Energy, Productivity, and Economic Implications of Resource and Environmental Policy in Southern California

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Recent developments in the regulation of air and water quality, and waste disposal in Southern California have placed added responsibilities on industrial plants and some commercial operations. More and more businesses are being required to abate their emissions and they are complying through a variety of mechanisms. Compliance alternatives coupled with resource needs can directly affect their choice of energy source as well as amount of energy consumed. This paper will describe and evaluate the compliance alternatives and resource requirements and examine their effects on energy use in the manufacturing industry.

Compliance options available to businesses range from retrofitting technical fixes to current processes through dramatic changes in processes (including fuel use changes), to changes in emission producing activities at the facility. Changes in energy use can include fuel switching that produces fewer emissions; efficiency improvements that reduce same-fuel use and emissions; and increasing energy use, where an additional energy-using procedure is incorporated to reduce emissions from an earlier process. In some cases, a plant may be able to purchase emission reduction credits (ERCs) in place of changing equipment because of Regional Clean Air Incentives Market (RECLAIM) recently adopted. In such cases, ERCs could also be sold by plants that achieve emissions reductions, offsetting the costs of their technology investments.

This paper will identify and classify the choices available and potentially usable by businesses to comply with environmental regulations or otherwise optimize their operations. The paper will also identify future trends in energy and environmental and productivity related technologies. All options will be considered, since they compete as alternatives to each other, including retrofit technologies that reduce emissions, but do not change energy use, fossil fuel technologies, and electrotechnologies.

Introduction

Resource Planning in Southern California Edison, an electric utility, requires a forecast of electricity demand to a fair degree of accuracy. Unlike the residential and commercial sectors the industrial sector energy use is much more complex to forecast. Two factors confound the problem, the heterogeneity of the manufacturing sector and the lack of a simple and logical link between energy intensity and productivity. Many factors affect energy use in the industrial sector but the primary focus of this project is on electrotechnology and other competitive technologies and their adoption by the manufacturing sector. More and more industries are switching to advance manufacturing technologies of which electrotechnology is a key component. Such a phenomenon is occurring in American industry because of competitive pressures and also because of environmental regulations. To date, such impacts were computed off-line and the industrial forecast was adjusted to accommodate the effects of electrotechnologies (Table 1).

The project termed Competitive, Environmental, Energy, and Technology (CEET) database and model was undertaken to quantify the impacts of electrotechnologies in an integrated fashion with the industrial energy use forecast. The project soon grew to meet the objectives of several other parties besides SCE. They included the California Energy Commission (CEC), the South Coast Air Quality Management District (SCAQMD), the Ventura County Air Pollution Control District (VCAPCD), and the Los Angeles Department of Water and Power (LADWP).

Table 1. Selected Industry Groups and Rankings

	Food SIC 20	Furniture SIC 25	Metals SIC 33	Metals SIC 34	Chemicals SIC 28
Evaluation Criteria					
Industry Type 1	Process	Assembly	Process	Assembly	Process
Electricity Consumption 2	10%	2%	8%	7%	10%
Gas Consumption 2	3%	18%	8%	6%	4%
Growth Trend—Industry	Growing	Growing	Declining	Declining	Growing
Growth Trend—Electricity Use	Growing	Growing	Declining	Growing	Declining
Environmental Compliance 3	3	1	2	1	1-2
Electrotechnology Potential 3	2	1	1	2	3
Customer Flight Risk 3	3	1	1	2	3
	Refineries SIC 29	**Plastics SIC 30**	**Equipment SIC 36**	**Aerospace SIC 37**	**Controls SIC 38**
Industry Type 1	Process	Assembly	Assembly	Assembly	Assembly
Electricity Consumption 2	17%	9%	9%	19%	9%
Gas Consumption 2	1%	14%	15%	11%	20%
Growth Trend—Industry	Declining	Growing	Growing	Declining	Growing
Growth Trend—Electricity Use	Growing	Growing	Growing	Growing	Growing
Environmental Compliance 3	1	1-2	2	3	3
Electrotechnology Potential 3	3	1	2	3	2
Customer Flight Risk 3	3	3	3	1	1

1 As defined by the CEC for ease of analysis.
2 Percent of use in the SIC Codes listed.
3 1=high, 2=medium, 3=low.

The objectives of each party included:

- SCE & LADWP:
  (1) Develop a comprehensive analytical tool to assist in the forecast of energy demand in the industrial sector.
  (2) Understand and quantify impacts due to environmental regulations pertaining to end use technologies.
  (3) Identify market potential and research needs in electrotechnologies.

