-Oil Tankers

Table VIII-1 provides a frequency distribution for crude-oil tankers visiting California ports in 2004. Crude-oil tankers making at least three visits to a port accounted for 81 percent of the total visits, while crude-oil tankers making six or more visits to a port accounted for nearly two-thirds of the total visits. Overall, these tankers visit the southern California ports 55 percent of the time and the San Francisco Bay Area ports the other 45 percent of the time.

Table VIII-1: Crude-Oil Tanker Visits to a California Port During 2004

Annual Visits During 2004	Total Ships Making "N" Visits	Total Visits by All Ships Making "N" visits	Cumulative Percentage for Total Ship Visits
1	77	77	100
2	35	70	90
3	14	42	81
4	10	40	76
5	10	50	71
6	8	48	65
7	4	28	58
8	4	32	55
9	4	36	51
10	3	30	46
12	3	36	42
13	1	13	38
14	2	28	36
15	1	15	33
16	2	32	31
17	1	17	27
19	2	38	25
23	1	23	20
25	1	25	17
26	1	26	14
34	1	34	10
47	1	47	6
Totals		787	

* Note: The number of ships is based on ships visiting a specific port. Since some ships visited multiple ports, they have been counted more than once in this table. For example, a tanker may make three total visits to California, visiting three different ports. This tanker would be counted three times in the category of one annual visit a year. Consequently, for some category counts, the total visits may exceed the total number of ships. These ships were identified during the cost-effectiveness analysis and counted only once. In fact, the economic synergism created by these ships was taken into account.

Crude-oil tankers come in many configurations. Older tankers transporting crude oil use steam-based power plants to both propel the ship and provide for electrical power, including pumping the crude oil. As discussed in Chapter V for a similar steam-powered container ship, cold-ironing one these ships would result in minimum emission reductions since the steam boiler would continue to operate while in port. Newer tankers transporting crude oil typically use a diesel engine to propel the ship, auxiliary diesel engines to provide power for lights and ballast pumps, and a boiler/steam turbine combination to drive the cargo pump.

In this case, the lights and ballast pumps activities can be cold-ironed. Finally, five tankers transporting crude oil to a California port are diesel-electric, where on-board power provides the needed electricity for lights, ballast pumps, and cargo pumping. This entire load can be cold-ironed.

The majority of the power requirements for a crude-oil tanker is for pumping out the crude. Since the majority of ships transporting crude oil use steam turbine/boiler units to pump the crude, this portion of a tanker's operation cannot be electrified. Consequently, except for diesel-electric tankers, the hotelling power requirements for crude-oil tankers will range between 50-600 kW. For diesel-electric tankers, where the cargo pumps are driven by electric motors, the power requirements are between 5-6 MW.

The hotelling times for tankers transporting crude oil range between 10 to 40 hours per visit. Tankers visiting the Port of Long Beach average 37 hours per visit, and tankers visiting ports in the Bay Area average 20 hours per visit. This hotelling time includes time necessary for the safety and operations conference, connecting and disconnecting from the shore piping system, and loading ballast as well as discharging the cargo.

Product Tankers

Table VIII-2 provides a frequency distribution for product tankers visiting California ports in 2004. As shown in this table, there are many product tankers that made only one or two visits to a California port, accounting for nearly 50 percent of the total visits made by product tankers. Product tankers making at least six visits to a port accounted for only 35 percent of the total visits. Overall, product tankers visited POLA/POLB 45 percent of the time, the San Francisco Bay Area ports 40 percent of the time, and El Segundo and other ports the remaining 15 percent.

Table VIII-2: Product Tanker Visits to a California Port During 2004			
Annual Visits During 2004	**Total Ships Making "N" Visits**	**Total Visits by All Ships Making "N" visits**	**Cumulative Percentage For Total Ship Visits**
1	314	314	100
2	85	170	71
3	33	99	55
4	12	48	46
5	13	65	41
6	4	24	35
7	5	35	33
8	1	8	30
9	4	36	29
10	2	20	26
13	1	13	24
15	2	30	23
19	1	19	20
24	2	48	18
27	1	27	14
33	1	33	11
41	1	41	8
47	1	47	4
Totals		1,077	

* Note: The number of ships is based on ships visiting a specific port. Since some ships visited multiple ports, they have been counted more than once in this table. These ships were identified during the cost-effectiveness analysis and counted only once. In fact, the economic synergism created by these ships was taken into account.

For product tankers, a diesel engine is typically used to propel the ship, while auxiliary diesel engines provide the ship's electrical power needs and product-pumping requirements. Many of the product pumps are either hydraulically driven or directly connected to the auxiliary engine. Electric motor-driven pumping systems (i.e., diesel-electric) are amenable for cold-ironing; the hydraulic or direct-drive pumps cannot be cold-ironed. There are two diesel-electric product tankers visiting California ports.

Product tankers are different than crude-oil tankers in one important fashion: products are not only pumped off but also pumped onto the ships while docked. On-shore pumps load the material into the product tankers. Even if the product pumps on the tanker were driven by electric motors, they would be shut down while receiving a product, which is about 40 percent of the time. As with crude-oil tankers, pumping the cargo from the ship uses significantly more power than general power consumption for lights and ballast pumps. Pumping requires

1-1.5 MW of power, while general power consumption ranges between 50-600 kW.

The hotelling times for product tankers range from 20 to 130 hours per visit. While the hotelling times appear long, a single visit by a product tanker to POLA/POLB may include stops at one to three different berths. Consequently, the average berthing time for a product tanker more likely varies from 25 to 50 hours.

B. Cost-Effectiveness Results

Staff analyzed two types of crude-oil tankers and one type of product tanker. Because of the significant difference in power requirements for diesel-electric crude-oil tankers, this type of tanker was analyzed separately from the other crude-oil tankers. The tanker analyses are based upon the shipping activities at each of the California ports that tankers frequent.

At each port, cost-effectiveness values were determined for three scenarios: 1) all ships visiting the port are cold-ironed; 2) only ships that make three or more visits per year to a port are cold-ironed; and 3) only ships that make six or more visits per year to a port are cold-ironed. In addition, the cost-effectiveness scenarios consider whether the necessary electrical transformers are constructed at the port (shore-side) or on the ships (ship-side).

Finally, staff calculated the cost-effectiveness values on the basis of pollutants reduced: 1) "all pollutants" (NOx, PM, hydrocarbons, and oxides of sulfur [SOx]); 2) NOx-only reductions; and 3) PM-only reductions. For purposes of this chapter, staff chose to present cost-effectiveness values for NOx reductions only because the majority of emission reductions from cold-ironing will be NOx. A discussion of staff's cost-effectiveness results for all other pollutants and scenarios analyzed, and the corresponding cost-effectiveness tables, are included in Appendix J.

The cost-effectiveness values presented below are based on using shore-side transformers and 0.1 percent sulfur distillate fuel. The shore-side transformer scenario was presented here because staff believes this to be the most likely approach to implementing cold-ironing. The 0.1 percent sulfur distillate fuel was used because the recently adopted fuel regulation requires its use statewide by 2010.

Crude-Oil Tankers (Non-Diesel-Electric)

Table VIII-3 summarizes the NOx cost-effectiveness values for crude-oil tankers using steam turbines for cargo pumping. The California ports visited by these tankers include Long Beach, El Segundo, Richmond, Benicia, and Martinez. As discussed in Chapter IV, the State Lands Commission Database did not accurately track the visits to the San Francisco Bay Area Ports. Bay Area ports identified in the State Lands Commission Database were Carquinez, Richmond, and San Francisco. Tanker traffic in Martinez and Benicia has been subsumed into one or more of these other designations.

