Cold Ironing
Cost Effectiveness Study
Executive Summary

Emulsified Diesel Fuel

ENVIRON

HPA

THE PORT OF LONG BEACH

EXECUTIVE SUMMARY

COLD IRONING COST EFFECTIVENESS
PORT OF LONG BEACH
925 HARBOR DRIVE
LONG BEACH, CALIFORNIA

Prepared for

Port of Long Beach
Long Beach, California

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1.0 EXECUTIVE SUMMARY

This report presents an analysis of the feasibility of various types of emissions control technologies that may be available to the Port of Long Beach (POLB) to reduce air emissions from ocean going vessels while they are docked at the POLB. The study focuses on the feasibility of provision of shore side electricity to power the various activities performed on these vessels while they are at berth. This technique is often referred to as "cold ironing", hence the title of this report. The report also considers the feasibility of using alternative approaches (e.g. cleaner diesel fuel, exhaust controls, and engine replacement), and a comparison is made of the cost effectiveness of the various approaches.

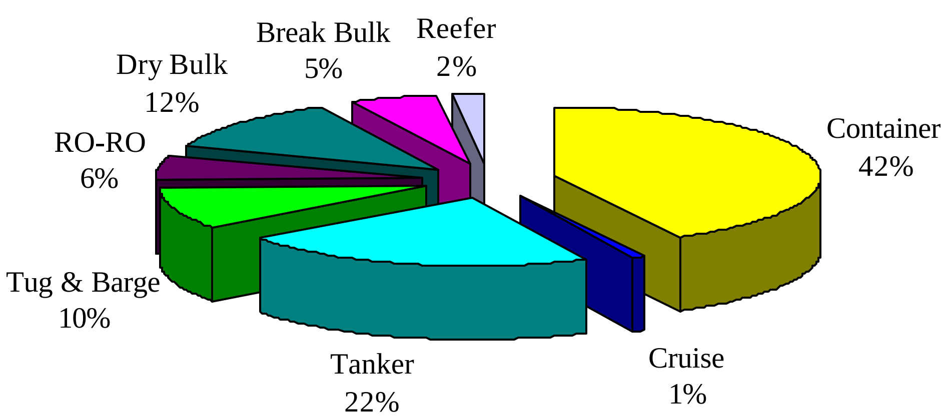
This report concludes that cold ironing is generally cost effective with vessels that spend a lot of time at the port, and therefore have high annual power consumption. Use of cold ironing for vessels that currently have high annual power consumption in the Port could cause a significant reduction in the overall annual emissions generated by docked vessels in the Port each year. The report also concludes that the availability of the various other types of emissions control technologies, while also potentially beneficial, is limited by a variety of implementation constraints that would slow their widespread application right away. Finally, the report concludes that the various technologies that are analyzed, including cold ironing, could have significant regulatory, legal, and logistical hurdles to overcome, particularly if the South Coast Air Quality Management District (SCAQMD) or other local agency wishes to mandate their use.

Between June 2002 and June 2003, 1,143 vessels made 2,913 calls at the Port of Long Beach, as shown on Table 1-1. As Figure 1-1 shows, container ships were the dominant vessel type in terms of vessel calls (1,231 calls) followed by tankers (635 calls), and dry bulk vessels (364 calls). These data (shown in Table 1-1 and Figure 1-1) do not include full operation by the cruise terminal on Pier G, which is projected to see more than 150 vessel calls per year or approximately 5% of calls.

Table 1-1. Frequency of Vessel Calls

Numbers of Calls per year	Number of Vessels	Percent of Total Vessels	Number of Calls	Percent of Total Calls
1 or more	1,143	100%	2,913	100%
2 or more	516	45%	2,286	78%
3 or more	302	26%	1,858	64%
4 or more	206	18%	1,570	54%
5 or more	158	14%	1,378	47%
6 or more	121	11%	1,193	41%
7 or more	97	8%	1,049	36%
8 or more	82	7%	944	32%
9 or more	60	5%	768	26%
10 or more	40	4%	588	20%

Figure 1-1. Vessel Calls at the Port of Long Beach



The frequency at which a given ship calls is particularly informative. As Table 1-1 shows, half of those vessels called only once, and less than 10 percent of the vessels called more than six times in a one-year period. These “frequent flyers”, however, accounted for more than 40 percent of all vessel calls.