- CEC:
  (1) Develop a database of environmental regulations and technology applications that help to meet them.
  (2) Develop a set of end use pollution credit values which could be used in emission reduction credits.

- SCAQMD & VCAPCD:
  (1) Develop a database of end use technology applications that help to meet air quality regulations.

The aims and objectives of each of the groups overlap and emphasis varies among the various objectives but essentially each of the parties is interested to understand and quantify the interaction of customer economics, environmental regulations, and utility programs. Technological innovations are occurring in the manufacturing industry at a dizzying speed, robotics and information technology being the foremost amongst them. At the same time, energy and environmental regulations are being imposed on industries at an equal, if not greater, speed. Are these regulations helping or hindering industry? How is industry changing as a result of such technological developments and regulations? Should California temper its regulations to address the concern of industry in terms of productivity and jobs? How should the electric utilities plan for and respond to these dynamic interactions? None of these questions is expected to be answered by this project but it is designed to provide clues and information which may lead to formulation of policies that better address such issues.

Study Methodology

The project was divided into two essential parts. The first part would involve collection and tabulation of data to develop a relational database and the second part would be the development of a technology choice model which will use the information from the database to produce forecasts of energy, emissions, and other impacts.

Database Structure

The database will be a multidimensional rational database using commercially available software. The industry segment is the most basic element of differentiation. The database structure will also allow data cross-referencing by technology. Each segment, identified at the three- or four-digit SIC level, is further segregated into key reference facilities. Each prototype facility within a segment is characterized by its component processes, each process being expressed as a matrix of end-use technologies versus the associated impacts.

Such impacts include:

(1) Electric energy use and demand.

(2) Other energy use including gas.

(3) Duty cycle and load shape of usage.

(4) Current saturation of technology.

(5) Unit size.

(6) Efficiency.

(7) Capital, O&M, and process cost.

(8) Age and life of technology stock.

(9) Production throughput.

(10) Environmental impact by emission, NOx, SOx, ROC, etc.

The database will group together data elements associated with each customer technology, linking technologies and processes as appropriate in each prototype facility.

Modeling Structure

All the data elements in the database will be used to form a matrix of information to answer the questions posed earlier. The outcome is dependent not only in the data available but how those data elements interact in a rational way to make the customer adopt a particular strategy of doing business, Representing the industrial customer's decision-making process is a key aspect of modeling the market penetration of a particular choice. They could include electrotechnologies, or gas technologies, or same fuel energy efficient technologies, or retrofit control technologies, or moving out of the service territory. This market penetration modeling ability is necessary to evaluate energy and environmental policy alternatives and forecast the impacts of customer technologies. Regulatory policies or utility programs may induce small perturbations in the customers decisions or they could have a major impact.

The selection of customer technologies to meet production demands is essentially an optimization problem in which the customer minimizes total costs across a menu of available technology options. Costs include explicit costs such as capital, energy, and other operating costs, as well as implicit costs such as productivity effects, risk premia, and others. The technology choice modeling developed in this project is fundamentally a cost minimization algorithm subject to energy service and environmental constraints. Each technology option also delivers an amount of energy service that is relevant to the energy requirements of the customer's production demands. The energy constrain assures that the option will meet production or output requirements. Each technology option also has emissions associated with it, of zero value or greater, which may or may not be sufficiently high to require a regulatory compliance action.