As mentioned previously, about half of the crude-oil tankers that visited California in 2004 were steam ships, and, if cold-ironed, would provide minimal emissions reductions. Staff expects that these tankers will be replaced by ships whose auxiliary-power needs, except for cargo-pumping, will be provided by onboard generators. Because of federal requirement for double hulls, staff expects most of these tankers will be replaced by 2010. The analyses below for non-diesel-electric crude-oil tankers assume that the steam ships have been replaced.

Table VIII-3: NOx Reductions Cost Effectiveness for Cold-Ironing Crude-Oil Tankers* (Dollars/ton)

Port	All ship visits	Ships with 3 plus visits to the port	Ships with 6 plus visits to the port
POLB	$60,000	$37,000	$33,000
El Segundo	$33,000	$29,000	$29,000
Carquinez	$61,000	$66,000	$74,000
Richmond	$38,000	$38,000	$40,000
San Francisco	$76,000	$88,000	$120,000

* Assumes shore-side transformer and 0.1 percent sulfur distillate fuel.

In general, the average cost-effectiveness values behave in a similar fashion to the other ship categories. The average cost-effectiveness values were the lowest for El Segundo and Richmond because these two ports had the most ship visits for this category.

<u>Crude-Oil Tankers (Diesel-Electric)</u>

Diesel-electric tankers are better candidates for cold-ironing because electrical power is used to drive the cargo pumps; therefore, total hotelling power requirements are significantly greater.

Currently, only five diesel-electric crude-oil tankers visit California, and two more are under construction. Of these seven, only two are expected to make frequent trips to California, visiting the Port of Long Beach at least six times annually. If this scenario situation changes—for example, diesel-electric tankers begin to frequent Bay Area tanker terminals—then the cost-effectiveness analysis for cold-ironing diesel-electric tankers needs to be revisited.

As shown in Table VIII-4, the average cost-effectiveness values are considerably lower than for non-diesel-electric crude-oil tankers; however, the range is substantial and is dependent upon the number of visits to the port. If the company operating the cold-ironed tankers commits the ships to bring crude oil to the Port of Long Beach exclusively, the tankers can make as many as 22 annual visits, resulting in very attractive cold-ironing economics. Conversely, if the cold-ironed tankers are not dedicated to Long Beach, but are operated as members of a West Coast fleet, they may not visit Long Beach more than six times annually, resulting in the higher cost-effectiveness values.

Table VIII-4: NOx Reduction Cost Effectiveness for Cold-Ironing Diesel-Electric Crude-Oil Tankers* (Dollars/ton)

Port	**All ship visits**
POLB	$11,000 - 45,000

* Assumes shore-side transformer and 0.1 percent sulfur distillate fuel.

Because of the large power demands needed for the cargo pumps, and the relatively low number of port visits, the electrical cost for the two ships represents a substantial part—over 50 percent—of the overall cost. Utility rates average between 18 - 47 cents per kW-hr. As has been mentioned earlier in this report, high, but infrequent, electrical usage is expensive. Average electrical rates are lower for more consistent, sustained use, i.e., greater berth utilization.

Product Tankers

Product tankers are smaller than crude-oil tankers, and they carry various types of finished petroleum products and chemicals. Since they may carry several products at the same time, their berthing times are usually short, and they may move around to several berths within a port. The major ports that product tankers visit include the San Pedro port complex of Los Angeles/Long Beach, El Segundo, Richmond, and Bay Area tanker ports, including the ports of Richmond, Benicia, and Martinez.

Staff made several assumptions about product tankers. First, the analyses assume that separate shore infrastructure would be required for crude-oil tankers and product tankers. Second, the cost-effectiveness values assume that all product tankers can be cold-ironed. Staff understands that some product tankers use either direct-drive pumps or hydraulic pumps that would not be amenable to cold-ironing. Consequently, the average cost-effectiveness values in the table are probably lower than if each individual product tanker could be fully analyzed.

Finally, staff assumed that the cargo pumps would operate 60 percent of the time the product tankers were in port. The other 40 percent of the time, the product tankers would be receiving product via shore-based cargo pumps.

Table VIII-5 summarizes the NOx cost-effectiveness values for product tankers visiting California ports. Based on the State Lands Commission designations, these ports include: Carquinez, El Segundo, Hueneme, POLA/POLB, Richmond, San Diego, San Francisco, and Stockton. For San Diego, none of the ships made more than two visits, and for Hueneme, none of the ships made more than three visits.

Table VIII-5: NOx Reductions Cost Effectiveness for Cold-Ironing Product Tankers* (Dollars/ton)

Port	All ship visits	Ships with 3 plus visits to the port	Ships with 6 plus visits to the port
San Diego	$380,000	-	-
Hueneme	$230,000	$400,000	-
Stockton	$88,000	$110,000	$130,000
POLA/POLB	$110,000	$110,000	$160,000
El Segundo	$45,000	$44,000	$49,000
Carquinez	$53,000	$47,000	$75,000
Richmond	$32,000	$22,000	$20,000
San Francisco	$46,000	$56,000	$190,000

* Assumes shore-side transformer and 0.1 percent sulfur distillate fuel.

In general, the average cost-effectiveness values behave in a similar fashion to the other ship categories. The cost-effectiveness values were the lowest for El Segundo and Richmond because they received the most ship visits. The cost-effectiveness values were the highest for the ports receiving few ships: San Diego and Hueneme.

The prior analyses have all addressed *average* cost effectiveness. When cold-ironing all ships, these average values include many ships that visit a few times and a few ships that visit many times. The following analysis addresses the cost effectiveness of cold-ironing a ship if the shore-side infrastructure is already in place, as a function of the number of ship visits.

Table VIII-6 provides incremental cost-effectiveness values for NOx reductions only for crude-oil tankers and Table VIII-7 provides incremental cost-effectiveness values for NOx reductions only for product tankers.

Table VIII-6: Incremental Cost Effectiveness to Retrofit a Crude-Oil Tanker* (Dollars/Ton)

Visits	NOx
1	$200,000
3	$67,000
5	$40,000
7	$28,000

* Assumes shore-side transformer and 0.1 percent sulfur distillate fuel.

Table VIII-7: Incremental Cost Effectiveness to Retrofit a Product Tanker* (Dollars/Ton)

Visits	NOx
1	$170,000
3	$56,000
5	$33,000
7	$24,000

* Assumes shore-side transformer and 0.1 percent sulfur distillate fuel.

Not surprisingly, the incremental cost-effectiveness values drop significantly with more visits made by a ship. The incremental cost-effectiveness values approach the average cost-effectiveness values discussed earlier for some ports at about 3-5 visits. More than likely, however, a crude-oil tanker visiting a port that many times would have been factored into the original assessment to cold-iron at that port.

C. Summary

The tanker category as a whole has higher cost-effectiveness values than the other ship categories reviewed in this report. In general, the cost-effectiveness values are substantially higher than the passenger, reefer, or container categories. Two ports—El Segundo for crude tankers, and Richmond for crude and product tankers—have the most attractive cost-effectiveness.

Most crude-oil tankers use steam turbines to drive their cargo pumps. These cargo pumps represent the majority of the power needed by tankers when they are berthed. The rest of the power needs are modest.

There are a handful of diesel-electric crude-oil tankers that visit California. Only two of these tankers are expected to visit more than six times annually. These two ships may be ideal candidates for cold-ironing, especially if they are dedicated to a particular berth.

Finally, because many product tankers make few visits to California ports and their berthing times are short, product tankers in general are much less attractive candidates for cold-ironing.

D. Future Trends

Tankers bring in material to largely support California refineries and meet California's fuel usage requirements. California currently obtains its oil from three sources: in-state production (42 percent), Alaska (22 percent), and foreign oil imports (36 percent). The Alaskan oil and foreign oil imports are delivered by ship, and in-state production is delivered primarily by pipeline.