While docked at the Port, the ocean-going cargo vessels shut off their propulsion engines, but they use auxiliary diesel generators to power refrigeration, lights, pumps, and other functions (activities commonly called “hotelling”). At present, the resultant air emissions -- nitrogen oxides (NO_x), sulfur oxides (SO_x), carbon monoxide (CO), volatile organic compounds (VOC), and diesel particulate matter (PM) -- are largely not subject to emission controls. However, the SCAQMD Governing Board has identified port emissions as a major source of air pollution that warrants controls. Of particular interest are the diesel PM emissions, which have been declared by the California Air Resources Board (CARB) to be a toxic air contaminant that causes cancer. The latest available ocean-going vessel emission inventory for the San Pedro Bay ports (Port of Los Angeles and the Port of Long Beach combined) indicated that of the reported 33.0 tons per day (tpd) of NO_x in 2000 from vessel activity in ports, 11.0 tpd of NO_x were derived from vessel auxiliary engines operating in hotelling mode. The situation with respect to diesel particulates is similar.

One approach to reduce hotelling emissions is called cold ironing. Cold ironing is a process where shore power is provided to the vessel, allowing it to shut down its auxiliary generators. This technology has been used by the military at naval bases for many decades when ships are docked for long periods.

At present, there are currently no international requirements that would mandate or facilitate cold ironing of marine vessels, and very few that attempt to regulate vessel emissions in ports at all. Note that a recently proposed worldwide emission control mechanism, Annex VI of 1997 to MARPOL -- The International Convention for the Prevention of Pollution of Ships -- under the auspices of the International Maritime Organization (IMO) does seek to address emission controls for hotelling vessels, but it does not mention cold ironing. Annex VI would reduce NO_x, SO_x, and particulate matter emissions from international cargo vessels by imposing emission controls on diesel engines rated at more than 130 kW (~175 hp) manufactured after January 2000. This requirement covers main propulsion engines and most auxiliary generators, and is based on the quality of the fuel they burn, most notably on the sulfur content. This international agreement has yet to be ratified.

At the United States federal level, the United States Environmental Protection Agency (USEPA) has promulgated NO_x and PM emission standards based on the proposed Annex VI controls for new marine diesel engines, but those standards only apply to U.S.-flagged vessels, which only comprise a small fraction of the world’s fleet. The USEPA has stated its intent to work with IMO to tighten the Annex VI standards, because most ocean-going vessels calling on U.S. ports are foreign flagged.

At the state level, CARB believes it has the legal authority to regulate marine vessels. The SCAQMD considered a cold ironing regulation for vessels in the South Coast Basin in the late 1980's, but eventually terminated the rule-making process. SCAQMD now states, in the Final Program Environmental Impact Report for the 2003 Air Quality Management Plan (AQMP), "the SCAQMD does not have authority to directly regulate marine vessel emissions and the SCAQMD cannot require retrofitting, repowering or controlling emissions from marine vessels. However, CARB and the USEPA have authority to regulate these sources …" Due to the high costs of cold ironing and the uncertainties in the legal framework, any regulation from environmental agencies that requires cold ironing is likely to meet with significant resistance and litigation.

Given the magnitude of vessel hotelling emissions and the uncertainty with regard to effective controls, the POLB commissioned this study of potential approaches available to the Port to reduce or eliminate hotelling emissions. The overall objective of the study is to provide the Long Beach Board of Harbor Commissioners with a summary of the technical feasibility, order-of-magnitude costs, potential emissions reductions, legal and institutional constraints and opportunities associated with each control strategy. The specific objectives of the study are:

- Assess opportunities and constraints associated with cold ironing and alternative emissions control measures;
- Identify vessel-side and land-side infrastructure requirements for cold ironing and other measures;
- Provide a conceptual cold ironing system design to estimate the cost of cold ironing;
- Evaluate the cost effectiveness of cold ironing and other emission control options; and
- Address potential labor, safety, legal and regulatory issues associated with the implementation of cold ironing and other control measures at the Port of Long Beach.

