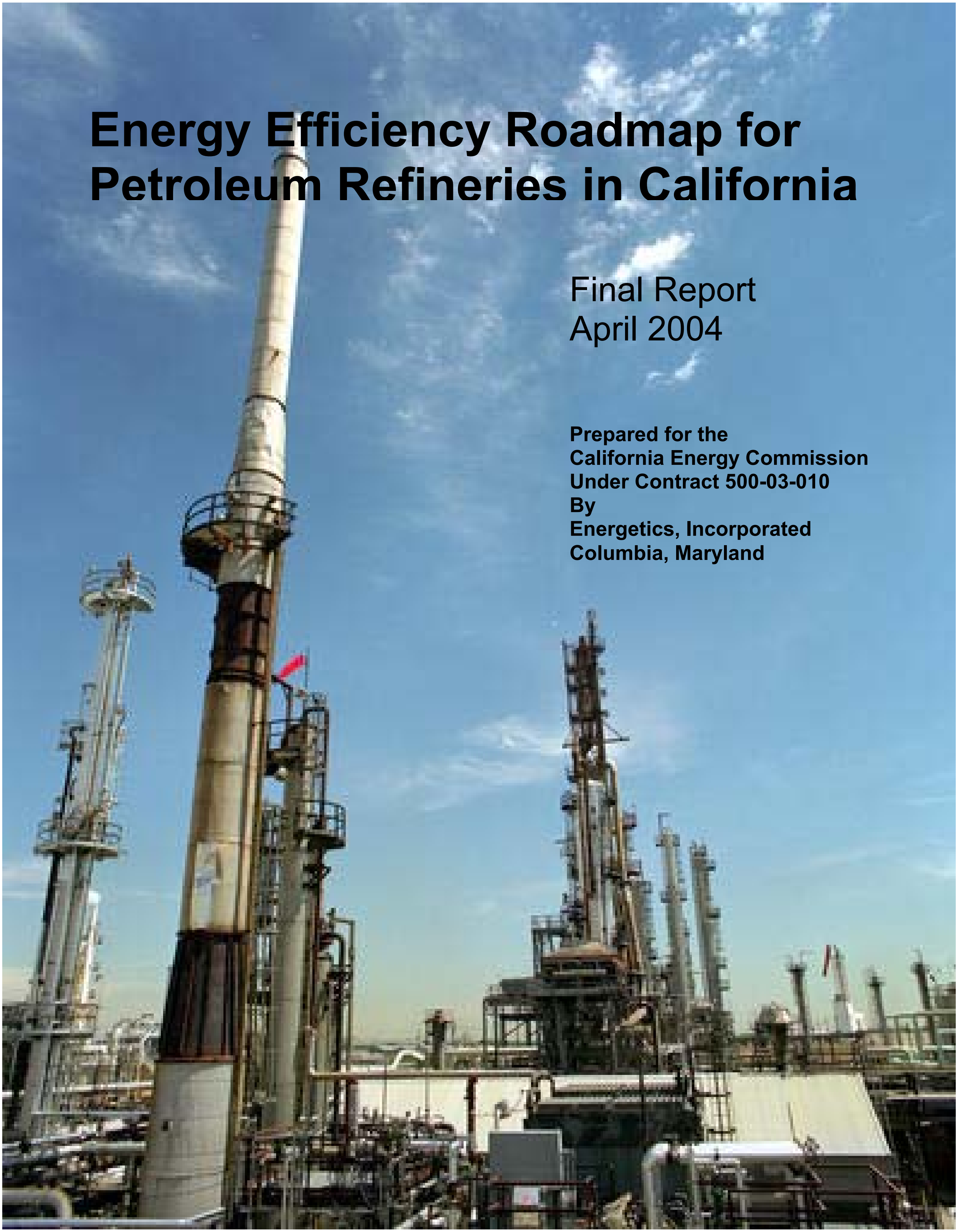
Energy Efficiency Roadmap for Petroleum Refineries in California

Final Report
April 2004

**Prepared for the
California Energy Commission
Under Contract 500-03-010
By
Energetics, Incorporated
Columbia, Maryland**



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DRAFT

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Legal Notice

Acknowledgments

This report reflects the inputs of participants from California refineries, industry trade associations, and California gas and electric utilities. The authors gratefully acknowledge the contributions of representatives from the following organizations:

California refineries:

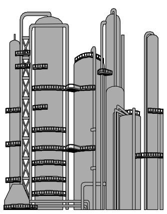
- BP West Coast Products
- ConocoPhillips
- ChevronTexaco
- ExxonMobil
- Kern Oil and Refining Company
- Paramount Petroleum Corporation
- San Joaquin Refining Company, Inc.
- Shell Oil Products U.S.
- Tesoro Petroleum
- Valero

Industry trade associations:

- American Petroleum Institute
- Western States Petroleum Association

California utilities:

- Pacific Gas and Electric
- Los Angeles Department of Water and Power
- South California Edison
- Southern California Gas Company



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Preface

The Public Interest Energy Research (PIER) Program supports public interest research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

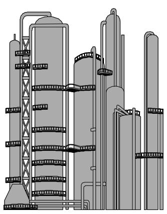
The PIER Program, managed by the California Energy Commission (Commission), annually awards up to $62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Strategic Energy Research.

What follow is the final report entitled "Energy Efficiency Roadmap for Petroleum Refineries in California"; Contract No. 500-03-010, conducted by Energetics, Incorporated, of Columbia, Maryland. This project contributes to the Industrial/Agricultural/Water End-Use Energy Efficiency program.

For more information on the PIER Program, please visit the Commission's Web site at: http://www.energy.ca.gov/research/index.html or contact the Commission's Publication Unit at 916-654-5200.



