A SUMMARY AND EVALUATION OF EXISTING ECONOMIC MODELS OF THE PETROLEUM REFINING INDUSTRY

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EXECUTIVE SUMMARY

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I. INTRODUCTION

The California Air Resources Board (ARB) is attempting to evaluate the impact of air quality regulations on California industry. Petroleum refining is one of the industries the ARB is analyzing, for a number of reasons:

- Refineries are an important source of production, employment, income and revenue in California. Nearly 20% of all operating refineries in the United States are located in California.

- Petroleum refineries are also major stationary sources of pollution, particularly NOx and SOx. For example, a study of pollution transport using 1977 data and a 50 x 50 mile grid within the South Coast Air Basin noted that petroleum refining and production accounted for 14% of total and 16% of stationary source sulfur oxide emissions.

- There is a relatively large amount of publicly available technical and cost data on refinery processes and refinery pollution control techniques. Furthermore, a number of models developed in the last twenty years have been exercised on petroleum refineries.

If existing petroleum refining models and data are applicable to pollution control issues in the state of California, they can greatly assist the ARB in its evaluation of the effects of air quality regulations on California industry. The problem now is to determine which (if any) of the existing petroleum refining and production models are applicable to the ARB need for an in-house capability to evaluate alternative pollution control options.

This report summarizes existing models of the petroleum refining industry, and evaluates their use to the ARB. The steps taken to complete the project were:

(1) acquisition of literature on existing petroleum refining models;

(2) identification of ARB policy-making needs;

(3) analysis of existing models;

(4) identification of modifications/steps necessary for the ARB to obtain a petroleum refining model which satisfies ARB needs.

Each of these steps is summarized in the following sections.

II. ACQUISITION OF LITERATURE

Published sources and personal contacts were used to develop a list of models pertaining to the petroleum industry and petroleum refining. Over a hundred articles, papers, books and other documents were identified in the search process. Many of these documents were not applicable to the current study, and were eliminated after reviewing the document abstract or the document itself. A formal search of published literature was completed first; references in these documents, and personal contacts with individuals and organizations having some experience in the field, supplemented the original number of listings.

The formal search identified 104 documents to be considered. An initial screening of the 104 document abstracts indicated that many would not be of further relevance to the present study. Some of the articles merely described new petroleum refinery technologies; several of the listings were only available in a foreign language; a few documents appeared more than once, or were separate references to individual volumes in a multi-volume report; two listings in a "Work in Progress" database were halted before the modeling effort was complete. The initial screening of abstracts eliminated 39 listings from further analysis.

The remaining 65 documents were ordered, received, and reviewed. During this second "screening," additional documents were found to be inapplicable. Some were brief news reports or simple technology descriptions; in one case the "refinery industry model" that was described was developed for the <u>aluminum</u> refining industry. This second screening further reduced the number of relevant documents to 39 listings.

Through personal contacts and references cited in previously acquired documents, an additional 21 listings were added to the 39 documents already under consideration via the literature search. All 60 listings are summarized in Appendix A of the final report.

The sixty references cited in Appendix A are not all independent studies of the refining industry. Many of the documents can be grouped together by performing organization, by a source of funds, or by interactions among individuals (e.g., a thesis advisor and student). If the references are grouped into separate modeling efforts, twenty-seven separate models can be identified. These models are listed in alphabetical order in Table ES-1.

III. COMPARISON WITH ARB POLICY-MAKING NEEDS

Whether or not a particular model is appropriate depends upon the purpose for which it will be used. A model may be extremely good at determining daily refinery production, yet it may not be at all suitable for setting long-range pollution control goals. The literature search identified several models of the petroleum refinery industry; which one (if any) is most applicable depends upon the needs of the Air Resources Board. Those needs must be carefully identified and articulated, because they are very likely to conflict: a need for detail may make one model the most relevant, while a need for low cost or ease of use may point to another modeling option.

Listed below are the general criteria which were sought in the candidate models:

<u>An Ability to Include a Variety of Policy Options</u>. This may sound almost trivial, but many models implicitly assume that economic and policy conditions do not change. Such models are unacceptable for further consideration.

Accuracy. This attribute contains two elements:

> Representativeness. The model should closely approximate economic conditions and aspects of the petroleum industry in California.
>
> Statistical Accuracy. According to various econometric and statistical tools, the model and individual equations should closely simulate actual situations.