Considering that in-state oil production is declining, tanker traffic will increase from overseas; additional oil will be brought to California to replace the declining production from domestic sources. The California Energy Commission projects that very large crude carriers—transporting one to two million barrels of oil—will make twice the number of current visit within the next several years, although the total number of tankers visiting California is expected to be the same in the foreseeable future.

California's demand for gasoline and diesel is already greater than the gasoline and diesel that can be produced by California refineries. In 2002, California imported 25,000 barrels of gasoline and 13,000 barrels of diesel to satisfy California's fuel demand. These fuels are largely transported to California via tankers. By 2010, California will import eight times the amount of gasoline it imported in 2002 and almost four times the amount of diesel it imported in 2002. Consequently, product tanker visits to California ports will also increase significantly by 2010.

If more of the crude-oil tankers are diesel-electric, or they stay in port for considerably longer due to their size, cold-ironing may become more attractive to this ship category. The same can be said for product tankers if they are larger, stay in port longer, and are dedicated to visiting the same ports frequently.

IX. BULK AND CARGO SHIPS

This chapter provides background on bulk and cargo ships, a discussion of staff's cost-effectiveness analysis for cold-ironing these ships, and a discussion of the expected growth of bulk and cargo ship traffic to California.

A. Background

Bulk and general cargo ships carry material that is not easily placed into containers. Examples of material a bulk or general cargo ship could transport include rolls of steel, large machines, gypsum, and wood products. Similar to reefer ships, most of these types of ships are equipped with cranes or other equipment to load or unload the cargo.

Similar to other ocean-going ships, bulk ships are propelled by a large low-speed diesel engine, and electrical power is provided by several auxiliary diesel engines. Electrical power is needed for lights and ballast pumps, and possibly for cargo loading/unloading equipment, such as cranes or conveyer belts.

Table IX-1 provides a frequency distribution for bulk and cargo ships visiting California ports in 2004.

Table IX-1: Bulk and Cargo Ship Visits to a California Port in 2004

Annual Visits During 2004	Total Ships Making "N" Visits	Total Visits by All Ships Making "N" visits	Cumulative Percentage For Total Ship Visits
1	665	665	100
2	132	264	51
3	48	144	31
4	23	92	21
5	10	50	14
6	1	6	11
7	2	14	10
8	4	32	9
10	1	10	7
12	1	12	6
18	3	54	4
19	1	19	1
Totals		1,362	

* Note: The number of ships in this table is based on ships visiting a specific port. Since some ships visited multiple ports, they have been counted more than once here. These ships were identified during the cost-effectiveness analysis and counted only once. In fact, the economic synergism created by these ships was taken into account.

Note that bulk ships making only one visit to a California port in 2004 accounted for *half* of all the total visits made by this ship category. Although some of these ships may have visited multiple ports, they visited no more than once at any one port. Only 31 percent of bulk ships made three or more visits to a California port, and only 11 percent made six or more visits to a California port.

B. Cost-Effectiveness Results

Bulk and general cargo ships visit all ports in California and have the largest population of ships among the six ship categories, although as Table IX-1 shows, many made only one or two visits. Furthermore, unlike with other ship categories, the cargos of the bulk ships are very diverse, making it more difficult to take advantage of any synergistic opportunities among ships visiting the same port. For example, a port may have three bulk cargo ships visit, but one of them is shipping newsprint, another gypsum, and yet another petroleum coke. These three ships would not visit the same berths to load or unload their cargo.

Bulk and general cargo ships have modest power needs, and those needs depend on whether the ships have onboard cranes that are used frequently. Power requirements can vary from 300 kW up to over 1 MW for ships equipped with cranes. For this analysis, staff assumed a hotelling load of 1 MW, with an average hotelling time of 77 hours. Although bulk ships visit Oakland, the bulk cargo is actually loaded at another port. These ships then visit Oakland, where containers are loaded onto their decks. Even though these ships are classified as bulk ships in the Lands Commission database, staff determined that the activity is container loading. Therefore, staff did not analyze bulk activity for Oakland.

At each port, cost-effectiveness values were determined for three scenarios: 1) all ships visiting the port are cold-ironed; 2) only ships that make three or more visits per year to a port are cold-ironed; and 3) only ships that make six or more visits per year to a port are cold-ironed. Only shore-side transformers were considered.

Staff calculated the cost-effectiveness values on the basis of pollutants reduced: 1) "all pollutants" (NOx, PM, hydrocarbons, and oxides of sulfur [SOx]); 2) NOx-only reductions; and 3) PM-only reductions. For purposes of this chapter, staff chose to present cost-effectiveness values for NOx reductions only because the majority of emission reductions from cold-ironing will be NOx. A discussion of staff's cost-effectiveness results for all other pollutants and scenarios analyzed, and the corresponding cost-effectiveness tables, are included in Appendix K.

The cost-effectiveness values presented below are based on using shore-side transformers and 0.1 percent sulfur distillate fuel. The shore-side transformer scenario was presented here because staff believes this to be the most likely approach to implementing cold-ironing. The 0.1 percent sulfur distillate fuel was used because the recently adopted fuel regulation requires its use statewide by 2010.

Tables IX-2 shows the NOx cost-effectiveness values calculated for bulk and cargo ships visiting POLA/POLB and San Diego respectfully. ARB staff included these three ports in this chapter because of the relatively high ship activity and diversity of scenarios. Other NOx cost-effectiveness values for bulk ships at other ports can be found in Appendix K.

Table IX-2: NOx Reduction Cost Effectiveness for Cold-Ironing Bulk Ships* (Dollar/ton)

Port	All ship visits	Ships with 3 plus visits to the ports	Ships with 6 plus visits to the ports
POLA/POLB	$41,000	$92,000	$55,000
San Diego	$54,000	$55,000	$71,000

* Assumes shore-side transformer and 0.1 percent sulfur distillate fuel.

For the POLA/POLB analysis above, staff assumed that 32 berths were retrofitted for the all-ship and the three-or-more-visits scenarios, assuming that the varied types of cargo and the specialized handling equipment warranted numerous berths. In the six-or-more-visits scenario, only eight berths were used because so few ships remained in the category.

For the Port of San Diego, the average cost effectiveness decreases as more ships are cold-ironed. Two berths are cold-ironed in the first two scenarios and only one in the third. Electricity costs are considerably higher in San Diego than at other ports, so operating costs are higher, especially when few ships are cold-ironed and demand charges represent a substantial portion of the total electrical bill.

The prior analyses have all addressed *average* cost effectiveness. When cold-ironing all ships, these average values include many ships that visit a few times and a few ships that visit many times. The following analysis addresses the cost effectiveness of cold-ironing a ship if the shore-side infrastructure is already in place, as a function of the number of ship visits.

Table IX-3 provides incremental cost-effectiveness values for NOx reductions only for bulk ships.

Table IX-3: Incremental Cost Effectiveness to Retrofit a Typical Bulk Ship* (Dollars/Ton)

Visits	NOx
1	$59,000
2	$30,000
3	$21,000

* Assumes shore-side transformer and 0.1 percent sulfur distillate fuel.

Not surprisingly, the incremental cost-effectiveness values drop significantly with more visits made by a ship. These incremental cost-effectiveness values may be somewhat misleading in that they assume the shore-side infrastructure has already been installed, which is less likely for this ship category than for others, such as container ships and passenger ships.

