Appendix

APPENDIX A

The Industrial Sector Technology Use Model

One approach to assessing the potential impact of legislative options on industrial energy use and related investment has been the use of the Industrial Sector Technology Use Model (ISTUM). * The ISTUM approach is to specify end-use energy services (e.g., bleaching in the pulp and paper industry) and to balance technologies providing similar services and outputs in order to predict minimum, direct, lifecycle costs. The model's fundamental decision criterion, minimum lifecycle costs, is used to assess market penetration levels of each competing energy service technology, after which it is possible to project total energy demand, fuel mix, and energy-related investment for each industry and for the overall industrial sector. It is the changes in these projections, resulting from the impact of various policy measures, that are used as part of OTA's assessment.

ISTUM provides a framework for a comprehensive accounting of energy use in the entire industrial sector. It focuses, however, on those industries that are major energy users and on those in which process heat or feedstocks are a significant share of required energy services. Thus, ISTUM targets iron and steel, pulp and paper, petroleum refining, and chemicals industries for particular emphasis. Together with aluminum these industries represent all of industry's feedstock energy uses, over 60 percent of current fuel use in boilers and nearly half of fossil fuel used in industrial process heat.

The key elements of organization of ISTUM are the 27 industrial sector classifications listed in table A-1 and the 52 energy service categories listed in tables A-2 and A-3. Primary emphasis is on energy end use rather than on fuels use. In steel making, for example, emphasis is on the energy needed to convert scrap and pig iron into liquid steel, to shape steel, and to increase the structural strength of steel products.

As shown in table A-2, ISTUM identifies 13 energy services as generic—i e., common to most industries. These include such services as steam generation, mechanical drive, and space heating. Table A-3 lists the 39 industry-specific services, such as bleaching in the pulp and paper industry and heat treating in the iron and steel industry. This distinction is important because many energy services are generic, and thus there is a large market for energy efficiency-improving technologies throughout the industrial sector.

Figure A-1 lists the data inputs required for ISTUM and illustrates schematically this model's approach to projecting market shares of competing energy service-providing technologies.

The time horizon of ISTUM is long, extending to 2000 in 5-year increments. Its base year is 1976, the most recent year for which detailed energy use data is available from the U.S. Department of Commerce. Future industrial energy demands are calculated for each energy service by converting external (to the

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Table A-l.—Standard Industrial Classification Codes Covered in ISTUM

SIC	Name	SIC	Name
.	Crops	29	Petroleum
2	Livestock	30	Rubber
10, 14	Nonenergy mining	31	Leather
11-13	Energy mining	32	Stone, clay, and glass
15-17	Construction	331	Iron and steel
20	Food	3334	Aluminum
21	Tobacco	334	Other primary metals
22	Textiles	34	Fabricated metals
23	Apparel	35	Nonelectric machinery
24	Lumber	36	Electric equipment
25	Furniture	37	Transportation equipment
26	Paper	38	Instruments
27	Printing	39	Miscellaneous
28	Chemicals		

SOURCE *Standard Industrial Classification* Manual (Washington, D C Office of Management and Budget, 1972)

Table A-2.—Generic Energy Services Used in the Industrial Sector Technology Use Model

Boiler generated steam
Cogenerated steam
Machine drive
Space, H, V, and AC
Electricity generation
Refrigeration
Transportation
Lighting
Direct steam
Heating, dirty
Heating, direct, clean
Drying, dirty
Drying, direct, clean

SOURCE: Mellon Institute, *Industrial Energy Productivity Project, Final Report,* vol. 1, Executive Summary, September 1982,

Table A-3.—Industty Specific Energy Services Used in the Industrial Sector Technology Use Model

Lime calcining	Paper lime calcining
Concentration	Distillation
Paint drying	Cracking
Textile drying	Alkylation
Food drying	Hydrogen production
Metal melting	Hydrotreating
Forging	Reforming
Heat treating, generic	Agglomerate ion
Feed stocks	Iron making
Aluminum melting	Coking
Aluminum heating	Steel making
Aluminum electrolysis	Primary finishing
Brick firing	Secondary finishing
Cementmaking	Heat treating
Glass melting	Organic chemicals
Pulping	Inorganic chemicals
Bleaching	Plastics and resins
Papermaking	Chemical fertilizers
Chemical recovery	Chemical feedstocks
Pulp drying	

SOURCE: Mellon Institute, *Industrial Energy Productivity Project, Final Report, vol.* 1, Executive Summary, September 1982,

model) projections of future product demand into requirements for specific energy services, taking into account anticipated material substitutions and production process changes.

ISTUM technological options are used in three ways: as potential energy conversion technologies, as potential energy carrier technologies, and as possible add-on conservation technologies. It is this multilevel approach that constitutes the basic framework of the technology market competition. Technology competition at each level reflects technology choices made at lower levels. The penetration rates of all technologies are determined after the top-level decision has been made. Relative market shares are then translated into actual investments, and technology penetrations and capital stocks are adjusted accordingly.