Availability. The model, data, and documentation should be available to Air Resources Board staff for further analysis and evaluation.

Detail. Disaggregation at the refinery level, so that different sizes of refineries may be analyzed, is preferable. Regional disaggregation would also be helpful, but is not considered as crucial to the current study as disaggregation by refinery type.

Time Horizon. The model should be suitable for longer-range (10-15 year) planning purposes.

Cost Effectiveness. For two models with similar capabilities, the less expensive model will be chosen.

IV. ANALYSIS OF EXISTING MODELS

If the ARB is trying to determine how their decisions affect trends in industry and the California economy, there are a number of approaches which may be used. The two main alternatives are top-down (also known as "macro" models) and bottom-up, or "micro," options.

The main problem with top-down techniques is that they must assume too many things remain the same. Fixed coefficients -- whether they are for simple "scale up" models such as the one used by the Texas Air Control Board, or for large and complex input-output models -- cannot account for variations in future technical/environmental/economic conditions, nor are they flexible enough to allow for an array of policy options. But this is exactly the kind of information a public agency such as the ARB would be seeking. If top-down analyses are not adequate for policy-making purposes, then the alternative options -- bottom-up, or "micro" models -- must be considered.

Bottom-up approaches allow for variation in policies and background conditions, and are therefore better for longer-range regulatory purposes than "top down" approaches. One subset of bottom-up options, known as process models, are relatively expensive to construct and update, but can include many more options for reducing emissions. Which of the alternative bottom-up options is chosen depends upon the characteristics of the industry under consideration. Industries such as agriculture and construction may not have many production alternatives, while some of the manufacturing processes may entail a welter of choices. This is part of the reason the ARB is interested in models of the petroleum refining industry; refining is a relatively complex process, and recent technology improvements in refining only add to the need for a model which can evaluate the many production alternatives and their implications for the development of reasonable air pollution control regulations.

Of the twenty-seven models listed, seven (DRI, Hudson/Jorgenson, Lakhani, Sweeney, the Texas Air Control Board model, Wilkins, and Wilkinson) use a "top down" approach, and are therefore unsuitable for use by the ARB.

Thus, the first criterion in the previous section -- an ability to include various environmental policy options -- dropped seven models from the list in Table ES-1 (DRI, Hudson/Jorgenson, Lakhani, Sweeney, the Texas Air Control Board, Wilkins, and Wilkinson). These were the "top down" models discussed above; because top-down models must assume so many factors do not change, they are inappropriate for the types of environmental analysis the ARB will be conducting.

Another criterion -- availability -- removed six more models from further consideration. Four of the models (Gulf, Kellogg, Parsons, Turner-Mason) were company-developed, proprietary models; on-line usage of the results was not a possibility. Two more models (the French models, and the University of London model) were dropped from further consideration because even simple documentation was unobtainable.

A third criterion -- time horizon -- would remove short-run models from further consideration. The Wilkinson model, a short-run macroeconometric model, would have been dropped from further consideration on the basis of this criterion if it had not already been ousted on the policy-inclusion criterion.

Table ES-2 enumerates the petroleum refining models which are still potentially applicable after a simple first screening; nearly half the candidates have been removed from further consideration. The remaining fourteen models were analyzed in detail in Chapter V of the main report: a summary of the results are given in Table ES-3.

The first column of Table ES-3 reiterates the most important characteristic of the "Accuracy/Representativeness" criterion; models are identified as supply-only, demand-only or supply-and-demand (D&S) models. The second column indicates the available information for the "Statistical Accuracy" criterion: little information is available, but the Adams/Griffin, Rice/Smith and Verleger/Sheehan models are all very good, while the Arthur D. Little model does an acceptable job. (The error in the ADL model is far greater in PAD V -- the region in which California is located -- than in any other region). All of the models are either publicly available, or available in some limited manner subject to negotiation with the model owner.

The amount of detail varies widely; Table ES-3 indicates whether or not emissions information is included, and how detailed the other information is in the model on a "good-fair-poor" basis. The information available in four of the models -- Kennedy, Pagoulatos, Rice, and Rollins -- is so aggregated or so scant that the models should be excluded from further consideration.

The remaining three columns in Table ES-3 provide information on the time horizon of the model and on initial and recurring costs. Most of the models have a medium-range (10-15 year) horizon, although a few are in the short-to-medium range (3-5 years) time frame. The combinations of initial and recurring costs are varied: the smaller models and publicly available models tend to have lower initial costs, and the larger and simultaneously determined models tend to have higher recurring costs.