C. Summary

The bulk and cargo ships have higher average cost-effectiveness values for cold-ironing because of the low number of repeat visits to any port and the lower electrical power demand. Furthermore, bulk ships carry diverse cargos, which may require dedicated terminals with specialized cargo-handling equipment. Nevertheless, specific shipping scenarios at specific berths may warrant a closer examination. A focused application to dedicated ships would improve the economics of some bulk and general cargo ships.

D. Future Trends

A 2005 report by The U.S. Department of Transportation's Maritime Administration, *Vessel Calls at U.S. Ports*, summarizes vessel calls from 1999 to 2003 for various regions in the U.S. The region that includes California is the Pacific Southwest region, which includes ports from Carquinez, the northern boundary, to San Diego, the southern boundary, and includes Hawaii. The Pacific Southwest region is not inclusive of the Port of Humboldt. Table IX-4 shows the historical trends for dry bulk and general cargo for this region.

Table IX-4: Ship Calls in the Pacific Southwest Region of the U.S.

Ship Category	1999	2000	2001	2002	2003	Percent Change 1999-2003
Dry Bulk	1,400	1,613	1,395	1,389	1,424	2
General Cargo	526	575	624	570	636	17

As can be seen in the table, dry bulk ship visits grew a modest two percent from 1999 to 2003, while general cargo ship visits increased 17 percent. The U.S. Army Corps of Engineers' 2002 report, *National Dredging Needs Study of U.S. Ports and Harbors*, projects the annual increase in visits from 2000 to 2020 for dry bulk ships and general cargo ships on the Pacific Coast to be three percent and two percent, respectively.

X. VEHICLE CARRIER SHIPS

This chapter provides background on vehicle carrier ships, a discussion of staff's cost-effectiveness analysis for cold-ironing vehicle carrier ships, and a discussion of the expected growth in vehicle carrier ship traffic to California.

A. Background

Vehicle carriers are specialized ships where vehicles are driven on and off the ship. This category also includes other ships, referred to as "RoRos," that are designed for cargo to be rolled on and rolled off. Similar to other ocean-going vessels, a vehicle carrier is typically propelled by a large low-speed diesel engine, and the electrical power is provided by two to three auxiliary diesel engines. Vehicle carriers require low power while in port—about 700 kW. The average hotelling time for these ships is 45 hours.

In 2004, 227 vehicle carriers visited California ports, accounting for about eight percent of the total ship visits to California. Two of these ships are steam ships. Cold-ironing these types of ships would result in minimal emission reductions.

Table X-1 provides a frequency distribution for vehicle carriers visiting California ports in 2004.

Table X-1: Vehicle Carrier Ship Visits to a California Port During 2004

Annual Visits During 2004	Total Ships Making "N" Visits*	Total Visits by All Ships Making "N" Visits	Cumulative Percentage For Total Ship Visits
1	238	238	100
2	83	166	68
3	35	105	46
4	8	32	32
5	13	65	28
6	3	18	19
7	3	21	17
8	2	16	14
9	2	18	12
10	1	10	9
11	1	11	8
24	2	48	6
Totals		748	

* Note: The number of ships is based on ships visiting a specific port. Since some ships visited multiple ports, they have been counted more than once in this table. These ships were identified during the cost-effectiveness analysis and counted only once. In fact, the economic synergism created by these ships was taken into account.

Table X-1 shows that a large number of vehicle carrier ships only made one visit to a port, accounting for 32 percent of the total visits. Vehicle carriers visiting three times or more accounted for 46 percent of the total visits, and vehicle carriers visiting six times or more accounted for just 19 percent of the total visits.

B. Cost-Effectiveness Results

Vehicle carrier ships principally visit POLA/POLB, Hueneme, and San Diego, and to a lesser extent Carquinez, Richmond, and Oakland.

As was done previously for other ship categories, for each port, cost-effectiveness values were determined for three scenarios: 1) all ships visiting the port are cold-ironed; 2) only ships that make three or more visits per year to a port are cold-ironed; and 3) only ships that make six or more visits per year to a port are cold-ironed. In addition, the cost-effectiveness scenarios consider whether the necessary electrical transformers are constructed at the port (shore-side) or on the ships (ship-side).

Staff calculated the cost-effectiveness values on the basis of pollutants reduced: 1) "all pollutants" (NOx, PM, hydrocarbons, and oxides of sulfur [SOx]); 2) NOx-only reductions; and 3) PM-only reductions. For purposes of this chapter, staff chose to present cost-effectiveness values for NOx reductions only because the majority of emission reductions from cold-ironing will be NOx. A discussion of staff's cost-effectiveness results for all other pollutants and scenarios analyzed, and the corresponding cost-effectiveness tables, are included in Appendix L.

The cost-effectiveness values presented below are based on using shore-side transformers and 0.1 percent sulfur distillate fuel. The shore-side transformer scenario was presented here because staff believes this to be the most likely approach to implementing cold-ironing. The 0.1 percent sulfur distillate fuel was used because the recently adopted fuel regulation requires its use statewide by 2010.

Table X-2 shows the cost-effectiveness values for the ports that vehicle carrier ships frequent.

Table X-2: NOx Reduction Cost Effectiveness for Cold-Ironing Vehicle Carrier Ships* (Dollars/ton)

Port	All ship visits	Ships with 3 plus visits to the port	Ships with 6 plus visits to the port
San Diego	$62,000	$61,000	$85,000
Hueneme	$60,000	$68,000	$250,000
POLA/POLB	$72,000	$75,000	$120,000
Carquinez	$68,000	$190,000	-
Richmond	$81,000	$99,000	-

* Assumes shore-side transformer and 0.1 percent sulfur distillate fuel.

The average cost-effectiveness values are high for this ship category. Vehicle carrier ships visiting six or more times had the highest average cost-effectiveness values because there were so few ships that met this criterion. In fact, no ships visited Carquinez and Richmond at least six times. Poor berth utilization (minimal ship traffic) results in poor cost-effectiveness values.

The prior analyses have all addressed *average* cost effectiveness. When cold-ironing all ships, these average values include many ships that visit a few times and a few ships that visit many times. The following analysis addresses the cost effectiveness of cold-ironing a ship if the shore-side infrastructure is already in place, as a function of the number of ship visits.

Tables X-3 provides incremental cost-effectiveness values for NOx reductions only for vehicle carriers.

Table X-3: Incremental Cost Effectiveness to Retrofit a Vehicle Carrier Ship* (Dollars/Ton)

Visits	NOx
1	$141,000
3	$52,000
5	$35,000
7	$27,000

* Assumes shore-side transformer and 0.1 percent sulfur distillate fuel.

Not surprisingly, the incremental cost-effectiveness values drop significantly with more visits made by a ship. These incremental cost-effectiveness values are somewhat misleading in that they assume the shore-side infrastructure has already been installed. The average cost-effectiveness values presented earlier may cast doubt on that premise.

C. Summary

As a category, vehicle carriers are much less attractive candidates than other ship types to cold-iron. Few ships visit a port often, and their power requirements are modest compared to other types of ships.

D. Future Trends

Vehicle carriers, or RoRos, showed a 10-percent decline in the number of visits from 1999 to 2003. Staff was unable to obtain enough data to determine future trends in this category.

XI. SUMMARY OF THE COST-EFFECTIVENESS ANALYSIS

This chapter discusses the expected emission reductions from cold-ironing ships, the overall financial impact of cold-ironing, the potential increases in hotelling emissions at California ports and how cold-ironing can mitigate these emission increases, and the potential impact of cold-ironing on the State's electrical grid.

A. Emission Reductions

Table XI-1 provides ARB staff's estimate of the 2004 hotelling emissions for all ocean-going vessels that visited California ports. As discussed in Chapter II, these emissions represent about 1,900 ships making just over 9,600 visits. The emission estimates are based upon the use of the current fuel mix, which is largely residual fuel.