As of this writing, there is only one commercial cold ironing application of an appreciable size in actual operation (Section 3 of this report provides a more detailed analysis), and none of the other control technologies considered in this study are known to have been put into commercial operation. Accordingly, this study relies heavily upon reasonable assumptions and best professional judgments.

The first large-scale cruise vessel cold ironing installation in the world was in Juneau, Alaska, and, by the 2002 cruise season, five Princess Cruise vessels were using shore power when they docked in Juneau. This application serves the five Princess passenger vessels only; no cargo vessels use the facility. Princess spent approximately $5.5 million to construct the shore side facilities and to retrofit the vessels (about $500,000 each). Princess estimates the cost of the shore power (which is about a third the cost of power in Southern California) to be approximately $1,000 per vessel per day more than the cost of running the on-board diesel generators. No oceangoing commercial vessel cold ironing operations currently exist, although it is likely that in 2004 vessels operated by China Shipping will begin calling at Berth 100 in the Port of Los Angeles, where they will be required to use shore side electrical power.

The information gathered during this study including the recent vessel activity data from the Marine Exchange of Southern California, led to the selection of 12 vessels and associated berths at the Port of Long Beach for a detailed cost effectiveness study. The selected vessels (Table 1-2) represent a cross section of various vessel types, vessel ages, service routes, and Port call frequency, and provide useful surrogates for possible candidate vessels for cold ironing or other emission control strategies; their selection does not mean that those specific vessels should or should not be retrofitted.

Hotelling emissions were calculated based on the time at dock per call (hours), number of calls per year, generator load (kilowatts, denoted by the symbol kW), and the pollutant emissions factors of their auxiliaries (pounds per kilowatt-hour [lbs/kW-hr]). As Section 4 of this report shows, time at dock for the 12 study vessels ranged from 12 hours (Carnival's *Ecstasy*) to 121 hours (a large container vessel), calls per year ranged from 1 (a tramp bulk vessel) to 52 (*Ecstasy* for a partial year), and generator load from 300 kilowatts (a small coastal tanker) to 7,000 kilowatts (*Ecstasy*). This wide range of characteristics indicates the technical complexity of the hotelling emissions issue. Table 1-3 and Figure 1-2 show the results of the emissions calculations. These figures are the target of the various emissions control strategies and represent the theoretical maximum reduction that could be gained by eliminating all hotelling emissions from the study vessels.

Cost effectiveness estimates were calculated by developing conceptual designs for cold ironing installations at the various berths where the study vessels docked and for retrofitting the vessels to receive the shore side power, and by evaluating the application of the other emission control technologies considered to the study vessels. Conceptual designs for providing shore-side electrical power to the 12 study vessels (Section 5) included the needs and costs of upgrading Southern California Edison's (SCE) transmission and distribution infrastructure, constructing in-port and in-terminal facilities, retrofitting the vessels, and operating and maintaining the facilities. These figures were used to calculate the cost effectiveness of cold ironing (cost per ton of emissions reduction) for each study vessel. A similar approach was used to calculate the cost effectiveness of the other control technologies considered in this study. The cost effectiveness calculations utilized standard SCAQMD methodologies and were based on a number of assumptions (Section 6 of this report), the most important of which were:

- Existing vessels and berths are retrofitted for shore side power or exhaust control/clean diesel technologies; the analysis did not consider the case of new terminals or new vessels, both of which cases would be more cost-effective and would avoid some of the operational, safety, and engineering challenges of retrofitting;

- Electricity would be purchased from SCE at its current TOU-8 tariff, which makes no allowance for any alternative pricing structure that SCE might develop for cold ironing;

- The life of the project over which costs are accumulated and amortized is assumed to be 10 years and the service life of all vessels is assumed to be 15 years; and

- The costs associated with the loss of service of a berth or vessel while it is being retrofitted were not included because no reliable figures are available, but in the case of a berth those costs could be several million dollars per retrofit.