Ideally, the ARB would like to have one (or more) models with "D&S-Good-Public-Yes-Good-Medium-Low-Low" entries listed in Table ES-3. However, one of the main conclusions that can be drawn from the table is that there are no California-specific economic models of the petroleum refining industry currently available. Only a few of the models -- Kennedy, Pagoulatos, Rice and Rollins -- are so aggregated that they may be excluded from further study. The issue then becomes one of using the "bits and pieces" that are currently available to build a model that IS a California specific economic model of petroleum refining.

V. ADDITIONAL STEPS NECESSARY TO OBTAIN A SATISFACTORY MODEL

The California Air Resources Board is looking for tools which can improve the ARB ability to evaluate candidate control measures and proposed changes in pollution emissions from California petroleum refineries. The analysis provided in this report is used as a basis for the following general recommendations:

<ins>Recommendation #1</ins>: Any economic model of the petroleum refinery industry used by the ARB needs to have:

- a supply (production) component,
- a demand (consumption) component, and
- a means for reaching demand and supply decisions for the petroleum industry as a whole.

An accurate evaluation <ins>must</ins> include both supply and demand considerations. The complex process options associated with refining allow for a wide range of production decisions. How refiners respond to proposed control measures can have a significant impact upon refinery prices and output mix and consumer demand. Conversely, changes in consumer demands patterns can strongly affect refinery activity levels, with subsequent impacts upon emissions. Neither supply nor demand comes "first;" consumption and production decisions are made simultaneously. Until both demand and supply considerations are included, and until these considerations are included for the industry as a whole, it will not be possible for the ARB to evaluate some of the impacts of candidate control measures. Although cost impacts can be estimated from a supply model, and sales of gasoline can be estimated from a demand model, a number of important variables (such as employment, investment and tax revenues) can only be assessed in a framework that considers demand and supply simultaneously.

<ins>Recommendation #2</ins>: The ARB should not try to develop its own supply component, but should try to acquire one of the existing models or modeling services.

The supply aspects of petroleum refinery modeling are the most well developed. Private firms have used linear programming techniques to allocate refinery inputs and outputs since the 1950's. Linear programming models include thousands of variables, and can simulate the behavior of almost any refinery. LP models have been used repeatedly by oil companies and by public agencies concerned with petroleum issues. Currently, there are a variety of supply models in use. Some are completely proprietary; because the ARB is seeking a refinery model for its own use, completely proprietary models are excluded from further consideration. However, there are a number of process models for which at least an "on-line" access is possible. There are also two models in the public domain: these models would be relatively cheap to acquire, although they could place a significant burden on ARB personnel when installation costs and data acquisition are considered.

<u>Recommendation #3</u>: The ARB should carefully evaluate how much use it would make of a petroleum refining model: this will determine whether the supply portion of the model is "purchased" or "leased."

For several of the privately available models, both a licensing option (in which a California-specific supply model is created for and sold to the ARB) and a leasing option (where only the <u>use</u> of such a supply model is granted, usually for a designated period of time) are possible. The "lease or buy" options are also available for the Department of Energy (REMS) model -- the ARB could acquire the REMS model and install it on ARB facilities, or the ARB could make arrangements to access the DOE computer and models as needed. (The latter option is currently used by the Environmental Protection Agency). If a model is purchased, higher initial costs are incurred than under a leasing or time-sharing agreement. However, if the model is used extensively, lease costs and telephone charges could exceed the cost of buying a model. The "breakeven" point for purchasing a supply model is at <u>very</u> regular usage levels: the ARB should consider purchasing or licensing a model if it expects to use the model at least monthly, and plans to analyze at least 10-20 cases per month. If this level of usage is not anticipated -- if the ARB will only do periodic studies, or will do studies occasionally throughout the year -- then leasing of a model, or a time-sharing arrangement with the REMS model, is recommended.

<u>Recommendation #4</u>: The ARB should also evaluate how much internal expertise it has -- and expects to have -- available: this will determine whether the ARB chooses a privately developed supply model or a publicly available one.

The supply models that are currently available require a sophisticated knowledge of petroleum refining processes and familiarity with linear programming techniques. The ARB must have access to individuals with petroleum engineering and process economics backgrounds, so that the characteristics of particular refineries are accurately included.