Table XI-1: Hotelling Emissions from Ocean-Going Vessels (TPD)

Year	NOx	PM	HC	SOx
2004	24.2	2.1	0.6	15.5

At each port, cost-effectiveness values were determined for three scenarios: 1) all ships visiting the port are cold-ironed; 2) only ships that make three or more visits per year to a port are cold-ironed; and 3) only ships that make six or more visits per year to a port are cold-ironed. In addition, the cost-effectiveness scenarios consider whether the necessary electrical transformers are constructed at the port (shore-side) or on the ships (ship-side).

For purposes of this chapter, staff chose to present cost-effectiveness values for the scenario where only ships making three or more 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. Additional discussion of other cost-effectiveness scenarios can be found in Appendix M.

Table XI-2 provides the emission reductions for the case where only the ships that make three or more visits to a California port 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 XI-2: Emission Reductions from Cold-Ironing by Ship Category (for Ships with 3 or More Visits to a California Port)

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 in 2004 were cold-ironed, then the overall hotelling emissions would have been reduced by between 70 to 74 percent (compared to data in Table XI-1). For this scenario, the container ship category would provide 50 to 60 percent of the total reduction for NOx, PM, and HC.

Table XI-3 provides similar information on the potential emission reductions, but on a port basis. (Totals for Tables XI-2 and XI-3 differ due to rounding.) As can be seen, 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. The potential reductions from the ports of Los Angeles/Long Beach would come from other ship categories as well.

Table XI-3: Emission Reductions from Cold-Ironing by Port (for Ships Making 3 or More Visits to a California Port)

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**

B. Overall Financial Impact of Cold-Ironing

Table XI-4 provides the total capital cost for the three-visits-or-more scenario by ship category based on 2004 ship activity.

Table XI-4: Capital Cost to Implement Cold-Ironing by Ship Category (for Ships With 3 or More Visits to a California Port)* (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**

* Assumes shore-side transformer.

Table XI-5 provides the same shore-side capital costs information on a port basis. (Totals for Tables XI-4 and XI-5 differ due to rounding.)

Table XI-5: Capital Cost to Implement Cold-Ironing by Port (for Ships with 3 or More Visits to a California Port)* (Million Dollars)

Port	Shore-Side
Carquinez	$23
El Segundo	$10
Hueneme	$10
POLA/POLB	$350
Oakland	$70
Richmond	$17
San Diego	$25
San Francisco	$35
Total	**$540**

* Assumes shore-side transformer.

The above table shows that about 65 percent of the total capital costs will need to be spent at POLA/POLB.

Finally, Table XI-6 provides the costs based upon the commodity being affected. The cost to cold-iron container ships ranges from $4 to $13 per loaded TEU. The high end of the cost represents cold-ironing all container ships at Oakland. The low end of the cost represents cold-ironing container ships making six or more visits to POLA/POLB. These cost estimates are calculated by dividing the annualized cost of cold-ironing the ships being considered by the total units of that item moved during 2004. For example, the estimated annualized cost for cold-ironing the container ships making six or more visits to POLA/POLB is $60 million. During 2004, about nine million loaded TEUs were shipped through POLA/POLB. Therefore, the TEU unit cost is $60 million divided by nine million TEUs, or $6.66 per TEU. This cost is slightly more than one percent of the cost to ship a container freight across the Pacific, which is about $500 per TEU.

For the passenger-ship category, the cost to cold-iron represents about one to five percent of the cost of a cabin for a three-day or seven-day cruise.

Table XI-6: Costs for Cold-Ironing Based on Commodity

Container Ships	$4-13 per TEU (loaded only) $4-10 per TEU (loaded and empty)
Passenger Ships	$12-16 per passenger

These figures are based on 2004 data only. As will be discussed later in Section E, considering future emissions reductions will improve cost effectiveness across the board. Regardless, when the capital costs for implementing cold-ironing are examined on a commodity basis, cold-ironing is expected to have minimal impact on consumer costs.

C. Overall Electrical Impact of Cold-Ironing

Table XI-7 shows the projected total statewide electrical impact for cold-ironing for 2010, 2015, and 2020. As expected, the Ports of Los Angeles and Long Beach would have the highest electrical demand. Staff assumed that cold-ironing would reduce ship hotelling emissions by 20 percent, 60 percent, and 80 percent by 2010, 2015, and 2020, respectively. This level of activity for cold-ironing is consistent with ARB's draft *Emission Reduction Plan for Ports and International Goods Movement in California*.

For 2010, staff assumed the 20 percent emissions reduction could be satisfied by cold-ironing a modest percentage of container ships, as well most of the passenger ships and reefer ships that make at least three annual visits to a California port. By 2015, all container, passenger and reefer ships making three or more visits to a port would be cold-ironed. By 2020, either all of the bulk cargo and vehicle carrier ships making three or more visits to a port would also need to be cold-ironed—an unlikely scenario—or additional emission reductions would have to be found in the container, passenger, and reefer ship categories.

Table XI-7: Estimated Peak Power Demand for Cold-Ironing, by Port (MW)

Port	2010	2015	2020
Carquinez	0	0	5
Hueneme	4	5	13
Los Angeles/Long Beach	92	360	523
Oakland	2	91	110
Richmond	0	0	2
San Diego	55	89	140
San Francisco	37	62	100
Total	**190**	**607**	**893**

The current peak statewide energy demand is approximately 57,000 MW during the summer months and is expected to grow to about 75,000 MW by 2020. The electricity demand from cold-ironing implementation would represent about one percent of the total energy peak demand.

According to the California Energy Commission in 2004, the energy and capacity necessary to serve cold-ironing at California ports are not likely to cause a significant impact to the electricity system although new generation will be needed to meet expected loads in the future, with or without cold-ironing. Peak-pricing and interruptible-program participation could further reduce the impact to the electricity system at lower cost.

In the near term, there still exists some reserve-capacity issues in the State, especially under hot-weather conditions. Furthermore, regional and local transmission congestion may limit some resource options.

California's utility companies and energy agencies should be involved during the implementation of cold-ironing projects in the State so that additional loads can be reflected in their resource planning.

D. Future Trends and Emissions Reductions

In this chapter, we discussed the potential emission reductions that can result from cold-ironing ocean-going vessels. These estimates were based upon the ship activity that occurred in 2004. However, this assessment does not include the expected growth in port activities or the timeframe over which the cold-ironing implementation would occur. This section briefly discusses the projected NOx and PM emissions reductions resulting from cold-ironing for the years 2008 through 2020.

As discussed in each of the chapters on ship categories, ship traffic to California ports is expected to grow substantially in the next few years. Container ships will lead this growth. Container ships already represent about half of the total visits by ocean-going vessels, and the visits are expected to increase by 50 percent from current levels by the end of the decade and double by 2020.

Table XI-8 provides ARB staff's estimates of NOx and PM emissions from hotelling for 2004 and projected emissions for 2010, 2015, and 2020. The 2004 estimate is based on the current fuel mix (mostly residual), and the future year estimates is based on the use of 0.1 percent sulfur distillate, as required by the recently adopted ARB rule governing auxiliary engines. By 2010, the hotelling emissions for PM are substantially reduced, but emissions of NOx have increased by 40 percent—consistent with our knowledge that switching from the current fuel mix to a distillate fuel will result in substantial reductions in PM, but relative modest benefits to NOx. By 2020, because of the expected growth in activities at California ports, the emissions of NOx have more than doubled from 2004 levels, while the emissions of PM have increased by 50 percent from 2010 levels.