Executive Summary

Introduction

Petroleum refineries are the largest users of natural gas and electricity in the State of California. In addition to a high level of energy consumption, the industry is a major contributor to the productivity and employment of California, employing about 13,000 people and contributing 6% of the State's total value of shipments.

In light of the energy and economic value of the refining industry to the State, the California Energy Commission (Energy Commission) sponsored a workshop in January 2004 in Los Angeles, California to discuss the energy challenges facing California petroleum refineries. The goal of the workshop was to solicit input for a technology roadmap that would define the R&D needed to improve energy efficiency and help refineries meet future energy demand. Emphasis was placed on identifying the drivers, barriers and challenges to optimizing energy use, and understanding the technological R&D activities that would lead to improvements in energy efficiency.

Participants in the workshop included representatives from petroleum refineries, industry trade associations, utilities, and State and Federal government. About 80% of the refinery population in California (by volume production) was represented. This technology roadmap summarizes the results of the workshop, and outlines the priority R&D areas identified by California petroleum refineries. These priorities will be used to help guide decisions about the future RD&D efforts supported by the Energy Commission.

Energy Goals and Strategies

Exhibit E-1. Energy Goals and Strategies

- ***Stable, available energy supplies*** **–** lower cost power, innovative refinery-utility partnerships, selection of most efficient resources.
- ***Innovative energy resources*** – coke gasification, hydrogen, fuel cells, onsite gases, alternate energy.
- ***Development, demonstration, and adoption of energy efficient technologies*** – capital-efficient energy reduction, technology validation, leveraged resources for efficiency projects.
- ***Improved energy information and communication*** – central energy information, database for communication between refineries and energy specialists, access to proven efficiency projects.

California refiners identified a range of energy goals and the strategies that could be undertaken to help achieve those goals (see Exhibit E-1 and main report Exhibit 3). Overall, meeting energy demand at refineries in the future will need to be accomplished through a combination of better technology, alternative fuels and energy sources, and dissemination of information and training on how to improve energy use. The primary objective is a stable, reliable, energy supply.

As shown in Exhibit E-1, the goals are linked with strategies that encompass technology R&D and demonstration, finance, innovative partnerships, information dissemination, and other aspects.

Drivers, Barriers, and Challenges

Key drivers, barriers, and challenges for California refiners are summarized in Exhibit E-2 (and main report Exhibit 4). While there could be significant benefits obtained through development and deployment of more efficient technology, onsite power generation, and use of onsite-produced waste waste fuels, permitting and regulations constitute a significant roadblock. The current investment climate, along with the price volatility of fuels, also contributes to a perceived higher investment risk.

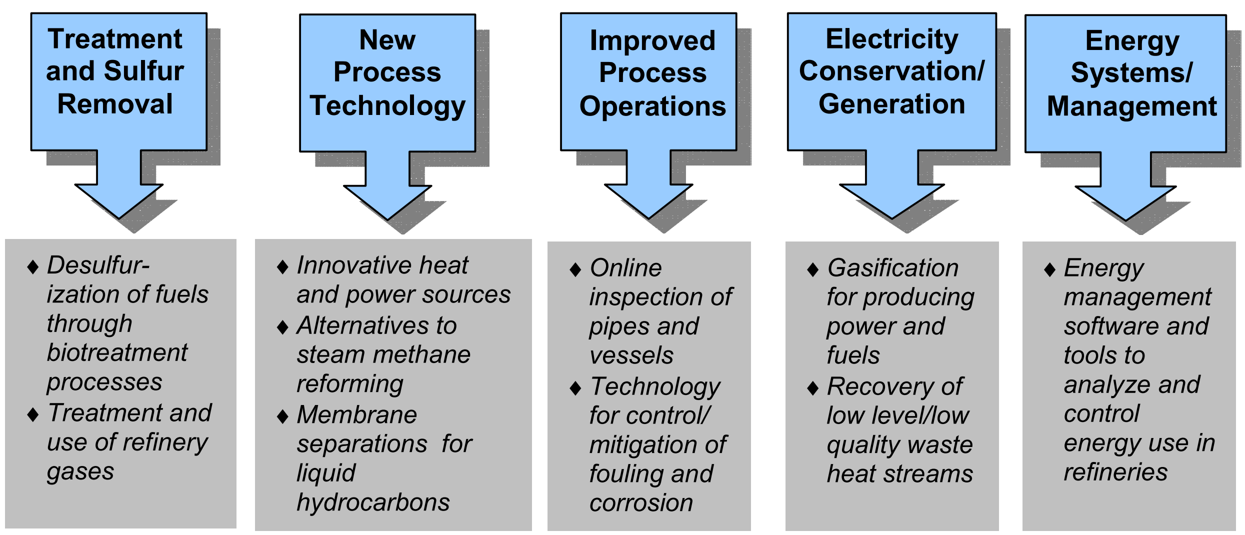
Exhibit E-2. Key Drivers, Barriers and Challenges

- ***Innovative energy sources*** – difficulty in using energy sources such as refinery gas, coke, and waste heat.
- ***Technology development and deployment*** – Lack of standards and proven reliability for new technology; and processing limitations.
- ***Permitting and regulation*** – fragmented, difficult, and lengthy permitting process; trade-offs between regulation and efficiency; and regulatory disincentives.
- ***Cogeneration*** – permitting issues, long payback, increased risk due to fuel uncertainty, regulatory disincentives.
- ***Power supply*** – power quality, outdated power protection, more demanding quality and reliability requirements.
- ***Plant investment*** – lack of capital, high up-front costs for efficiency projects, difficulty justifying efficiency projects.