If such individuals are available at ARB, then the entire range of modeling options may be considered. At one extreme, the ARB could acquire the REMS model from the Department of Energy and undertake all installation and usage activities itself. The initial external costs to the ARB of such a "go it alone" option would be minor, including items such as computer tapes on which to transmit the model. However, if linear programming or petroleum refining skills at ARB are scarce (or are expected to be scarce in the future), acquisition of the REMS model becomes risky -- since DOE provides no support along with the model, ARB staff would have responsibility for installing the model, learning to use it, and expanding it to include California-specific data. At the other extreme of choices, the ARB could request "on-line" access to one of the commercially available systems. Initial external costs would be higher, but the training, documentation and support services might be well worth the added cost.

Recommendation #5: The demand component, and the methodology for reaching demand and supply decisions for the industry as a whole, will have to be developed by the ARB.

The demand component of petroleum refining models is not as well developed as the supply component. Most of the existing models take demand estimates as given. Usually, these demand estimates are obtained from one of the major economic forecasting companies -- Data Resources Incorporated, Wharton Economic Forecasting Associates, Chase Econometrics, etc. -- or from data developed by public agencies such as the Federal Energy Administration.

Simultaneous, industry-wide determination of demand and supply is the least developed aspect of petroleum modeling. Many of the models are iterative: "reasonable" demand estimates are made, and used in the LP model to derive initial costs and output combinations. The results are used to revise the demand estimates, and a second round of modeling begins. Some models are block recursive -- subsets of the variables are determined simultaneously. In the past, use of simultaneous models was limited by computer capacity. As computing capabilities increase, so do the possibilities for simultaneous, industry-wide estimation of policy variables.

California-specific models that include supply, demand and general equilibrium considerations do not currently exist. Models that do include all three components are relatively aggregate, national ones. A state-specific model would have to account for relatively large interregional flows of refinery inputs and outputs as well as people, jobs, revenues, and incomes. This will require research that has not yet been undertaken elsewhere.

Recommendation #6: A petroleum refinery modeling capability should be acquired in stages. A supply component should be acquired first, followed by a demand component and industry-wide estimation capabilities.

This recommendation may sound like it conflicts with the first recommendation, but it does not. Eventually, a model of environmental policy in the petroleum refining industry should include production and consumption considerations, and include these considerations at an industry-wide and state-wide level, so that employment and revenue issues can also be evaluated. However, the best way to guarantee that such a model is never developed is to try and build it all at once, creating a heavy burden on ARB resources (both people and dollars) and increasing the number of places in which something can go wrong. If the model is developed in stages, the ARB can focus its attention more effectively on each component, and can have an opportunity to assess the value of each portion of the model as it is developed.

In the remainder of this report, specific tasks for building an economic model of the petroleum refining industry are outlined. Where possible, alternative options for undertaking a task are given, so that the option most suitable to ARB resources and needs may be chosen. The tasks are organized so that usable information is generated at the completion of each task: the ARB will not have to finish a huge modeling effort before results become available, although more types of questions can be answered as more tasks are completed.

Task 1: Developing a Supply Component

The supply component for an economic model of the petroleum refining industry will take the largest amount of ARB resources. However, once a supply model is acquired, the ARB can evaluate the impact of candidate control measures on refinery output mix and costs.

Obtaining and using a petroleum refining supply model requires the following categories of items:

(1) Computer capabilities

- access to a mainframe computer (such as the IBM S/370 Model 3033)

(2) A refinery model

- access to a refinery modeling system (such as PMS, REMS, or RPMS)

(3) Software (programs which can run the refinery model)

- problem-solving software, to solve the linear programming problem (examples are IBM's Mathematical Programming System -- MPS X -- and MPS III, available through Ketron, Inc.)

- software for generating the matrix of information and for report writing (examples of such programs are OMNI and MAGEN, both available through Haverly, Inc.)

(4) Data

- petroleum refining data (information on costs characteristics of the refinery technologies, inputs and outputs)

- emissions characterizations (information on the quantities and mix of pollution residuals associated with each type of refining process and input)

(5) Installation and Verification

- initial installation (getting the refinery model set up on the computer)

- verification (running the model for a known configuration)

- training

(6) Recurring costs

- modifications (changing the characteristics of refinery inputs, technical configuration, etc.)