Table XI-8: Future Hotelling Emissions from Ocean-Going Vessels (TPD)

Year	NOx	PM
2004	24.2	2.1
2010	34.5	0.9
2015	44.0	1.15
2020	53.4	1.4

Figure XI-1 graphically describes the impact of cold-ironing on hotelling NOx emissions. Staff assumed that cold-ironing would reduce ship hotelling emissions by 20 percent, 60 percent, and 80 percent by 2010, 2015, and 2020, respectively. By 2020, NOx emissions would be reduced by 41 tons/day. Between 2008 and 2020, cold-ironing could reduce emissions from hotelling by 100,000 tons. (See Section E below for additional details.)

Figure XI-1: NOx Reductions from Cold-Ironing

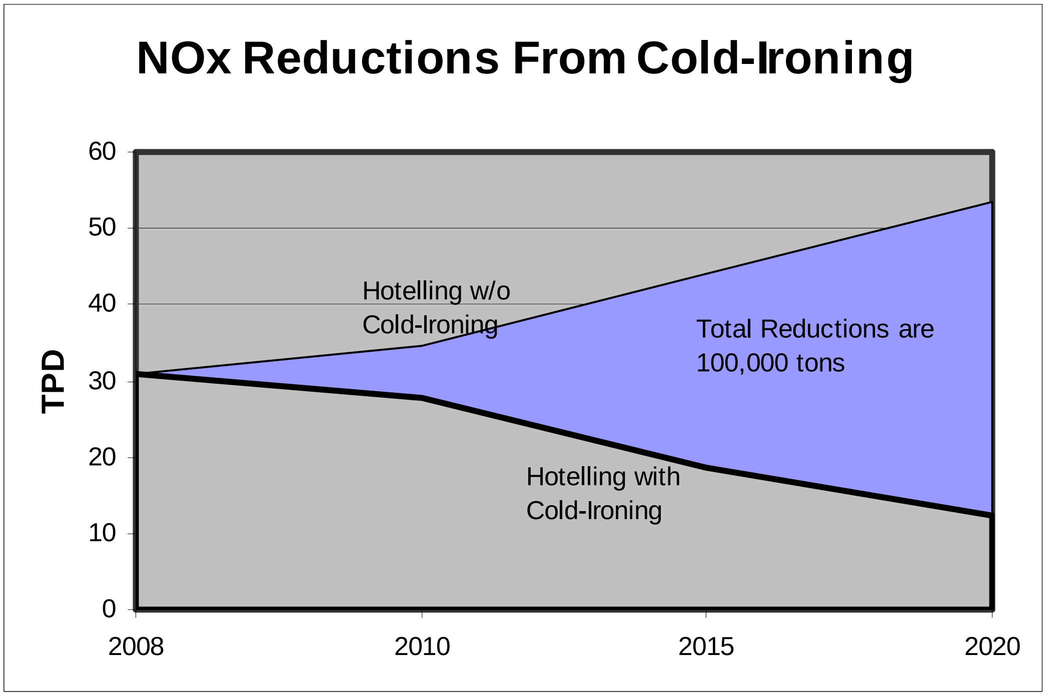


Figure XI-2 graphically describes the impact of cold-ironing on PM emissions. Because the Auxiliary Fuel Regulation reduces PM emissions by 83 percent from current levels, there are less available PM reductions for cold-ironing. For example, in 2010, when 20 percent of hotelling emissions are assumed to be reduced by cold-ironed, PM emissions would be reduced by 0.2 tons/day. By 2020, when 80 percent of hotelling emissions are assumed to be reduced by cold-ironed, PM emissions would be reduced by one ton/day. Between 2008 and 2020, cold-ironing could reduce emissions from hotelling by 2,400 tons.

Figure XI-2: PM Reductions from Cold-Ironing

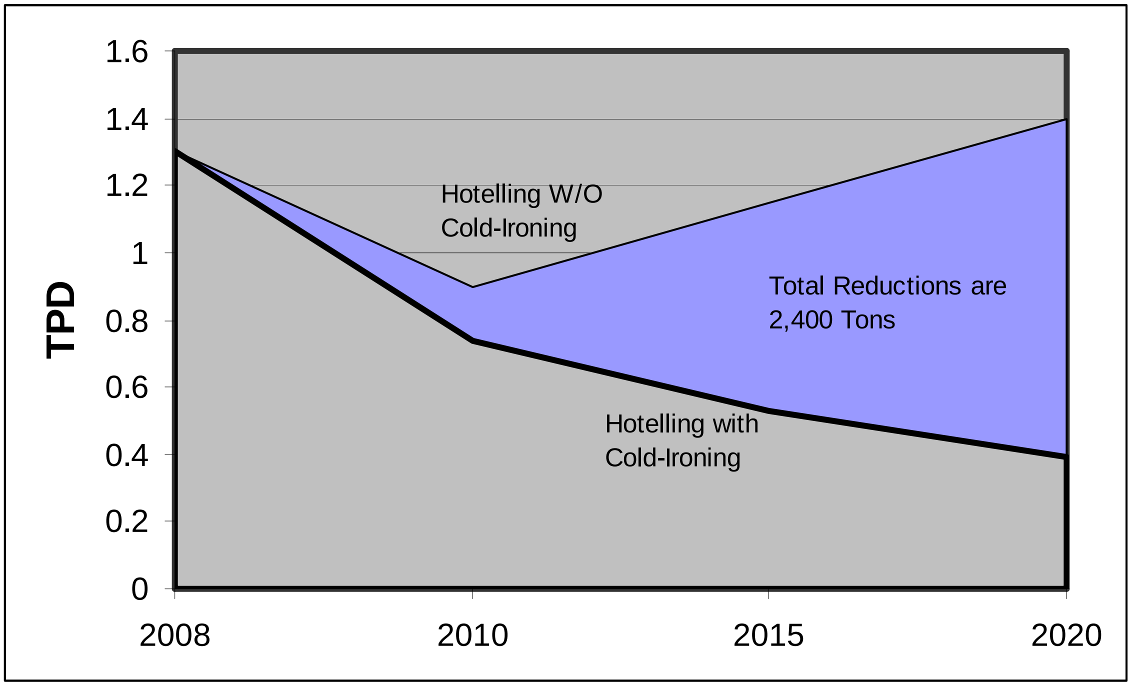


Table XI-9 numerically expresses the emissions reductions contained in Figures XI-1 and XI-2.

Table XI-9: Potential Emission Reductions from Cold-Ironing Ocean-Going Vessels (TPD)

Year	NOx	PM
2010	6.6	0.16
2015	25.3	0.62
2020	41	1.01

The cost-effectiveness values presented in this report are based on 2004 emission estimates. If future emission reductions were considered, as represented in Figures XI-1 and XI-2, then the cost-effectiveness values could improve significantly.

For example, if the number of TEUs unloaded at a specific terminal were doubled, the cost effectiveness of cold-ironing that terminal would improve considerably, depending on whether the increased activity was handled by more ships, larger ships, or a combination of the two.

Table XI-10 illustrates the effect of growth on cost-effectiveness values. The key assumption is that the cost of electricity is the same as the cost of using 0.1 percent sulfur distillate fuel—a likely scenario at reasonable electricity demand.

Table XI-10: Effect of Growth on Cost Effectiveness

Assumptions	Current	More Ships	Larger Ships
Ships	48	96	48
TEUs/Ship	4000	4000	8000
Annual Visits	6	6	6
Berthing Time (Hrs)	40	40	80
Avg. Power Needs (MW)	1.2	1.2	2.4
Shoreside Costs ($MM)	8.0	8.0	8.0
Ship Costs ($MM)	24.0	48.0	24.0
Annualized Capital Costs ($MM)	4.14	7.25	4.14
Electricity Costs vs. MGO Costs ($MM) *	-	-	-
Annual Labor Costs ($MM)	0.17	0.34	0.17
NOx Emissions (TPY)	200	400	820
Cost Effectiveness ($/Ton)	21,600	19,000	5,300
Reduction from Base Case	-	12%	75%

* Staff assumed that the cost of electricity for cold-ironing is about the same as the cost of operating auxiliary engines with distillate fuel

As Table XI-10 shows, larger ships have more auxiliary engine requirements while hotelling, and they stay in berth longer. For about the same operating costs, their higher total emissions can be reduced, thereby resulting in better cost effectiveness.