It should be noted that all costs used in this study were estimated based upon the information available at the time of this report, were not reviewed by the stakeholders (i.e., vessel and terminal operators and SCE), and reflect technical assumptions that may not be valid for specific applications. However, SCE did provide the estimates of purchased power cost.

Table 1-2. Selected Vessels and Berths in the Study

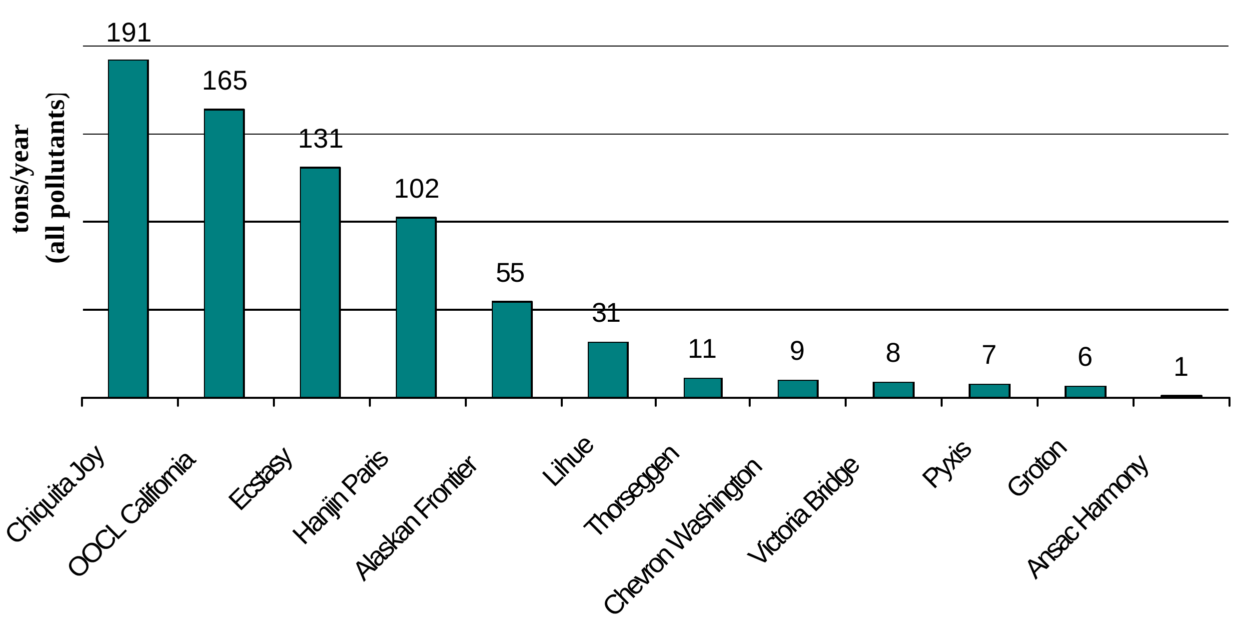
Vessel Type	Vessel Name	Vessel ID	Year Built	Vessel Operator	Usual Terminal & Berth	Terminal Operator	Average Berth Time (hrs/call)	Calls per Year
Container	*Victoria Bridge*	9184926	1998	K-Line	J232	International Transportation Services	44	10
Container	*Hanjin Paris*	9128128	1997	Hanjin	T136	Total Terminals	63	10
Container	*Lihue*	7105471	1971	Matson	C62	SSA Terminals	50	16
Container/ Reefer	*OOCL California*	9102289	1996	OOCL	F8	Long Beach Container Terminal	121	8
Reefer	*Chiquita Joy*	9038945	1994	Inchcape/WD	E24	California United Terminals	68	25
Cruise	*Ecstasy*	8711344	1991	Carnival	H4	Carnival	12	52
Tanker	*Alaskan Frontier*	NA	2004	Alaska Tanker	T121	ARCO Terminal Services Corp	33	15
Tanker	*Chevron Washington*	7391226	1976	Chevron Texaco	B84	Shell	32	16
Tanker	*Groton*	7901928	1982	BP	B78	ARCO Terminal Services Corp.	56	24
Dry Bulk	*Ansac Harmony*	9181508	1998	Transmarine	G212	Metropolitan Stevedore	60	1
RO-RO	*Pyxis*	8514083	1986	Toyofuji	B83	Toyota	17	9
Break Bulk	*Thorseggen*	8116063	1983	Seaspan Shipping	D54	Forest Terminals	48	21

To estimate the net hotelling emission shown in Table 1-3, this study accounted for air emissions associated with shore-based power generation (Section 6) using USEPA standard emission factors, associated with berthing time and engine load derived from survey data.