Technology Research, Development and Demonstration (RD&D)

The top priority R&D areas identified by California refineries are shown in Exhibit E-3 (and main report Exhibits 5-10). Some of the highest priorities were identified in treatment and sulfur removal, driven by increasingly stringent fuel formulations and decreasing crude quality. Developing viable alternative energy sources such as gasification and onsite fuels, and innovative processing methods to replace or supplement traditional distillation and steam reforming processes, were also identified as top priorities. In operations and maintenance, improved inspection technology and ways to reduce fouling and corrosion were deemed top priorities with the potential for significant energy impacts.

Figure E-3 Top Priority Research and Development Areas



Conclusion

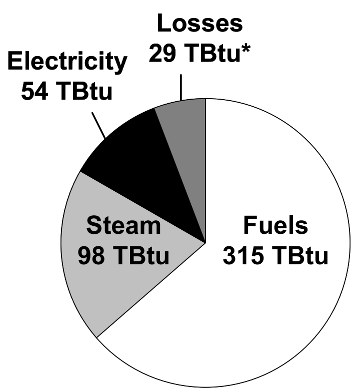
California refineries must balance competing goals for profitability, energy efficiency, and environmental compliance with increased demand for products and energy supply and price volatility. A key challenge is ensuring that electricity and fuel requirements are cost-effectively met in the future. A combination of technology RD&D, alternative energy sources, efficiency improvements, and onsite generation will be needed to meet future energy demands. Successful optimization of energy resources could reduce operating costs, enhance ability to meet environmental regulations, and augment productivity. Innovative partnerships between refineries, utilities, non-utilities, and the Energy Commission could play a key role.

Introduction

The California Energy Commission (hereafter, Energy Commission) is currently participating in the Industries of the Future (IOF) initiative supported by the U.S. Department of Energy (DOE), Industrial Technologies Program (ITP). The IOF initiative promotes the development and deployment of energy efficient, environmentally sound technologies in U.S. industries. The primary focus of the IOF is the basic industries – aluminum, chemicals, petroleum refining, glass, steel, forest products, metal casting, and mining.

The State Industries of the Future (SIOF) program serves to extend the national IOF strategies to the local and regional level, and to expand technology opportunities to a larger number of partners. State programs bring together various stakeholders to address the challenges that are unique to individual states and regions.

The Energy Commission has the lead for the SIOF effort in California, and is focusing on the industries that are most energy intensive, including petroleum refining, chemical processing, food processing, and electronics. The strategy is to develop technology roadmaps for research and development (R&D) that will lead to increased energy efficiency and the use of more environmentally benign technology in the State of California.



*Losses associated with onsite energy generation

Exhibit 1. Distribution of Energy Use in California Refineries (Worrell 2001)

Petroleum refineries represent the largest industrial users of natural gas and electricity in California as well as the United States. A recent study estimated that refineries in California consumed nearly 500 trillion Btus of energy in 2001 (Worrell, 2003), with over 67% in the form of natural gas or other fuels (see Exhibit 1). In addition to high energy consumption, the industry is a major contributor to the productivity and employment of California and the U.S. economy. The petroleum refining industry in California employs almost 13,000 people and accounts for 6% of the total value of shipments from the state. In addition, California refineries account for more than 11% of the value of shipments and about 13% of the workforce of the entire domestic petroleum refining industry.

In light of the considerable energy and economic value represented by refineries, the Energy Commission conducted a workshop in Los Angeles, California in January 2004 to provide input for a technology roadmap that outlines the R&D and other activities needed to address the energy challenges faced by California petroleum refineries. Representatives from California refineries were asked to provide input and help build consensus for the technology roadmap effort. The goal was to develop information that would reflect the views of at least 80 percent of California refineries (by volume production). The participating refineries and associated production capacities are shown in Exhibit 2.

California refiners were asked to provide their views concerning current and future energy challenges by responding to a series of topical questions, including:

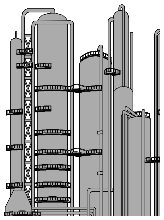
- What are the current goals and corresponding strategies that should be undertaken to ensure the availability of cost-effective, reliable energy resource source of energy for California refineries, and to minimize industrial demand for both electricity and natural gas?
- What are the drivers, barriers and challenges (technical or otherwise) to reducing energy demand in California refineries?
- What technological research and development (R&D) activities should be undertaken to improve energy utilization in California refineries and ensure the availability of energy supplies? What demonstrations are needed to promote the use of more efficient energy technologies?

The *Energy Efficiency Roadmap for Petroleum Refineries in California* is based on the results of the January 2004 workshop. The following sections of the report summarize the top priority R&D needs identified by California refineries, as well as some of the current regulatory and policy issues. These provide a good overall perspective of the current energy situation facing California refiners, and some of the components that could serve to improve conditions in the future. It is hoped that the *Energy Efficiency Roadmap* can be utilized by the Energy Commission as a useful tool for guiding decisions regarding future RD&D.