The technology choice model also incorporates three additional dimensions to the basic constrained cost minimization model. The three dimensions are:

(1) Heterogeneity of the customer population, in terms of facility size, imbedded cost characteristics, and secondary factors that affect cost

(2) Variations in customer attitudes toward technology innovation and implicit costs, such as risk, environmental image, competitiveness, and others

(3) Dynamics of technology characteristics, in which costs and benefits of technology options may shift over time as more experience is gained or competing options become obsolete.

The modeling approach begins with the simple one dimensional Technology Optimization Model (TOM) that uses a narrow definition of costs for a typical customer in a given industry segment. The model then progressively gets more sophisticated to capture the additional dimensions sequentially.

The First Dimension: The TOM model starts by accepting end-use energy demand by three- and four-digit SIC code generated by an industrial end-use forecasting model. The model used in this project is called INFORM, developed by EPRI (Electric Power Research Institute) and its subcontractors. The model provides a framework for developing and organizing end-use and technology data for the industrial sector, including production levels, value of shipments, etc., which are then used for developing long term forecasts of energy patterns at the end-use level. The customer's problem is to meet this energy demand at minimum cost and in an environmentally acceptable fashion. In general, the customer has a set of strategies, which may include the following:

- energy efficiency improvement technologies
- fuel switching technologies
- process change
- pollution control technologies
- purchase or sale of emissions reduction credits
- reduced operation of pollution-emitting technologies
- combinations of the strategies above
- relocation.

Each strategy has an energy end use value as well as cost characteristics. The costs include installed initial capital costs multiplied by the minimum acceptable rate of return. They also include a stream of non-capital costs or expenses such as energy costs, labor, material, and other operating costs. Strategies may also have benefits, such as reduced product wastes and improved marketability of the end product. The stream of expenses may thus include the monetized effects of changes in productivity or product quality caused by the strategy.

The expense stream may include the cost of emission reduction credits if they must be purchased to offset pollution caused by the option chosen. To meet emissions constraints, specific technologies may need to be combined with pollution control technology before they can be considered viable coping strategies. Absent such a combination, emission reduction credits may need to be purchased. RECLAIM offers the potential for positive or negative monetary values associated with emission characteristics. Each strategy has an associated discharge amount for each type of emission. This allows any one of a number of emission types, e.g., NOx, SOx, CO, ROC, PM 10, to be a binding constraint on the optimization problem.

The Second Dimension: Industrial customers are not a homogeneous group. They have important differences that may be due to site-specific cost characteristics, capital availability, site- or customer size-specific regulatory constraints, and other factors. Such differences in purchaser characteristics are modeled based on judgment gained through experience with industrial customers and the discrete choice model literature. The data will be condensed into differences in the minimum acceptable rate of return. Each industry segment is divided into discrete groups composed of homogeneous purchasers. The total heterogeneous group of purchasers within an industry segment is represented by a probability distribution for the rate of return.

The Third Dimension: The variations in perceived costs occurs because different customers value productivity, product quality, technology performance risk, or environmental image differently. This dimension of technology selection is modeled as an additional parameter of the rate of return variable.

The Fourth Dimension: There is a time delay associated with market penetration of new technologies which is also captured in the model. This dimension is modeled using the S-shaped function of the technology's market share life cycle. The S-curve for a given technology establishes the upper limit on the market share of that ethnology in a given time period. This upper limit is modeled in terms of the maximum share of total process energy demand that the technology can meet in a given time.

The Logit Function: All least cost optimization models as described above suffer from the so called "knife edge problem;" the least cost equipment tends to receive 100% of market share, even if the next cheapest piece of equipment costs just a little bit more. We know that industrial customers, or any customer for that matter, do not behave this way. Most customers look at a number of attributes before selecting a piece of equipment: costs, quality, flexibility, reliability, and risk to mention a few. Thus, some customers will pick the highest cost option, and others will pick some of the intermediate cost options, while most customers will pick the least cost option. To capture this "real world" perspective in the CEET model (Figure 1), the multinominal logit function will be employed.