Table 1-3. Annual Hotelling Emissions

Vessel Name	Emission (tons/yr)					
	VOC	CO	NO_X	PM_{10}	SO_X	Combined
Victoria Bridge	0.0	0.7	3.8	0.43	3.5	8.4
Hanjin Paris	0.6	2.3	53.9	4.93	40.4	102
Lihue	0.1	0.4	4.1	3.64	22.8	31.1
OOCL California	0.7	13.7	73.5	8.36	68.4	165
Chiquita Joy	0.9	15.9	85.5	9.72	79.5	191
Ecstasy	0.8	2.9	69.3	6.34	51.9	131
Chevron Washington	0.1	0.1	7.4	0.29	1.5	9.4
Groton	0.1	0.6	4.3	0.10	0.4	5.5
Alaskan Frontier	0.4	1.4	25.3	2.98	24.4	54.5
Ansac Harmony	0.0	0.1	0.5	0.06	0.5	1.2
Pyxis	0.0	0.6	3.2	0.36	3.0	7.1
Thorseggen	0.1	1.6	8.6	0.15	0.6	11.0
Total	**3.9**	**40.3**	**340**	**37.4**	**297**	**718**

Figure 1-2. Annual Hotelling Emissions



Many emission control measures reduce only a single pollutant, such as nitrogen oxides (NO_x) or PM_{10}, but some reduce multiple combustion-generated pollutants. The cost effectiveness calculations considered the total quantity of criteria pollutant emission reductions, treating each pollutant as equally important. While there are varying health effects for each pollutant, there is no standard method for taking those differences into account in cost effectiveness evaluations. After estimating the cost of potential emission reductions, the total Net Present Value (NPV) of each control technology for each vessel was developed. Cost effectiveness was then calculated using the following formula. This formula has been used by SCAQMD in a multiple-pollutant rule development process.

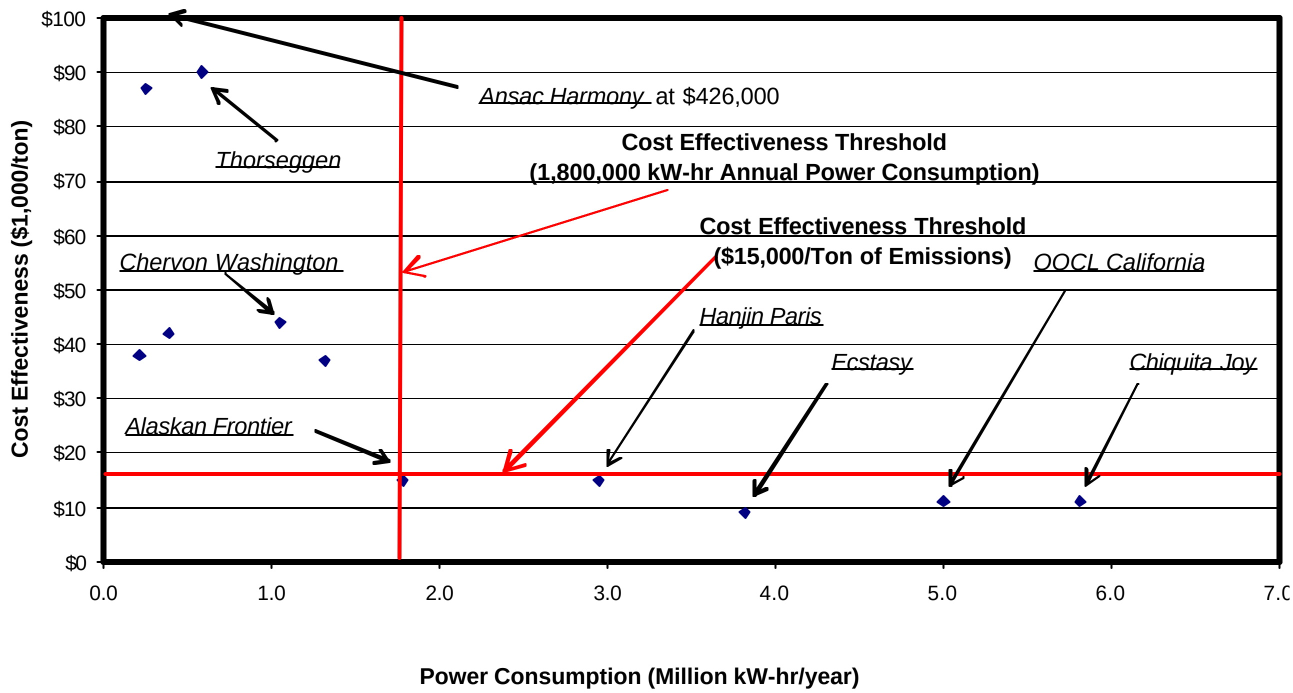
$$\textit{Cost Effectiveness} = \frac{\textit{Total Net Present Value (\$)}}{\textit{Total Emission Reduction of All Pollutants over the Project Life (tons)}}$$