Exhibit 2. Participating Refineries

Refinery/Location	Production Capacity (barrels/calendar day)
BP West Coast Products	
Los Angeles	260,000
ChevronTexaco	
El Segundo	260,000
Richmond	225,000
ConocoPhillips	
Wilmington	137,000
ExxonMobil	
Torrance	149,000
Kern Oil and Refining Company	
Bakersfield	25,000
Paramount Petroleum Corporation	
Paramount	50,000
San Joaquin Refining Company, Inc.	
Bakersfield	24,300
Shell Oil Products, U.S.	
Wilmington	98,500
Tesoro Refining	
Martinez	166,000
Valero	
Benecia	180,000
Total Operating Capacity Represented	**1,574,800**
Total CA Operating Capacity	**1,989,807**
% of CA Represented	**79.1%**

Source: EIA 2003



Energy Goals and Strategies

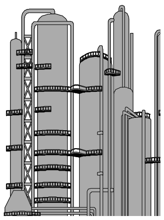
The overarching energy goals identified by California refineries and potential strategies for reaching those goals are shown in Exhibit 3. On the energy supply side, ensuring the availability of a reliable, stable energy supply is a goal that could potentially be met by increasing flexibility in the selection of energy resources and establishing more productive partnerships with energy suppliers. Taking advantage of innovative energy resources such as coke-based synthesis gas, fuel cells, hydrogen and fuels produced from biomass or landfills would increase the energy options available to refiners and enhance energy stability.

From an energy efficiency or conservation standpoint, implementation of more efficient technologies is a key goal. Strategies for meeting this goal include the use of government dollars to accelerate technology development and use (R&D, demonstration, other cost-sharing), and making sure government understands industry needs and where technology will have the most impact.

Improving the flow of information about new, more efficient technology, and developing data that will make the case for adoption of technology is an important goal and critical to reducing future energy demand in refineries. For example, case studies of successfully implemented efficiency projects could be used to make a convincing case for investments in more efficient equipment.

Exhibit 3. Energy Goals and Strategies

Goals	Strategies
Stable, Available Energy Supplies	• Eliminate the barriers to selecting the most efficient energy resource (dynamic energy supply – energy environment is changing daily, sometimes hourly). • Reduce the cost of power in California. • Develop more innovative partnerships between utilities and refineries to maximize overall electrical and fuel supply system; create more efficient business arrangements while serving the needs of both refineries and the public. • Take better advantage of the large heat sink that refineries represent (co-location).
Innovative Energy Resources	• Build coke gasification plants in northern and southern California. • Clarify the role of refineries in fuel cells and the hydrogen economy. • Make stationary fuel cells and alternate energy sources available at refinery sites. • Take advantage of gas expansion in refineries (e.g., to generate power). • Create innovative energy partnerships with non-utilities (e.g., landfill gas usage).
Development, Demonstration and Adoption of Energy Efficient Technologies	• Identify the most capital-efficient energy reduction opportunities; use government dollars to offset capital limits (without strings attached). • Undertake the energy efficiency projects that have been identified. • Provide feedback to the Energy Commission regarding which technologies need demonstration and validation for California refineries. • Let Government serve as the connection between venture capitalists and technology innovators for energy efficiency. • Move standards from lowest common denominator to encourage adoption of newer, more efficient technologies.
Improved Energy Information and Communication	• Create a central information source for low-capital technology vendor options, including past use information. • Establish a database of refineries and energy specialists to form communication lines; work together to avoid vendor bias; create 5-page case studies of successful implementation of efficient technology (i.e., “what it took”). • Enhance access to available information on improving efficiency; feedback is needed on what information is most valuable.



Drivers, Barriers and Challenges

There are a number of drivers, barriers and challenges facing California refiners now and in the future. These fall into the major categories of innovative energy sources, technology development and deployment, permitting and regulation, cogeneration, power supply, and plant investment (see discussion below and Exhibit 4).

Innovative Energy Sources

Fuel flexibility would improve the energy options available to refiners. Advances in technology are needed to ensure that fuel flexibility and processing goals are not at odds. There are also many technical challenges to using refinery gas and coke instead of other fuels. For example, current technology is inadequate for cost-effectively cleaning some refinery off-gases so they can be used to displace natural gas during periods of high prices. Significant energy is required to remove the last few parts per million (ppms) of contaminants, and more efficient technology is needed to accomplish clean-up.

Improvements are also needed for coke and asphalt gasification to utilize these byproducts as fuels (e.g., produce liquid fuels that are sulfur-free), with cleanup of gasification streams constituting a major issue. Technology is also lacking for the economic and efficient use of some excess energy resources, especially low grade waste heat generated in the plant.

Technology Development and Deployment

Deployment of energy efficient technology is sometimes inhibited by lack of proven reliability. For example, plant owners may not be convinced that high-efficiency motors are sufficiently reliable. Variable speed drives are in use at some refineries, particularly those that have upgraded their infrastructure. However, some new motors and variable speed drives have not proven to be reliable, leading to lost opportunities for improving efficiency. Another issue is the limited availability of updated codes and standards for new technologies, which increases the risk of deployment.

More efficient technology can make a significant impact on energy use and plant profitability, especially when fuel prices are high. There are many technologies on the shelf (commercially available) that were not considered before, but should be re-evaluated in light of higher gas prices. In some cases, innovation may be required. Better catalysts for hydrogen plants, for example, could make refineries more responsive to natural gas price peaks.

Permitting and Regulation

California refineries are being squeezed by rising demand, increasing regulations, and difficulties in obtaining permitting. Permitting is fragmented and non-uniform across the State, which creates uncertainty in the permitting process and adds complexity to new energy projects. The length of time required for permitting affects the economics and ability of companies to take on some energy efficiency projects. The lack of a broader view behind permitting in California makes it difficult for refiners to take advantage of opportunities to export excess energy (e.g., electricity) back to the local grid. This impacts their propensity to add new, more efficient onsite generation facilities.

Regulations are costly to comply with and often provide disincentives to energy efficiency. New Source Performance Standards, for example, are a disincentive to putting in new, efficient equipment versus rebuilding or retrofitting of old equipment. If a refiner builds and installs new equipment, regulations dictate the use of natural gas, which eliminates the possibility of using inexpensive, readily available waste gases. NOX reduction efforts may reduce heater efficiencies because equipment is already working at technology limits, with the end result of increasing energy use.