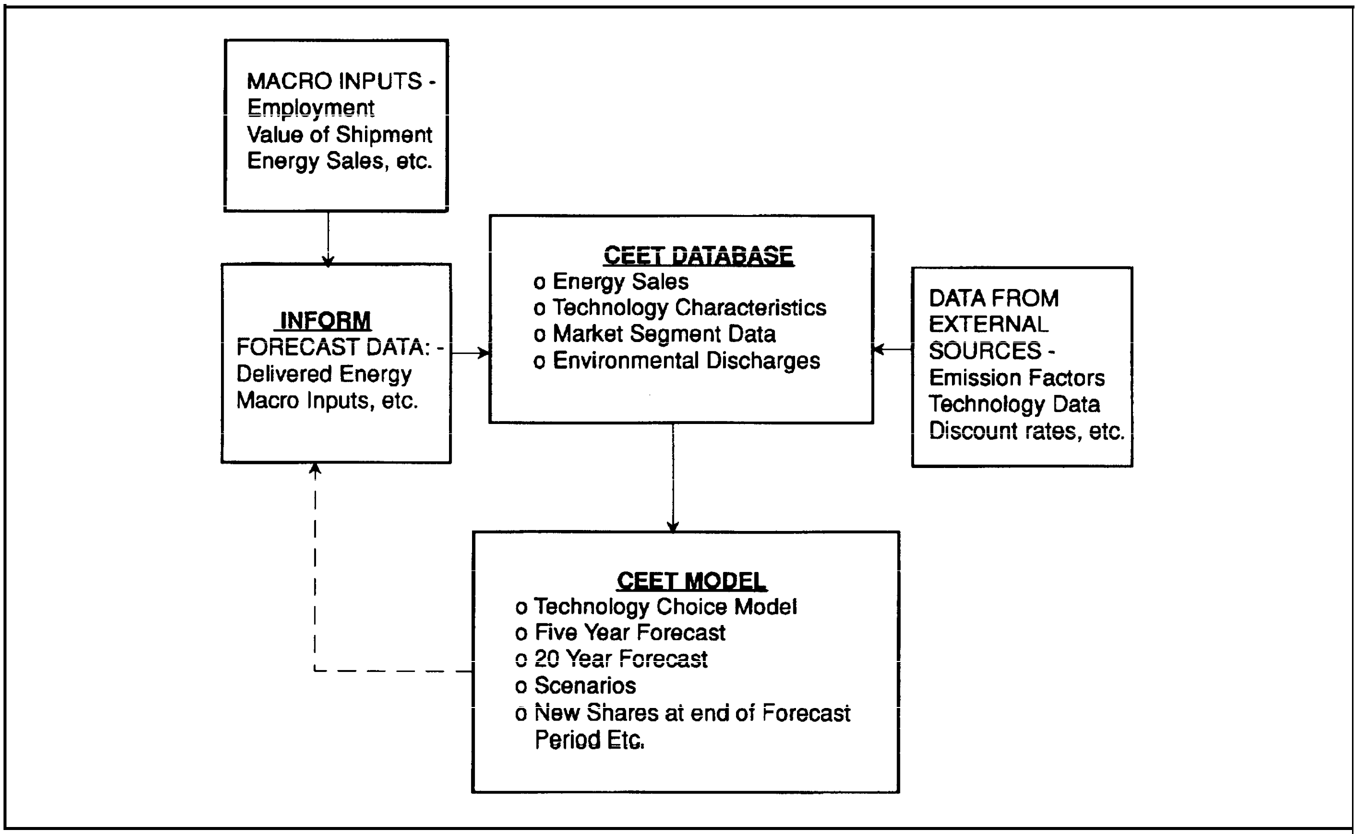

Figure 1. Ceet Modeling System

The multinominal logit function predicts the market share of a given equipment type, i as follows:

$$MS_i = \exp(\beta * Cost_i)/\Sigma(\exp(\beta * Cost_i)$$

Where *MS* is market share, exp is the exponential function, ß is a parameter that measures cost sensitivity, *Cost is* annualized production costs, and Σ denotes summation over all equipment type choices available.