This method provides cost effectiveness values in dollar per ton of reduction and a ranking among the 12 vessels. There is no broadly accepted method for calculating a cost effectiveness threshold for control measures for multiple pollutants. The cost effectiveness values for the 12 vessels evaluated in this study have a significant break as shown on Figure 1-3, where the most cost-effective vessels have values less than $15,000/ton, and the other vessels are far higher. This value is important because, for example, the SCAQMD Governing Board Policy for VOCs is not to adopt retrofit rules that cost more than $13,500/ton unless special analyses are done. Moreover, the Carl Moyer program has a threshold for NO_x emissions of $13,600/ton of NO_x for projects that use that funding mechanism. Based on the natural break that appears in the cold ironing values and the comparison with other cost effectiveness values and thresholds, the study selected $15,000/ton of total pollutant removed as the threshold for cost effectiveness.

Based on this cost effectiveness criterion, this study found that five of the 12 study vessels – the cruise ship *Ecstasy*, the refrigerator vessels *Chiquita Joy* and *OOCL California*, the container ship *Hanjin Paris*, and the tanker *Alaskan Frontier* – would be cost-effective candidates for shore-side electrification, or cold ironing (Figure 1-3). These vessels share the characteristics of high hotelling power demand, frequent port calls, and, except in the case of the cruise ship, significant time at berth per call. These factors combine to result in significant annual energy consumption (kW-hr) and, therefore, greater potential for emissions reductions. As Table 1-3 shows, cold ironing those five vessels would eliminate about 90 percent of the emissions generated by the twelve study vessels. The remaining seven vessels do not meet the cost effectiveness criterion of approximately $15,000 per ton of emissions reductions, primarily because of the combination of low power demand and fewer vessel calls.

Further, and upon close review of Figure 1-3, it becomes apparent that annual power consumption by a vessel at berth is the best single indicator of cost effectiveness. This analysis shows that cold ironing is generally cost effective as a retrofit when the annual power consumption is 1,800,000 kW-hr or more (Figure 1-3). Table 1-4 shows the vessel calls, power consumption, and cost effectiveness for the 12 study vessels. For a new vessel with cold ironing equipment installed calling at a terminal with cold ironing capability installed during the construction of the terminal, cold ironing would generally be cost–effective if the vessel's annual power consumption exceeds 1,500,000 kW-hrs.

Figure 1-3. Cost Effectiveness vs. Annual Power Consumption



Section 7 evaluates the feasibility and costs of other emission control technologies as alternatives to cold ironing in vessel auxiliary generators with for reducing vessel hotelling emissions. Some more advanced concepts for emission control were not investigated in this study such as fuel-cell technology, non-thermal plasma technology, NO_x adsorbers, lean NO_x catalyst, battery-electric technology, and flywheel technology. At this time, there is not enough information about these technologies to assess their feasibility for marine vessel hotelling applications.