Regulations put pressure on refineries to make cleaner fuels such as low sulfur diesel (which requires higher processing energy and results in greater plant emissions) and simultaneously reduce plant emissions. As a result, refiners are faced with a difficult balance between environmental and energy regulations. Refineries are too often faced with trying to survive economically while regulations surpass technical capabilities.

Exhibit 4. Drivers, Barriers and Challenges

Innovative Energy Sources	Technology Development & Deployment	Permitting & Regulation	Cogeneration	Power Supply	Plant Investment
Technical challenges to using refinery gas and coke versus other fuels Inadequate technology for efficient use of excess energy, especially low grade waste heat Conflicts between fuel flexibility and processing goals	Lack of updated codes and standards for new technologies Variable reliability of high-efficiency motors Catalytic limitations in hydrogen plants and impacts on natural gas demand Commercial technologies not fully evaluated for energy savings potential due to previously low fuel costs	Fragmented, non-uniform permitting Time required for permitting Disincentives of New Source Performance Standards Trade-off between NOX reduction and heater efficiencies Regulations based on technical targets vs. specific additives Balancing regulations for cleaner fuels and plant energy emissions Constantly changing regulations Regulations dictating use of natural gas vs. plant waste gases Inadequate understanding of refineries by regulators	Significant permitting issues for new cogeneration facilities Long payback and increased risk due to fuel price uncertainty Constantly changing (and hostile) regulations in California toward generation of electricity onsite Regulations preventing plants from being "good neighbors" and providing excess power to the community Higher energy costs creating a push toward cogeneration Refineries approaching maximum cogeneration capacity	Power interruptions/ bumps Inadequate, outdated power protection systems in refineries Standardized reaction at utility to voltage dips More demanding electricity quality and reliability requirements of new technology Variability of energy use and availability Response of refineries to peaks	Lack of capital for installation of new equipment High up front cost for efficiency projects (capital, permitting) and long paybacks No means of communicating the economic and resource value associated with refinery energy efficiency Justifying energy conservation projects with uncertain fuel situation

Cogeneration

Cogeneration (production of electricity and steam) has many energy advantages. Cogeneration has higher thermal efficiency, can provide excess electricity to the local grid, and could be beneficial to both California rate payers and refineries. However, cogeneration technology has a long payback and fuel price uncertainty increases the risk. Fuel flexible cogeneration could help to avoid gas price peaks and reduce risk.

Despite the benefits, permitting and regulation continue to limit the use of cogeneration. Cogeneration facilities are difficult to build in California due to constantly changing (and perceived hostile) regulations toward generation of electricity onsite. While plants in suburban settings would like to take "good neighbor" actions and provide excess power to the community, regulations prevent this. On the other hand, refiners continue to explore cogeneration as an energy option in California due to high energy costs, and because utilities are not permitted to enter partnerships. Wildly fluctuating natural gas prices are also driving a desire to use alternative fuels in cogeneration, but significant permitting issues remain. In some cases, refineries are reaching their maximum capacity for use of cogeneration, particularly when it is difficult to transport excess energy offsite.

Power Supply

Power interruptions and bumps are deadly to refineries, and utilities could explore new technologies to mitigate bumps, perhaps using a coordinated, state-wide approach. Coordination among utilities and refineries to minimize bumps could be an effective approach (e.g., have preliminary discussions before bringing a 10,000 hp motor on-line). Power protection systems in refineries are often old and inadequate to meet the power requirements of new technology. Utilities and refineries can work together to identify and address these issues. In addition, the standardized reaction of the utility to voltage dips does not always benefit the industry.

New technologies have more demanding electricity quality and reliability requirements, and require more electrical reliability and economics. The variability of electricity use eventually impacts utility rates and the capability to ensure energy is available during peak periods.

Plant Investment

There is generally a lack of capital for installation of new equipment in California refineries. Exacerbating the problem is that the up front cost for efficiency projects is typically prohibitively high (capital, permitting, delays). These projects often have longer paybacks and can be stalled or killed by the difficult regulatory and permitting process. In justifying the investment, it is difficult to gain the full value for energy saved due to fuel imbalances, the cost of meeting regulations, and utility constraints.

Energy conservation projects overall are often hard to justify because of the uncertainty in fuel price and supply. It is also difficult to demonstrate and quantify the real economic and resource value of improving energy efficiency in refineries, in order to justify such projects to corporate, State government, or other decision-makers. Under the current investment climate, funds for such projects must also compete with investments for environmental compliance or product-related research with a more transparent return on investment. Utilities have some funds available for energy efficiency projects, but indicate that these would need to be leveraged by refinery cost-sharing, and that refineries would need to make the technology available.

Technology Research, Development and Demonstration

Technology R&D

R&D needs were identified in five major areas: treatment and sulfur removal, process improvements, electricity conservation and generation, energy systems and energy management, and new process technology. A prioritized summary of R&D needs is shown in Exhibit 5. From the prioritization of ideas emerged a group of 'top ten' research topics that were of interest to California refineries. The technical elements of these 'top ten' research topics are illustrated in Exhibits 6-10.