Data Elements and Results

Data Sources

One of the most daunting tasks of the project was the data collection phase. We had to rely on secondary sources of data since there were no resources to conduct primary data collection. The two types of data collected were customer specific data of SCE and LADWP and technology specific data. The customer specific data included energy use by specific SIC code and equipment for electricity and fossil fuel. The electricity data was relatively easy to acquire since the principle sources, SCE and LADWP, are both active partners to the project. The gas usage data was much more difficult to get since we had to rely on Southern California Gas Co. (SoCalGas) who is not an active player. Other customer specific data included emissions discharge which was obtained from the two air districts, SCAQMD and VCAPCD. Customer technologies and their applications to different processes were obtained from the various National laboratories, industry research arms like EPRI, GRI (Gas Research Institute), AGA (American Gas Association), manufacturers, research and audit work completed by SCE and LADWP, and other utility studies.

Data Analysis

After the data were collected which was substantial, it was analyzed to screen out superfluous information. The applications were then prioritized tology pairs for a given process is shown in Table 2 for some selected processes.

Results

At the time of writing this paper some preliminary results were available from model runs conducted on three four-digit industry segments. They were SIC3462-Iron and Steel Forgings, SIC3463-Nonferrous Forgings, and SIC2033-Canning. Table 3 shows the results for the Iron and Steel Forgings industry. With a ß of -120 the direct resistance electrotechnology gets all of the market share in the year 2015 whereas its share in the base year 1995 is only 63%. This illustrates the knife edge problem when the cheapest option is chosen. As we move towards an

Table 2. Technology Application Pairs

Process	Representative Electrotechnology	Representative Gas Technology
• Drying	Microwave (MW), radio frequency (RF), infrared (IR), electric resistance, heat pump dehumidification drying	Convection oven, low temperature drying, direct/indirect, IR, air dry, kiln drying (wood), spray dryer (food), Yankee dryer (paper)
• Curing/Coating	IR, ultra violet (UV), electroplating, electron beam (EB), MW/RF, plasma arc spraying	Convection oven
• Cooking Appliances	Induction cooktop, electric resistance	Convection oven, gas cooktop
• Dry Cleaners	Ventless cleaner	Convection oven
• Bonding	IR, UV/EB	Convection oven
• Separations	Membrane, freeze concentration, electrolysis, heat pumped distillation evaporation	Evaporation, distillation, combustion
• Metal Melting	Electric arc, induction, direct resistance, vacuum, plasma arc, electroslag remelting	Cupola, gas reverb, crucibles
• Metal Thru Heating	Induction, direct and indirect resistance, laser, EB, plasma	Convection, radiant, slot, rotary, walking beam
• Non-Metal Melting	Direct resistance, indirect resistance	Regenerative furnace, unit melters
• Fluid Heating	Immersion, direct	Direct, indirect
• Motor Drive	Standard & high efficiency motors, variable speed drives	Direct drive, internal combustion (IC) engines
• Metal Cutting/ Joining	Laser cutting, welding, EB	Standard welding/cutting
• Waste Treatment/ Recovery	Reverse osmosis, freeze concentration, plasma technology	Incinerator

option which takes into account non-cost factors the market share is not dominated by any one technology. The case where ß is 0 is also an unlikely situation when cost plays no part in the customer's decision.

A more likely possibility is a ß, which takes cost into account but there are other factors considered as well. One of the challenges of this project is to properly estimate the value of ß. It clearly varies by industry and the preferred way to estimate it is through statistical regression analysis of primary market research data. Currently such data is scant for the industry segments and equipment types contained in the CEET model.