Further, based on low emission reductions, the questionable state of currently available equipment, inadequate fuel availability, and other specific constraints to implementation, the technologies in Table 1-5 were not considered feasible near-term (i.e., within the next ten years) alternatives for the POLB. Of particular concern is the fact that several technologies only address NO_x emissions and several of those actually increase diesel particulate emissions, whereas the reduction of diesel particulates is a key goal of any POLB emissions reduction strategy. Another concern with

Table 1-4 – Vessel Calls, Power Consumption, and Cost Effectiveness

	Victoria Bridge	*Hanjin Paris*	*Lihue*	*OOCL California*	*Chiquita Joy*	*Ecstasy*	*Chevron Washington*	*Groton*	*Alaskan Frontier*	*Ansac Harmony*	*Pyxis*	*Thorseggen*
Total calls per year	10	10	16	8	25	52	16	24	15	1	9	21
Average Berth Time (hrs/call)	44	63	50	121	68	12	32	56	33	60	17	48
Average Power Demand at Berth (kW)	600	4,800	1,700	5,200	3,500	7,000	2,300	300	3,780	600	1,510	600
Total Annual Power Use (Million kW-hr)	0.3	3.0	1.3	5.0	5.8	3.8	1.1	0.4	1.8	0.0	0.2	0.6
Cost Effectiveness ($1,000/ton)	$87	$15	$37	$11	$11	$9	$44	$42	$15	$426	$38	$90
Ranking	10	5	6	3	2	1	9	8	4	12	7	11
Cost-Effective (Yes/No)	No	Yes	No	Yes	Yes	Yes	No	No	Yes	No	No	No

technologies outlined in Table 1-5 (on the following page) is the potential that most of the cleanest diesel fuels cannot be used safely (per the International Convention for the Safety of Life at Sea [SOLAS] regulations) in marine vessels because their flash points and viscosities are much lower than those of the heavy fuel oil for which modern auxiliary marine diesel engines and fuel systems are designed and calibrated. Accordingly, none of these technologies were considered cost-effective and practical for application at the Port of Long Beach at this time.

Finally, several technologies for reducing hotelling emissions as alternatives to cold ironing were identified for examination in this report. These technologies fell into five basic categories:

- Engine Repowering (replacing auxiliaries with cleaner diesel engines [EPA Tier 2 standards] or natural gas engines);

- Clean Diesel Fuel (marine gas oil, CARB #2 diesel, emulsified diesel, Fischer-Tropsch diesel, bio-diesel);

- Combustion Management (injection timing delay, direct water injection, humid air motor technology, exhaust gas recirculation);

- Exhaust Gas Treatment (diesel oxidation catalysts with CARB #2 diesel, diesel particulate filters with CARB #2 diesel, selective catalytic reduction); and

- Cryogenic Refrigerated Containers (to reduce the electrical demand of refrigerated containers).

Note that most of these technologies are ship-based: little or no landside infrastructure would be required, although some provision might need to be made for additional fueling facilities.

Table 1-5. Not Practical Near-term Alternatives for POLB

Technology	Facts Considered
Injection Timing Delay	Increases PM, CO and VOC emissions
Exhaust Gas Recirculation	May increases PM, VOC and CO emissions
Direct Water Injection	Only reduces NO_x emissions
Humid Air Motor	Only reduces NO_x emissions
Selective Catalytic Reduction	Only reduces NO_x emissions
Repowering with EPA Tier 2 Engine	Only reduces NO_x emissions
Fischer-Tropsch Diesel	No adequate fuel supply available; Difficulty to distribute to vessels
Bio-Diesel (B100)	Increases NO_x emissions; Difficulty to distribute to vessels
CARB No. 2 Diesel Fuel	Flash point too low to be allowable under the Safety of Life at Sea (SOLAS) regulations.
Diesel PM Trap with CA On-road #2 Diesel	Flash point too low to be allowable under SOLAS regulations; Fuel distribution to vessels; no marine application yet.
Diesel Oxidation Catalyst with CA On-road #2 Diesel	Flash point too low to be allowable under SOLAS regulations; Fuel distribution to vessels; no marine application yet.
Cryogenic Refrigerated Container	Has not reached large scale application yet

Table 1-6 lists those technologies that have demonstrated potential benefits for overall emission reductions and potential applicability to marine vessels.