In summary, implementation of cold-ironing would result in substantial emission reduction emissions, particularly NOx emissions, with the bulk of this reduction occurring after 2011.

E. Achieving Emission Reductions Goals from Cold-Ironing

As discussed earlier, the draft *Emission Reduction Plan for Ports and International Goods Movement in California* set emission reduction goals of 20 percent, 60 percent, and 80 percent by 2010, 2015, and 2020, respectively.

For 2010, in addition to the existing cold-ironing occurring at two container terminals at POLA/POLB, the 20 percent goal can be achieved by cold-ironing a modest percentage of container ships, as well as most of the passenger ships and reefer ships making three or more visits to a California port. To achieve the 60 percent emission reduction target by 2015, all container, passenger and reefer ships making three or more visits to a port would be cold-ironed. Finally, to achieve the 80 percent emission reduction target by 2020, either all of the bulk cargo and vehicle carrier ships making three or more visits to a port would also need to be cold-ironed—an unlikely scenario—or additional emission reductions would have to be found in the container, passenger, and reefer ship categories.

As discussed in each of the ship category chapters, shipping activities in California are expected to increase dramatically between now and 2020. To determine the increase in the number of ships, ship visits, and hotelling emissions for each category that would occur between now and 2020, staff used the same growth factors that were used to project the 2010, 2015 and 2020 emissions inventory for ocean-going vessels. These factors are listed in Table XI-11. As can be seen in this table, significant growth is expected for the container, passenger, reefer, and vehicle carrier ship categories.

Table XI-11: Growth Factors Relative to 2004 Ship Activities

Category	2010	2015	2020
Container	1.47	1.78	2.24
Bulk	1.06	1.09	1.17
Passenger	1.87	3.11	4.81
Reefer	1.46	1.76	2.15
Tanker	1.04	1.04	1.04
Vehicle Carrier	1.4	1.82	2.5

XII. ALTERNATIVE CONTROL MEASURES

In this chapter, staff discusses other methods that could be considered for reducing emissions when ocean-going vessels are docked at port. These technologies are currently available or projected to be available in the near future. Some of these technologies are currently being used or demonstrated on marine auxiliary engines, some have been used only on land-based engines, and none would provide the same emissions reductions as cold-ironing.

Switching Fuels

One available alternative control technology is switching the fuel used to operate the auxiliary engines. Most auxiliary engines on ocean-going vessels use residual fuel; however, some ships use distillate fuel as an alternative. Switching from residual fuel to distillate fuel would reduce PM emissions by over 75 percent, SOx emissions by over 80 percent, and NOx emissions by 5 -10 percent.

In December 2005, the Board adopted a regulation to require auxiliary engines on ocean-going vessels to use cleaner-burning marine distillate fuels when operating within 24 nautical miles of the California coastline, including while in port. The staff report for this regulation, *Proposed Regulation for Auxiliary Diesel Engines and Diesel-Electric Engines Operating on Ocean-Going Vessels within California waters and 24 Nautical Miles of the California Baseline*, includes a discussion on the availability of cleaner-burning fuels and the ability of ocean-going vessels to use these types of fuel.

Selective Catalytic Reduction (SCR)

Selective Catalytic Reduction (SCR) is an exhaust after-treatment method that can control NOx emissions up to 90 percent. The SCR process works by using ammonia (NH_3) as a reagent and injecting it into the exhaust gas of the engine. In the presence of a catalyst, the NH_3 and NOx form nitrogen (N_2) and water (H_20). This technology has been demonstrated on stationary and mobile diesel engines, and on a few marine engines. The four ships that cold-iron at the USS-POSCO steel mill plant in Pittsburg, California, have operated with SCR installed on their main engines since 1991. In addition, another shipping company has installed SCR on an auxiliary engine on a container ship and is currently testing the effectiveness of this technology.

Add-on Particulate Reduction Technologies

The technologies that can be used to reduce emissions of diesel PM include diesel oxidation catalyst (DOC) and particulate filters. DOC reduces the emissions of PM, CO, and HC. The range of reduction for PM from using a DOC is typically between 10 to 30 percent. Particulate filters reduce PM emissions from about 50 percent for flow-through filters to over 85 percent for ceramic filters. Both DOC and particulate filters have been demonstrated on mobile and stationary engines. Staff is not aware of any demonstrations of these types of technologies on ocean-going vessel engines.

<u>ACTI Technology</u>

Advanced Control Technology Inc. (ACTI) is developing an emission reduction technology for auxiliary engines based on using a two-stage wet scrubbing process. The equipment would be placed on a barge, and the emissions from the ship would be ducted to the barge. Currently, ACTI is installing this technology for demonstration purposes at a California rail yard and has introduced its technology to the Port Of Long Beach Harbor Commissioners for consideration as a possible future auxiliary-engine control measure.

XIII. IMPLEMENTATION APPROACHES

The infrastructure for cold-ironing will require significant capital investment. There are several options for implementing cold-ironing at the ports, including traditional regulations and incentives, port policies and programs, and federal funding. This chapter briefly describes and assesses implementation approaches to cold-ironing.

Regulations and Incentives

Over the past 30 years, California has steadily improved air quality in the face of tremendous economic and population growth. The vast majority of that progress has come from a reliance on cost-effective regulations. In the regulatory paradigm, polluting sources pay for the necessary emission controls. Regulations are crafted so that industries can absorb the expense of installing pollution controls or upgrading technology as part of the cost of doing business. Regulated industries pass these costs on to consumers in the form of higher prices, although competition and other factors may prevent some companies from recouping all of their control costs. Low-interest loans with extended payment periods are available to aid smaller businesses that need upfront capital to comply.

In recent years, regulatory programs in some sectors have been supplemented with incentives to accelerate voluntary actions, such as replacing older equipment. Incentive programs like the Carl Moyer Program are both popular and effective but require the allocation of public funds, which are in limited supply. Most of the existing incentive programs are designed to pay for the incremental cost between what is required and advanced technology that exceeds that level. The incentive programs are currently funded by general fund taxes or by fees imposed on California drivers as part of their annual registrations, smog inspections, or new tire purchases. California is currently investing up to $140 million per year to clean up older, higher emission sources. Ten percent of the Carl Moyer funds that flow through the State budget are reserved by ARB for projects of statewide significance, including goods movement-related clean up.

However, it is likely that Carl Moyer Program funds used for port-related goods movement emissions will focus on efforts to reduce diesel emissions through vehicle retrofits or upgrades. For example, ARB staff has identified the need to incentivize the clean-up of older, high emitting port trucks. Staff does not expect Moyer incentive funds to be a significant source of money for cold-ironing projects.

A far more likely source of public funding for some portion of cold-ironing is the use of state general obligation bonds issued to generate revenues for a special port-related incentive program. Governor Schwarzenegger has proposed

$1 billion in bonds to be matched by another $1 billion in funding from other sources to reduce goods-movement related pollution.

One use of these funds could be to help finance cold-ironing in the State, especially a portion of shore-side development costs. However, even if public funding becomes available, ARB staff presumes that traditional regulations, user fees, or port lease requirements (which place the costs of control on the owners and operators of polluting sources) will provide a large share of progress needed to deploy cold-ironing.