The ß parameter will be obtained in the project in two stages through secondary data. In the first stage, we will review the base year (1995) market shares and see what value of ß corresponds to these market shares, given the base year annualized cost information. In the second stage, we will seek to refine this value of ß through interviews with a number of industry experts and trade allies such as equipment manufacturers. Since one of the objectives of the project is to identify future research

Table 3. Preliminary Results of SIC3462—Iron and Steel Forgings

Industry Type: SIC3462-Iron and Steel Forgings
End Use Segment: Preheat
Process Type: Short production run at low volume

Technology Operations and Market Shares:

	1995	2015			
		*b=			
		-120	-50	-25	0
Direct Resistance	63%	100%	88%	66%	25%
Rotary Hearth	12%	0%	5%	15%	20%
Recuperative Slot	0%	0%	8%	19%	25%
Unrecuperative Slot	25%	0%	0%	0%	25%

*Note: High values implies customer is very cost sensitive.

directions, primary market research data collection will be recommended in segments where the data obtained at the end of the project are weak.

Potentials

After the database and model are fully developed various scenarios will be established to test alternative futures. They include

- Business as Usual: Considered the base case.
- Strict Environmental Regulations: This scenario will include specific events which could trigger strong regulations, such as scientifically confirmed link between CO2 emissions and climate change, insufficient air quality improvement resulting from existing regulations and leading to tougher standards, or broader definition of hazardous wastes and disposal requirements resulting from more alarming evidence of adverse health effects. On the other hand, the possibility of lenient standards for some discharges may be established to foster greater economic growth.
- Energy Regulations: Even higher standards for equipment and buildings, as well as potential versions of an energy tax. Scenarios of this condition may also include the likely market penetration of non-gasoline fueled vehicles and their impact on energy demand.
- Economic Growth: Low and high economic growth rates in Southern California.
- Utility Programs: Currently SCE and SoCalGas have programs in place which allow them to encourage their respective customers to switch fuel if they meet certain conditions. The current criteria used by the California Public Utilities Commission (CPUC) is called the three pronged test described below. But such rules could easily be altered depending on the future gas and electricity supplies.

The three-pronged test outlined by the CPUC is

(1) The program must not increase source-Btu consumption. What this means is that if SCE has a program which promoted a customer to switch from drying with ovens which run on natural gas to infra-red drying using electricity then the resulting energy consumption, after accounting for generation and transmission losses, must be less than the Btu content of the natural gas burned in the oven.

(2) The program must past the total resource cost (TRC) test as well as the Utility Cost (UC) test. Interestingly this test allows for non price factors to be taken into account. The comparisons between technology pairs must be based on the most efficient same fuel technologies. For instance, if an induction furnace replaces an existing gas reverbs furnace then the economic

analysis that needs to be conducted should be between the induction furnace and the most efficient gas reverbs furnace available in the market and not necessarily the furnace that was to be replaced.

(3) The program must not adversely impact the environment. This is interpreted to mean that using currently adopted residual emissions factors the alternative technology must show a net reduction in environmental cost .

Based on any given scenario the various potentials can be estimated using the model. These include, technical, economic, and market potential. Technical potential of electrotechnologies is defined to be the complete penetration of all applicable electrotechnologies regardless of cost. Economic potential from society's perspective could be the adoption of all electrotechnologies which result in a net reduction of resource cost. Market potential is the penetration of electrotechnologies given a set of market conditions including utility programs and environmental regulations.

Discussion

The driving force behind the customer's choice of technology is not energy use alone. It is usually a combination of productivity improvement, air quality regulations, and efficient energy use. Preliminary results indicated that the single most determining factor is productivity improvement.

Electrotechnologies are efficient and clean and they may offer an effective solution to meet the increasing challenges faced by modern American industry. It is also important to understand the particular needs of the customer in light of his geographic location, business climate, and economic viability before the right mix of technologies can be suggested. The most effective solution may not necessarily be a 100 percent switch from fosht of his geographic location, business climate, and economic viability before the right mix of technologies can be suggested. The most effective solution may not necessarily be a 100 percent switch from fossil fuel to electric but a hybrid of fossil and electric that meets the customer's needs best. In many other instances the best choice may not be a fuel switch at all but an effective control mechanism to reduce emissions. Yet in other cases it may be in the best economic interest of the customer to continue to pollute in their particular industry but clean up some other site by buying clean air credits.

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