Exhibit 5. Technology Research and Development Needs

Refinery Priority = ● Other Participant Priority = ◘

Treatment and Sulfur Removal	Process Improvements	Electricity Conservation/ Generation	Energy Systems/ Energy Management	New Process Technology
Gas treatment technology to enable use of plant gas instead of natural gas ●●●●●●◘◘◘ Desulfurization of fuels via biotreatment to eliminate hydrotreatment ●●●●●● Alternative fuel processing technology to meet future low sulfur fuel requirements ● More efficient low capital and operating cost process to remove sulfur and ammonia ● Technology to mitigate fuel gas corrosion and trap oxygen during fuel gas processing ● Characterization of crude oils with respect to sulfur compounds	Advanced technologies for online inspection of pressure vessels and piping ●●●●◘ Reduce corrosion and fouling in cooling water systems, particularly in higher load areas; better understand heat exchanger fouling ● ●●◘◘ More activity from existing reactors (e.g., better catalysts) for diesel treating and hydrocracking ● Air preheat technology demonstration in California without increasing NOX ● Improved desalting technology (e.g., examine upstream factors that impact desalter performance) Less energy-intensive, more reliable flare/purge gas recovery systems	Use gasification gas for electrification or gas-to-liquids projects ●●●●●◘◘◘ Efficient recovery of low-level heat for useful electrical or thermal energy ●●● Combine coke gasification with municipal waste disposal ●● Lower-cost, smaller scale cogeneration systems ● Capture low grade waste heat with industrial heat pumps or adsorption chillers ◘◘	Software to help end-users understand where energy is used ●◘◘◘ Energy management systems specific to refineries ●◘◘ Hydrocarbon properties available in an easy-to-use format ● Monitors for NOX, O2 to control fuel streams to heaters and optimize efficiency ◘◘ Smart systems to optimize electrical applications and reliability Reliable steam traps (not incremental improvements	Innovative ways to supply heat/power to unit operations to reduce losses (e.g., microturbines) ●●●◘◘◘ Alternatives to steam-methane reforming for hydrogen production (e.g., recovering hydrogen from hydrogen sulfide and ammonia) ●●●●●●●◘ Membrane separations for propane/butane as alternative to distillation ●●● Better technology to cut coke, remove coke from coke drum ◘ Microwaves for heating feed streams to towers ◘ Advanced distillation processes

Some of the highest priorities identified were in the area of **treatment and sulfur removal** (see Exhibit 6). With increasingly stringent fuel formulation requirements on the horizon, and the decreasing quality of crude, cost-effective treatment and upgrading of refinery streams is becoming even more critical. Research is needed to explore new technologies such as biodesulfurization of fuels and treatment of refinery waste gases to upgrade fuels and remove fouling components. Waste gas clean-up, for example, will be critical to greater utilization of byproduct fuels as an inexpensive energy source.

Research to develop **new process technology** (see Exhibit 7) is another high priority. Innovative or alternative ways of integrating energy-intensive operations in the refinery with energy sources could optimize energy use and improve control of processes. Another priority is the development of advanced technologies that represent alternatives to current processes that are energy-intensive. This might include technologies to replace distillation, which is used throughout the refinery, and steam reforming of methane for hydrogen production. Both are large energy consumers and relatively inefficient. New technologies for recovering hydrogen from refinery gases such as hydrogen sulfide and ammonia could provide alternative sources of hydrogen.

The development of **energy management** (see Exhibit 8) tools was identified as a priority for enabling energy optimization and control in refineries. Effective tools could provide real-time analysis of refinery data and relay information on energy sources and sinks within the plant. Beta testing of software and models for improving energy efficiency was also identified as a potential area for future demonstrations.

A priority issue for **improved process operations** (see Exhibit 9) is the ability to monitor the condition of pipes, vessels, and other equipment. On-line inspection technology is needed to reduce failures, improve productivity and run times, and reduce energy use associated with maintenance, shut downs and startups. Another priority is the mitigation and control of corrosion and fouling in plant equipment. Better understanding of fouling mechanisms is a key component.

Priority topics identified in **electricity conservation and generation** (see Exhibit 10) would broaden the energy options available to refineries and increase fuel flexibility. Gasification of refinery byproducts such as coke or residuals could provide fuels to run turbines and process equipment, and also be a source of hydrogen. Low level waste heat is a large source of energy that could be recovered with the right technology and used productively in the plant for thermal or electrical energy. While some technology exists, innovative working fluids and new heat exchanger designs may be needed.

Technology Demonstration

Demonstration and validation is an important element in fostering industry adoption of new technology. For energy efficiency projects, input should be obtained from industry on a project-by-project basis to assess the level of interest in specific technology demonstrations. Soliciting refinery interest at the front end will provide the Energy Commission with a clear understanding of the value of the demonstration to other refineries in the State.

The Energy Commission and refiners should devise innovative ways to work together on demonstrations. The Energy Commission, for example, could provide equipment instead of cash or loans. Another approach is to support collaborations for technology sharing (e.g., vendors working with end users to validate technology). Beta testing of new energy management software is a potential demonstration activity that could yield benefits for refineries with little investment required.

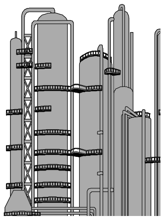


Exhibit 6. Priority Research Areas
Treatment and Sulfur Removal

Desulfurization of Fuels Via Biotreatment

The goal is replacing conventional hydrotreatment with a less energy-intensive biotreament process for desulfurization of fuels. Biotreatment requires less severe operating conditions (lower pressure and temperature), which results in a reduction in energy use and associated emissions.

Key Technical Elements

- Resilient to process upsets and varied conditions (reliability)
- Capable of handling necessary fuel flow rates
- Successful resolution of scale-up issues
- H_2S handling capability

Risk

LOW — HIGH

Technical Risk

Requires considerable R&D, basic science and applied.

Commercial Risk

New technology, not demonstrated, trade-off between energy and O&M costs not known.