- computer operation time

Item (1) and the first listing under Item (3) are not discussed further in the task outlines that follow, since the ARB has access to an IBM mainframe computer with MPS software on it. The items which need to be considered further are:

- the refinery modeling system
- matrix generation software
- refinery production data
- emissions characterization
- installation
- verification
- training
- modifications
- computer operation time

Each of these items is discussed in the options which are outlined below.

The ARB has two main options in acquisition of a supply model: it can obtain a publicly available model, or it can use a supply model generated from a private source (such as Bonner and Moore or PACE). Within each of these two main options, there are two sub-options: regardless of whether the ARB goes with a private or public model, the model may be purchased (licensed), or it may be used as needed (leased).

Of the publicly available supply models, the REMS model is preferable: it is receiving continuing support, whereas models such as the one by Russell were developed for specific studies and are no longer being updated and modified. Whether REMS is acquired for use on the ARB system, or time-sharing arrangements are made with DOE, is dependent upon the amount of use ARB will make of petroleum refinery modeling.

If ARB acquires the REMS model, the following costs and activities are to be expected:

- the refinery modeling system: the REMS model may be obtained by sending a letter requesting the model along with a blank magnetic tape to the Department of Energy.
- matrix generation software: REMS currently uses OMNI, which is available from Haverly, Inc. in New Jersey (telephone 201-627-1424). OMNI is preferable to alternatives such as MAGEN (since MAGEN is no longer supported). However, the software is a significant investment: OMNI can be purchased for $30,000 or it can be leased for approximately $1,000/month.
- refinery production data: information on petroleum flows and refinery operations can be obtained from the Department of Energy: DOE PAD District information is based upon state data. For state agencies such as ARB, the information is available free of charge.
- emissions characterization: this step requires some research and refinery engineering know-how, since emissions are usually not a simple correlation with refining output or technology. An outside organization, such as Bonner and Moore, Pace, or Sobotka, could do such a characterization for approximately $5,000 (the range would be about $3-10,000, depending upon how specific the refining areas and technology descriptions need to be).
- installation: Terrence Higgins is now at Sobotka, but was at DOE when REMS was developed and assisted EPA in its use of the REMS model. Higgins estimates that his firm could complete installation on

the ARB computer and train "systems" people in the use of REMS for about $6,000, including travel. There are probably other organizations that could also help ARB install the model, but Sobotka has worked with this model in the past.
- verification: a small "dry run," using the REMS model on a known configuration, will help validate the model and train ARB personnel in the use of REMS. Simple verification runs could be done in about 2 weeks; if an outside organization is used to evaluate and verify the model, it would cost around $7,000 ($5-10,000, depending on the amount of detail in the case study).
- training: since verification is an excellent opportunity for training, ARB personnel should be involved in the verification task, whether or not outside help is also used. Some additional training may also be helpful: Sobotka would be the place to go for this help, and it would probably cost around $3,000.
- modifications: REMS is a fairly flexible modeling system; most modifications can be done with the system as it stands.
- computer operation time: these costs are minimal ($10-15), but are incurred each time a case is run on the computer.

If the ARB chooses to use REMS on DOE facilities, the costs and activities are as follows:

- the refinery modeling system: already available at DOE.
- matrix generation software: already available at DOE.
- refinery production data: already available at DOE.
- emissions characterization: still needs to be done (see above).
- installation: no longer applicable.
- verification: no longer applicable.
- training: still needed (see above).
- modifications: see above.
- computer operation time: in addition to the recurring costs identified above, telephone charges for access to the DOE computer in Washington DC must also be added.

This is the option used by the Environmental Protection Administration; EPA transferred some "up front" money to DOE for this modeling effort, and the funds have been used up over time to help support the model. The exact details of an ARB-DOE time-sharing arrangement would have to be finalized in negotiations between the Air Resources Board and DOE.

As an alternative to the REMS model, ARB could license or lease a model from a private company engaged in petroleum refinery modeling. If ARB preferred to buy (obtain an exclusive license for) a supply model, a "package deal" is usually developed, in which the modeling system, matrix generating software, use of a refinery data library, installation, modifications, verification, and extensive training are included. ARB would still have to do an emission characterization (although that could also be one of the items requested from the private firm) and would still incur computer operations costs. Such licensing agreements would cost between $50,000 and $150,000, depending on the level of detail the ARB expects to include. Leasing arrangements are also possible, and range from $15,000 to $50,000 per year, depending again on the level of complexity.