Port Policies and Programs

Another implementation mechanism relies on the ports themselves. The ports, through their policies and lease agreements, can provide incentives for cold-ironing.

For example, the Port of Los Angeles has developed a program called the Alternative Maritime Power (AMP) to allow container and passenger ships to be powered by shore-side electrical power while at berth. The Port is supporting this program through the implementation of shore-side infrastructure and by providing incentives to container- and passenger-ship operators to retrofit their vessels for shore power. Currently the financial incentive includes up to $810,000 per ship operator or affiliate company who has a permit with the Port of Los Angeles. The ship operators must commit to keeping the vessel in service at the Port for five years. In addition, container-ship operators must commit the vessel to seven shore-powered visits per year, and passenger-ship operators must commit to 20 shore-powered visits per year. For more details, please see the Port of Los Angeles website: http://www.portoflosangeles.org/. Similar efforts are underway at the Port of Long Beach.

Federal Funding

Federal funding is one funding mechanism currently being used or considered at the ports to implement cold-ironing projects. The U.S. EPA has provided several small grants thus far, through the West Coast Clean Diesel Collaborative, for California goods movement-related projects. The Collaborative is a partnership between federal, state, and local governments, the private sector, and environmental groups throughout the West Coast. The goal of the Collaborative is to allocate federal funds to reduce emissions from the most polluting diesel sources in the most affected communities and to significantly improve air quality and public health.

Last year, EPA allocated $15 million in funding for a National Clean Diesel Initiative that will in part fund the Collaborative. The Collaborative seeks funding for a variety of port projects, including cold ironing for ocean-going vessels and plug-in power for on-shore equipment. For example, in 2004, the U.S. EPA issued a $50,000 grant to Seattle City Light to help cover the costs of infrastructure improvements needed to cold-iron the ships of Princess Cruises calling at the Port of Seattle. Another potential project the Collaborative has identified is funding a shore-power installation at the new passenger terminal at the Port of San Francisco, if the Port goes forward with this option. Construction of the terminal may begin as soon as 2006 and is due for completion by 2008. Additional information is available on the West Coast Collaborative website, http://www.westcoastcollaborative.org/.

XIV. CONCLUSIONS

Based on the results of this cold-ironing study, there are several overall conclusions that can be drawn.

First, it is feasible to cold-iron ocean-going vessels visiting California ports, as ships of various types and designs are already connecting to shore power at California ports, and other cold-ironing installations are already planned.

Cold-ironing could produce large emission reductions and is cost effective at a large number of terminals and for a large percentage of ship visits. The most attractive ship categories are container ships, passenger ships, and reefers. Cold-ironing container ships and passenger ships is especially crucial for emissions reductions, as these ships account for 56 percent of all ship visits to the State, and container shipments and passenger ship visits are both growing dramatically. On the other hand, there are cases when cold-ironing, while feasible, may not be cost effective, such as for ships with infrequent and irregular visits to California, especially for those vessels with lower power needs and shorter berthing times. This is especially true with the tanker and bulk cargo ship categories.

Table XIV-1 shows a range of cost-effectiveness values based on ship category.

Table XIV-1: NOx Cost Effectiveness by Ship Category ($/ton)

Category	Cost Effectiveness
Container	$14,500 - $56,500
Passenger	$17,000 - $44,000
Reefer	$25,000 - $32,000
Bulk	$41,000 - $92,000
Vehicle Carrier	$72,000 - $120,000
Crude-Oil Tanker	$33,000 - $60,000
Product Tanker	$110,000 - $160,000

These values are based on ship activity and emissions during 2004. As shipping volumes increase, the emission reductions achievable from cold-ironing increase dramatically, and the cost effectiveness of the strategy improves considerably.

For example, for container ships, if the number of TEUs unloaded at a specific terminal were to double (consistent with the expected average growth rate in the next ten years), the cost effectiveness of cold-ironing that terminal could improve by 10 – 75 percent. The range depends on whether the increased activity were handled by more ships, larger ships, or a combination of the two.

Growth is expected for all of the ship categories over the next 15 years. Table XIV-2 shows the expected growth in statewide NOx emissions based on ship category.

Table XIV-2: Expected NOx Emissions Growth Based on Ship Category (Tons/Day)

Category	**2010**	**2015**	**2020**
Container	18.7	23.5	28.2
Bulk	5.3	5.7	5.8
Passenger	4.1	7.1	10.6
Reefer	2.9	3.5	4.1
Tanker	2.1	2.2	2.1
Vehicle Carrier	1.4	2.0	2.6
Total	**34.5**	**44.0**	**53.4**

Cold-ironing container and passenger ships must be a priority if significant emissions reductions are to be realized, as they comprise over 70 percent of all hotelling emissions statewide by 2020.

The draft *Emission Reduction Plan for Ports and International Goods Movement in California* recommended goals for emissions reductions from the hotelling of ships. These emissions reduction targets were 20 percent, 60 percent, and 80 percent by 2010, 2015, and 2020, respectively.

Table XIV-3 shows the emissions reductions achievable through these goals, taking into account the expected growth in shipping. By 2020, when 80 percent of the ship calls are assumed to be cold-ironed, NOx emissions would be reduced by 41 tons/day. Between 2008 and 2020, cold-ironing could reduce emissions from hotelling by 100,000 tons.

Table XIV-3: Potential Emission Reductions from Cold-Ironing Ships Pursuant to Goods Movement Plan (Tons/Day)

Year	**NOx**	**PM**
2010	6.6	0.16
2015	25.3	0.62
2020	41	1.01

Cold-ironing will require significant infrastructure investment by both the ports and the shipping companies. Table XIV-4 illustrates the order of magnitude of the necessary investment, assuming all ships making at least three annual visits to a California port are cold-ironed—a scenario consistent with the 80 percent emissions reduction target for 2020. Table XIV-5 shows the shore-side capitol cost by port.

Table XIV-4: Total Capital Cost to Cold-Iron All Ships Making Three or More Annual Visits to a California Port* (Million Dollars)

Shore-Side	Ship-Side	Total
$540	$370 **	**$910**

* Assumes electrical transformer on shore.
** Assumes 686 ships retrofitted.

Table XIV-5: Shore-Side Capital Cost to Implement Cold-Iron by Port* (for Ships with 3 or More Visits to a California Port) (Million Dollars)

Port	Shore-Side Cost
Carquinez	$23
El Segundo	$10
Hueneme	$10
POLA/POLB	$350
Oakland	$70
Richmond	$17
San Diego	$25
San Francisco	$35
Total	**$540**

* Assumes electrical transformer on shore.

Cold-ironing will have an impact on the State's electricity grid, increasing peak electrical demand, but the increase can be absorbed by the State's power system. Table XIV-6 shows the expected electrical impact of cold-ironing, assuming the targets in the goods movement emissions reduction plan are achieved.

Table XIV-6: Estimated Peak Power Demand for Cold-Ironing

Year	Peak Demand, MW
2010	188
2015	607
2020	893

The peak statewide energy demand is currently approximately 57,000 MW during the summer months and is expected to grow to about 75,000 MW by 2020. The electricity demand from cold-ironing implementation would represent about one percent of the total energy peak demand.

Finally, the cost-effectiveness values in this report assume that all of the costs and the benefits will be borne by California. As cold-ironing becomes commonplace, other ports—whether U.S. or foreign ports—will reap the benefits of cold-ironing when they install the necessary infrastructure to service the ships retrofitted to cold-iron in California. As this happens, some of the ship-side costs allocated to emission reductions in California should more properly be allocated to these other ports. This would further improve the cost effectiveness of this technology for use in California.

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