Potential Partnerships

Universities
Biotechnology companies specializing in biotreatment
Refining industry
Federal – funding for university and national laboratory R&D

Benefits to Industry

LOW — HIGH

Energy

Potential to Reduce Electric Demand

Potential to Reduce Natural Gas Demand

Production Cost Benefits

Productivity/Yield Improvements

Environment/Regulatory

Time Frame for Results:
Long Term (more than 10 years)

Treatment and Use of Refinery Plant Gas

Technology is needed to treat plant fuel gas to remove fouling components (SO_2, moisture) so it can be used to replace natural gas in turbines and other equipment without causing performance problems or additional emissions.

Key Technical Elements

- Capable of meeting equipment feed requirements (e.g., turbines, gas engines, hydrogen plant feed, tank blanketing)
- Disposal requirements must be adequately addressed
- Constituents of concern: H_2, O_2, S (not H_2S), water, combustion characteristics (olefins, H_2, Btu variability)

Risk

LOW — HIGH

Technical Risk

Requires considerable R&D, multi-disciplinary topics

Commercial Risk

New technology, not demonstrated

Potential Partnerships

Suppliers of equipment utilizing the gas (turbine manufacturers)
Suppliers of process equipment
Refining industry
AQMD

Benefits to Industry

LOW — HIGH

Energy

Potential to Reduce Electric Demand

Potential to Reduce Natural Gas Demand

Production Cost Benefits

Productivity/Yield Improvements

Environment/Regulatory

Time Frame for Results:
Mid Term (3 years)

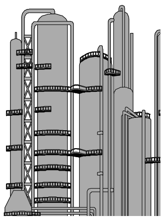


Exhibit 7. Priority Research Areas New Process Technology

Innovative Heat and Power Sources

Innovative ways of supplying heat and power to refining unit operations are possible through more effective integration of units operations with utility systems. In addition to energy savings, heat integration analysis will provide an energy footprint and improve process control.

Key Technical Elements

- Heat integration analysis
- Heat recovery and heat pumping
- Total system design /development: up-front connection of unit operations to utilities
- Entropic analysis versus enthalpic analysis

Risk

LOW HIGH

Technical Risk

Moderate R&D required.

Commercial Risk

Low to moderate capital investment

Potential Partnerships

Equipment vendors
Gas turbine/engine manufacturers
Electric and gas utilities
Process technology developers/ designers
U.S. DOE
National laboratories
Energy Commission

Benefits to Industry

LOW HIGH

Energy

Potential to Reduce Electric Demand

Potential to Reduce Natural Gas Demand

Production Cost Benefits

Productivity/Yield Improvements

Environment/Regulatory

Time Frame for Results:
Mid Term (3 to 7 years)

Alternatives to Steam Methane Reforming for Hydrogen Production

Natural gas supplies are variable, and the U.S. will likely continue to be net importers of natural gas. Technologies are needed to provide alternatives for producing hydrogen that are not based on natural gas. R&D advances will help to prove technical viability of new options.

Key Technical Elements

- Reduced cost of electrolysis
- Production options using ethanol, methanol, renewables (solar and wind), and nuclear energy
- High volume capacity
- Recovery of hydrogen from hydrogen sulfide or ammonia

Risk

LOW HIGH

Technical Risk

Considerable R&D required

Commercial Risk

Unproven technology, large capital investment

Potential Partnerships

Industrial gas suppliers
Power companies
U.S. DOE
National laboratories
Energy Commission

Benefits to Industry

LOW HIGH

Energy

Potential to Reduce Electric Demand

Potential to Reduce Natural Gas Demand

Production Cost Benefits

Productivity/Yield Improvements

Environment/Regulatory (CO_2)

Time Frame for Results:
Long Term (> 7 years)

Exhibit 7 (cont'd). Priority Research Areas
New Process Technology

Membrane Separation Technologies for Liquid Hydrocarbons

Physical separation technologies for liquid hydrocarbons are needed to replace or supplement distillation.

Key Technical Elements

- Identification of high potential streams for separation
- Screening of existing membranes (e.g., molecular sieve)
- Evaluation of new options, i.e., electrophoreses
- Cost effective scale-up to meet capacity requirements
- Adequate service life

Risk

LOW — HIGH

Technical Risk

Considerable R&D required.

Commercial Risk

Unproven technology, large capital investment

Potential Partnerships

Universities
National research laboratories
Membrane manufacturers
Catalyst/separation/sieve manufacturers
U.S. DOE
Energy Commission
Refinery Industry

Benefits to Industry

LOW — HIGH

Energy

Potential to Reduce Electric Demand

Potential to Reduce Natural Gas Demand

Production Cost Benefits

Productivity/Yield Improvements

Environment/Regulatory

Time Frame for Results:
Mid- to Long-Term (3 to 7 yrs)

Exhibit 8. Priority Research Areas
Energy Systems and Energy Management

Energy Management Software Tools

User-friendly, simple, low-cost energy management software tools are needed to analyze and control energy usage in refineries. Energy software will enable refinery operators to better understand where energy is being used and identify opportunities for optimizing energy.

Key Technical Elements

- Design to accommodate data dumping
- Requires long-term maintenance support
- Must be maintainable by user
- Supported by effective training curriculum

Risk

LOW — HIGH

Technical Risk

Does not require extensive new R&D or fundamental science

Commercial Risk

Relatively easy to implement, low upfront investment

Potential Partnerships

Software developers
Refining industry
U.S. DOE
Energy Commission
Electric Power Research Institute
Utilities

Benefits to Industry

LOW — HIGH

Energy

Potential to Reduce Electric Demand

Potential to Reduce Natural Gas Demand

Production Cost Benefits

Productivity/Yield Improvements

Environment/Regulatory

Time Frame for Results:
Near Term (within 3 years)

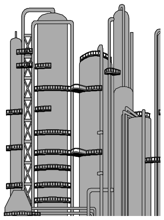


Exhibit 9. Priority Research Areas
Improved Process Operations

Online Inspection of Pressure Vessels and Pipes

On-line inspection technology is needed to more effectively monitor and assess condition of pipes and equipment with regard to corrosion, fouling, and boundary integrity. On-line inspection would increase run time of process equipment and reduce energy use associated with start-up and shut-down.