If a private supply model is preferred, the following organizations are possibilities:

- Arthur D. Little, Inc. [The ADL Model]
- Bonner and Moore Management Science, Inc. [The RPMS System]
- Operational Economics, Inc. (OPCON) [The University of Houston Model]
- The Pace Company [The PMS Model]

Although Bonner and Moore has done more work with the state of California, there is not a "best" candidate: which one is chosen would depend on costs and services supplied along with the model. Each organization is described in Appendix B of this report.

Currently, the REMS modeling option appears to be the most suitable for ARB needs. This conclusion is based upon two facts and one observation. Fact 1: the REMS refinery modeling system is available to the ARB free of charge. Fact 2: public agencies, such as the ARB, have access to the state data available in the DOE/EPA database. The observation (and perhaps the most important reason for reaching the conclusion noted above): some ARB employees have the computer skills and modeling knowledge necessary for understanding and using economic models of the petroleum refinery industry. <u>If this situation is expected to change</u> -- in particular, if the experienced individuals are first on the cutback list or likely to job-hop -- then the ARB should instead rely upon private firms for supply modeling capabilities.

<u>Task 2: Developing a Demand Component</u>

The success (or problems) which the ARB has with obtaining a supply model will have implications for the remaining two tasks. If ARB finds that it makes little use of a petroleum refining supply model, it may decide not to devote funds toward development of a demand module or exploration of industry-wide assessment techniques. Alternatively, extensive use of a supply model would give ARB a better idea of the types of information it needed to generate in the next two tasks.

However, the development of a demand module is necessary for evaluation of environmental policy options, since supply aspects are "only half the story." The amount of petroleum refining activity depends not only upon the cost structure and production techniques facing refiners, but also upon the utilization of refined products by consumers and by other industries. An understanding of the factors which encourage or discourage refined petroleum demand is crucial to an ability to forecast refined product usage and the associated environmental consequences.

Previous studies of demand have found that purchases of a product depend upon the following kinds of factors:

<u>current income</u> -- this is included as a measure of spending power,

<u>current prices</u> -- the price of the product, the prices of items which are used in conjunction with the product (such as the cost of operating a car) and the prices of alternatives are usually included, since these indicate the relative costliness of the product,

the stock of durable goods using the product -- variables such as the number of automobiles or jets provide an indication of overall demand levels,

characteristics of of items which use the product -- fuel efficiency, weight, and the presence of air conditioning on a car influence use of refined petroleum products on a per-car basis,

demographic characteristics -- population measures such as the number of licensed drivers or indices of urban "sprawl" can indicate total demand levels, while characteristics such as the number of individuals or children per household provide clues to the kind of cars which are driven, and

other variables -- "habit" is often an important variable; individual driving patterns rarely change overnight.

Many of these variables overlap: the number of licensed drivers and the number of licensed automobiles could both be used to measure total levels of demand for gasoline. Thus, part of the effort associated with the demand modeling task will be choosing among alternative measures of demand, or using economic and statistical tools to develop indices of demand variables.

The demand modeling task should segment refinery demand into at least two parts: demand for gasoline (which represents the majority of refinery output in the state of California) and the demand for other refinery products. Demand in the gasoline segment is for final use by consumers, while demand in the other segment (for products such as asphalt) tends to be industrial demand, and the refined products are used as inputs to construction and to other manufacturing processes. While both segments will depend upon the factors listed above, the most appropriate measures may differ between the two segments. (As an example, the prices of diesel fuel and public transportation might be included as alternatives in the gasoline market, whereas the prices of cement and construction labor might be more appropriate prices to consider in the asphalt market).

Most of the previous modeling efforts associated with refinery product demand have emphasized gasoline demand; ARB demand models will be able to draw upon the work of Adams and Griffin, Data Resources Inc., Kennedy, Rice, Sweeney, and Verleger and Sheehan. However, since most of these studies emphasized world or national demand, the ARB modeling task will need to determine how many of these national estimates are appropriate to the State of California, since California pollution control regulations and vehicle use patterns are different from those of the rest of the United States. These models tend to divide demand into two components: a short term demand (where consumers are "stuck" with whatever brand of automobile they own, but can vary the number of miles driven), and a long term demand which depends on the type of car they choose to own and how they choose to drive. Gasoline usage becomes more flexible the longer the time horizon, since decisions about what to drive as well as how much to drive become possible.