Table 1-6. Potential Alternatives to POLB

Technology	Potential Implementation Constraints	Average Cost Effectiveness	Cost-Effective Vessels
MGO Diesel	Design and operation of engine; Separate fuel system and delivery infrastructure	\$4,000/ton (No NO_x reduction)	All Vessels except for *Groton, Thorseggen,* and *Chevron Washington)*
Repowering with NG/Dual Fuel Engine	Safety concerns; fuel distribution system, separate on-board fuel system; in-use compliance if dual fueled engine	\$9,000/ton	All Vessels except for *Ansac Harmony*
Emulsified Diesel Fuel	Includes effectiveness of MGO use; Fuel distribution to vessels; design and operation of engine; separate fuel system; in-use compliance; loss of power; fuel phase separation.	\$42,000/ton	Seven Vessels (except *Groton, Ansac Harmony, Pyxis, Thorseggen,* and *Chevron Washington)*

However, they should not be considered readily available alternatives at this time until the identified implementation constraints are adequately addressed. A number of implementation issues would need to be investigated more thoroughly than the scope of this study permitted including safety, on-board fuel system and engine capabilities, and proven demonstrations on large vessels.

Several of the technologies have been demonstrated to reduce emissions and have potential feasible application to marine vessels (Table 1-6 above) although, as mentioned above, none (with the exception of low sulfur marine gas oil (MGO)) has actually been widely, if ever, applied to international cargo vessels. The use of other fuel types (natural gas, on-road diesel, and emulsified diesel) could have unforeseen issues with safety (most especially volatility and flammability), operation (such as fuel filter plugging, fuel pump or injector leakage, or compatibility with other marine fuels), and practical considerations including the construction cost and space limitations of maintaining separate fueling systems. After treatment devices, such as oxidation catalysts or especially particulate (PM) traps, have taken years of development to produce viable retrofits for use with on-road diesel engines, so application onto marine engines is likely to reveal additional implementation considerations.

There are many additional issues generally outside of the scope of this study that require more investigation, including safety of fuels and hardware, practical considerations of the size and cost of new and/or additional engines and fuel systems, compatibility of fuels and engines, and other issues that may be discovered only during the implementation of these alternative methods. In most cases, the measures reviewed below have not been widely, if at all, employed on large commercial vessels. Some of the more important of the issues are discussed below:

According to the ISO standards 8217 and 2719, marine fuel must have a flashpoint of a minimum of 60^{o} C. According to SOLAS Chapter 11-2, part B, Regulation 4, no fuel oil with a flashpoint of less than $60^{o}C$ shall be used. The flashpoint of MGO fuel is between $57^{o}C$ and $69^{o}C$. This fuel should only be used if the flash point of the specific fuel is above $60^{o}C$. California on-road diesel No. 2 has a flash point less than $60^{o}C$, and so this measure along with other exhaust treatment devices such as diesel oxidation catalysts and diesel particulate filters that rely on this fuel were eliminated for safety reasons.

Other fuel switching alternatives have significant costs and uncertainties related to the availability of the fuel, the distribution systems for the fuel, on-board storage of the fuel, and the modifications required to burn the fuel in engines designed for other fuels. Another concern is related to the fact that some fuels are not broadly available, so that the vessels would have to incur additional costs to switch back and forth from the conventional fuels to the alternatives. The study did not evaluate the cost of making that switch.

Many regulatory, logistical, and labor relations issues could affect implementation of cold ironing. These are discussed in Section 8. There is no regulatory agency with the clear authority to require cold ironing or any of the alternative control measures discussed in this report.

All these possible control techniques have significant regulatory, legal, and logistical hurdles to overcome, particularly if the SCAQMD or other local agency wishes to mandate their use. Given such constraints, a voluntary program, or an incentive program may be the most productive means of reducing emissions from hotelling in the Port of Long Beach.