Key Technical Elements

- Fiber optic/wireless systems
- Non-intrusive
- Monitoring of corrosion in pressure vessels, piping and tanks

Risk

LOW — HIGH

Technical Risk

Requires moderate R&D and demonstration

Commercial Risk

Retrofit technology, moderate up-front investment, requires demonstration.

Potential Partnerships

Refining industry
National laboratories
Sensor Companies
Energy Commission

Benefits to Industry

LOW — HIGH

Energy

Potential to Reduce Electric Demand

Potential to Reduce Natural Gas Demand

Production Cost Benefits

Productivity/Yield Improvements

Environment/Regulatory

Fast Response to Safety Issues

Time Frame for Results:
Mid Term (3 to 10 years)

Reduction of Fouling and Corrosion in Cooling Water Systems

New technologies and predictive or preventive measures needed to reduce fouling and corrosion in cooling water systems.

Key Technical Elements

- Capabilities for high load areas
- Better fundamental understanding of heat exchanger fouling mechanisms

Risk

LOW — HIGH

Technical Risk

Some technologies exist.

Commercial Risk

Moderate to low investment, good payback.

Potential Partnerships

Universities
National research laboratories
U.S. DOE
Energy Commission
Refinery Industry

Benefits to Industry

LOW — HIGH

Energy

Potential to Reduce Electric Demand

Potential to Reduce Natural Gas Demand

Production Cost Benefits

Productivity/Yield Improvements

Environment/Regulatory

Time Frame for Results:
Mid- to Long-Term (3 to 7 yrs)

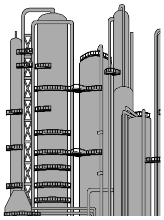


Exhibit 10. Priority Research Areas Electricity Conservation and Generation

Gasification for Electricity and Fuels

Technology is needed to utilize gasification syngas for electrification or gas-to-liquids. Feedstock options might include coke-to-gas, resid-to-gas, or tower bottoms-to-gas. Gasification could also provide a source of hydrogen and methane.

Key Technical Elements

- Reliability of refractories
- Optimized flexibility between liquid to gas
- Utilization of byproducts
- Capital cost

Risk

LOW — HIGH

Technical Risk

Proven technology

Commercial Risk

Reliability is an issue

Potential Partnerships

Universities
U.S. DOE
Energy Commission
Refinery industry

Benefits to Industry

LOW — HIGH

Energy

Potential to Reduce Electric Demand

Potential to Reduce Natural Gas Demand

Production Cost Benefits

Productivity/Yield Improvements

Environment/Regulatory

Time Frame for Results:
Near Term (up to 3 years)

Recovery of Low Level Heat Streams

Technology is needed to cost-effectively recover and utilize low value energy streams, such as low pressure or temperature steam, for thermal or electrical energy.

Key Technical Elements

- Low pressure condensing turbine
- Absorption chillers
- Alternative fluid power generation
- Heat pumps

Risk

LOW — HIGH

Technical Risk

Proven technology

Commercial Risk

Medium to high

Potential Partnerships

Equipment suppliers
Utilities
Refinery industry

Benefits to Industry

LOW — HIGH

Energy

Potential to Reduce Electric Demand

Potential to Reduce Natural Gas Demand

Production Cost Benefits

Productivity/Yield Improvements

Environment/Regulatory

Time Frame for Results:
Near Term (up to 3 years)

Conclusions

California refineries must balance competing goals for profitability, energy efficiency, and compliance with increasingly stringent environmental regulations. Mixed into the balance are the immediate issues of energy price volatility, and the need to meet rising demand for products. Refineries are already stretched to capacity and operating under a severely restrained investment climate, which creates additional challenges.

Energy is a critical element in plant operations, as it can significantly impact production costs as well as environmental compliance. A key challenge for California refiners is ensuring that electricity and fuel requirements are met in the future in the most cost-effective, reliable manner possible. Rising natural gas prices and the potential for disruptions in electricity during peak periods continue to make energy supply problematic and costly for refineries. Energy volatility, however, also makes energy efficiency improvement an increasingly attractive proposition.

To meet future energy challenges, California refiners will need to implement a combination of new technology, energy efficiency improvements, and onsite generation capability. Fuel flexibility, the use of innovative energy resources, advances in technology, potential streamlining of permitting processes, and technology demonstrations will all be important aspects of future energy solutions.

The priorities presented here reflect the technology RD&D that California refineries believe will help them to meet future energy demand in their facilities. The Energy Commission will consider these priorities in guiding future decision-making regarding investments in RD&D and promoting the efficient use of energy in California.

To help meet future challenges, the Energy Commission will have a role in future RD&D partnerships with the refining community that could include research as well as validation of technology. Creative partnerships between refineries, utilities, non-utility energy providers, and government agencies will also have a necessary role in fostering innovative energy solutions.

References

(Worrell 2003) Worrell, E., and C. Galitsky. 2003. *Profile of the Petroleum Refining Industry in California* (Draft). Energy Analysis Department, Environmental Energy Technologies Department, Lawrence Berkeley National Laboratory, Berkeley, CA.

(EIA 2003) 2003 Petroleum Supply Annual, Volume I, Energy Information Administration, U.S. Department of Energy, 2003.

Appendix A

Workshop Participants

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