Relatively little analysis has been done on non-gasoline demand for refinery output. Demand analyses for some products may be found in Adams and Griffin, DRI, Kennedy and Rice, although the analysis is again at the aggregate level (for the world or for the United States). Since the non-gasoline segment basically reflects industrial demands, production models (models in which the refined product is merely one input, and the user chooses as much of the refined product and any other inputs as will maximize producer profits) are most appropriate.

Because of the interdependence among variables in the model, the resulting equations can NOT be estimated separately. Several simultaneous estimation techniques -- Two Stage Least Squares (2SLS), Instrumental Variables (IV), error component techniques, and three stage least squares (3SLS) are all possible estimation methods, but Ordinary Least Squares (OLS) is not. Which of the estimation methods is actually chosen depends upon the form of the model and the types of variables which are included. Lagged variables and quarterly or monthly data create special estimation problems; prospective model-builders will need to indicate what problems they anticipate and how they intend to handle the problems if they include such variables.

As with the supply model, obtaining and using a demand model of the petroleum refining industry requires the following categories of items:

(1) Computer capabilities
(2) A demand model
(3) Software (programs which can run the model)
(4) Data (information on refinery output prices, demand for each type of refinery product, consumer income, the stock of petroleum-using capital goods, consumer utilization of those capital goods, etc.)
(5) Installation and Verification (getting the model set up on the computer and producing reasonable results for known situations)
(6) Recurring costs

Item (1) is not discussed, since the ARB has access to an IBM mainframe computer. Item (3) is also not discussed; the software would need to be compatible with existing or proposed ARB software, but will not require extensive acquisitions of software as the supply model will. The remainder of the discussion of this task divides the effort into two main categories; the development of a demand model (including installation), and the acquisition of California-specific data for the demand model. These need not be separate subtasks, although the talents needed for each subtask are slightly different.

A demand model would need to indicate consumer response to changing product prices, incomes, and demographic characteristics. The model needs to distinguish between the demand for gasoline and the demand for other petroleum products. In the gasoline portion of the model, distinctions between short-run demands (where the stock of automobiles is fixed, but usage of the automobile can vary) and long-run demand (where usage and stock are flexible) would need to be made. Nationwide models of gasoline demand have been developed: although these efforts provide useful background, regional versions of these models would be required. For the non-gasoline markets, intermediate-goods modeling would need to be included.

Several organizations and individuals have the ability to do demand modeling. To obtain a demand model, the ARB would let a contract for about $50,000 ($30,000-$100,000, depending upon the level of detail required). The Request for Proposals (RFP) would need to indicate the types of variables of interest and existing and anticipated software at ARB. (The exact measures used in the demand model, particularly those explaining automobile usage, should not be specified in advance -- a little "casual empiricism" followed up by comparisons among competing measures would be most useful). The RFP should also request that the respondent compare the output of the demand model with historic information or with the output from other economic models, and that the model be installed on the ARB system and be clearly documented.

Data acquisition could probably also be requested in the RFP. Price data for petroleum products is available from sources such as Petroleum Marketing Monthly and the Monthly Energy Review. Gasoline sales data is available by state by month from the American Petroleum Institute and from the Federal Highway Administration. Data on population, income, and price deflators are available on a state-by-state basis from the Commerce Department's Bureau of Economic Analysis. Other variables are available from a variety of sources -- the Department of Motor Vehicles has information on licensed drivers, the Environmental Protection Administration develops estimates of fuel efficiency. Much of this data has already been pulled together by economic research services such as Data Resources Inc., Wharton Economic Forecasting Associates, and Chase Econometrics -- it might be easier for the ARB to subscribe to one of these services (if it doesn't already) than to acquire and periodically update the information. However, public agencies such as the ARB have access to state data from DOE, EPA and the Census Bureau free of charge. Thus, it would probably be best for the ARB to request information on those variables already available on a state-by-state basis from national agencies such as DOE, and to request information on other demand variables (automobile utilization rates, etc.) be developed or acquired by the contractor developing the demand model.

Task 3: Developing an Industry-Wide Modeling Capability

The simultaneity and general equilibrium issue is more speculative: if it successfully accomplished, it would provide an ability to assess investment, employment, and revenue effects of ARB control measures. It would also greatly increase the computer time needed to assess each case.

For now, one or two small research contracts (of about $25,000) could be given to explore alternative econometric methodologies that combine supply and demand components. The Request for Proposals would require simultaneous determination of particular demand and supply variables (to be specified by the ARB, but likely to include demands for major petroleum products). Models by Chou, Kennedy, Rice and the University of Texas at Austin have begun to explore simultaneous estimation methods. However, these models were for the United States as a whole or for the Texas region; they also used a variety of econometric methods.

A general equilibrium approach (which could more directly address the long-range employment impacts of ARB actions) would be a much larger research effort, and further in the future. Before embarking on a large simultaneous modeling effort, the ARB should consider waiting for the results of some general equilibrium model development that is being done at EPA. (A word of warning: the EPA effort is far behind schedule).

TABLE ES-1. LIST OF CANDIDATE MODELS

The Adams/Griffin Model
The Arthur D. Little (ADL) Model
The Chou Model
The Data Resources, Incorporated (DRI) Model
The French Models

The Gulf Model
The Hudson/Jorgenson Model
The Kellogg Model
The Kennedy Model
The Lakhani Model

The Pace LP Modeling System (PMS)
The Pagoulatos Model
The Parsons Model
REMS -- The Refinery Evaluation Modeling System
RPMS -- The Refinery and Petrochemical Modeling System

The Resources for the Future (RfF) / Russell Model
The Rice/Smith Model
The Rollins Model
The Sweeney Model
Texas Air Control Board Model

The Turner-Mason-Solomon (TMS) Model
The University of Houston Model
The University of Texas at Austin Model
The University of London Model
The Verleger/Sheehan Model

The Wilkins Model
The Wilkinson Model

TABLE ES-2. LIST OF CANDIDATE MODELS AFTER FIRST SCREENING

The Adams/Griffin Model
The Arthur D. Little (ADL) Model
The Chou Model
The Kennedy Model
The Pace LP Modeling System (PMS)

The Pagoulatos Model
REMS -- The Refinery Evaluation Modeling System
RPMS -- The Refinery and Petrochemical Modeling System
The Resources for the Future (RfF) / Russell Model
The Rice/Smith Model

The Rollins Model
The University of Houston Model
The University of Texas at Austin Model
The Verleger/Sheehan Model

TABLE ES-3. SUMMARY OF MODEL EVALUATIONS

	...ACCURACY...			....DETAIL....	
MODEL	D/S	STAT	AVAIL	EMISSIONS	OTHER
Adams	D&S	Good	S.T.Neg	Yes	Good
ADL	Supply	Fair	S.T.Neg	Yes	Good
Chou	D&S	NA	Public	No	Fair
Kennedy	D&S	NA	S.T.Neg	Yes	Poor
PACE	Supply	NA	S.T.Neg	Yes	Good
Pagoul.	D&S	NA	Public	No	Poor
REMS	Supply	NA	Public	Yes	Good
RPMS	Supply	NA	S.T.Neg	Yes	Good
RfF	Supply	NA	Public	Yes	Good
Rice	D&S	Good	Public	No	Poor
Rollins	D&S	NA	Public	No	Poor
U. Hous.	D&S	NA	S.T.Neg	Yes	Good
U.T.Aust.	D&S	NA	S.T.Neg	No	Fair
Ver/Shee	Demand	Good	S.T.Neg	No	Good

D&S: Demand and supply components are included
NA: Not available
S.T.Neg: Subject to negotiation
Good: Model rates above average in listed aspect
Fair: Model acceptable in listed aspect
Poor: Model rates below average in listed aspect

TABLE ES-3. SUMMARY OF MODEL EVALUATIONS
(continued)

MODEL	TIME	.....COST EFFECTIVENESS.... INITIAL COST	RECURRING COST
Adams	M	Avg	Avg
ADL	M	Avg	Avg
Chou	M	Low	High
Kennedy	M	Avg	Avg/High
PACE	S/M	Avg/High	Avg
Pagoul.	M	Low	Avg
REMS	M	Low	Avg
RPMS	M	Avg/High	Avg/High
RfF	S/M	Low	Avg/High
Rice	M	Low	Avg
Rollins	S/M	Low	Low
U. Hous.	M	High	Avg/High
U.T. Aust.	S/M	Avg	High
Ver./Shee.	M	Avg	Avg

TIME: Time horizon of model
M: Medium-range time horizon
S/M: Short-to-medium-range time horizon