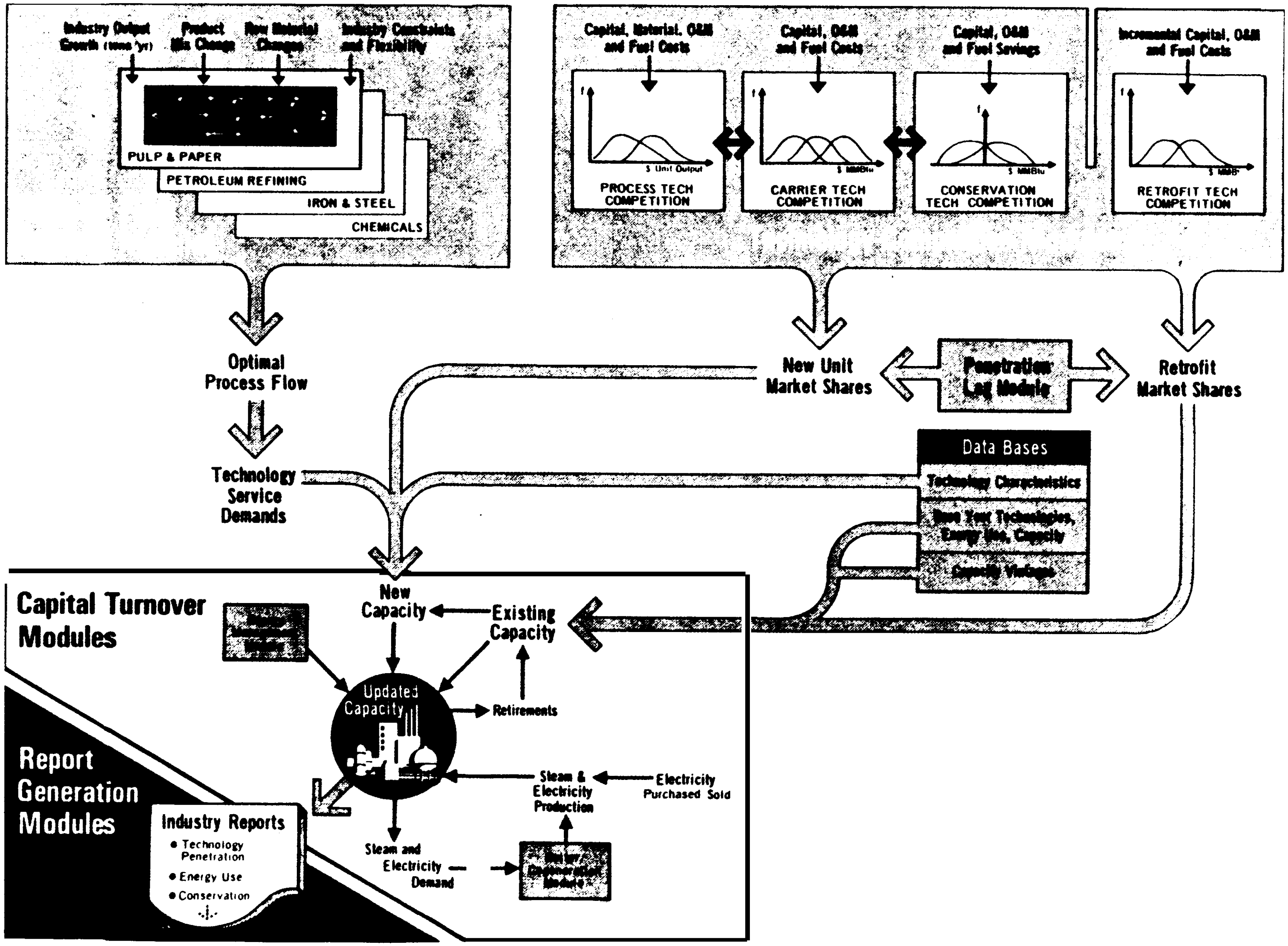
At the top level, energy conversion technologies (i.e., technologies used to process intermediate products or raw material inputs) compete—i.e., are compared side-by-side such that the most cost-effective technology can be identified. Alternative technologies in a given service category may perform the task differently, but will produce the same output. For example, in papermaking, conventional and displacement bleaching technologies can each treat pulps to the desired degree of brightness. These technologies compete against each other under the criterion of minimizing lifecycle cost per unit of product output.

At the next level, energy carrier technologies are compete—i.e., technologies that convert fuel forms to energy suitable for use in energy conversion technologies. For example, fixed- and fluidized-bed combustion technologies could compete in converting coal to useful process heat. In addition, several energy carriers could compete against one another for use in a particular conversion technology. For a given industry, ISTUM will examine the lifetime dollar costs of each energy carrier technology as a function of fuel, capital, labor, and materials costs, and identify that which provides the needed energy carrier at the best cost. These carriers could be primary fuels such as coal, oil, and natural gas, or a processed carrier such as electricity. Processed carriers may be generated within an industrial plant (e.g., low-Btu gas brought onsite as coal and processed in a gasifier) or purchased from an external utility or supplier. Competition at this level is based on minimizing cost per unit of energy service provided. Finally, either a carrier or conversion-level technology may benefit from the addition of equipment that improves the technology's efficiency of energy use. These add-on conservation options, such as heat exchangers, heat pumps, and computer control systems, are examined at the third level, where they compete against the value of the energy they would displace. This competition is based on minimizing cost per unit of energy required.

A key assumption underlying the market competition analysis is that the costs of alternative technologies cannot be represented adequately as single-point estimates, even at the level of disaggregation built into ISTUM. Site-specific factors will often affect costs significantly so that when all such cases are examined, a distribution of costs results. These distributions are developed explicitly within ISTUM.

Comparison of technologies on a lifecycle cost basis requires knowledge of how each industry discounts future costs and the accruing benefits of a given investment. In ISTUM, this aspect of industrial behavior is represented by an explicit discount rate applied over the useful period of the investment. With this approach, one-time investments and recurring operating,

Figure A-1.—Overview of the Industrial Sector Technology Use Model



SOURCE: Mellon Institute, *Industrial Project, Final Report*, vol. 1, Executive Summary, September 1982.

maintenance, and fuel costs can be placed on a common basis, thereby allowing different technologies to be compared on an equivalent basis.

Given the large number of industrial process steps and the even larger number of technologies available to carry out these steps, the first task of the ISTUM market competition analysis was to gather technologies into groups, known in the model as homogeneous cells. Each cell, corresponding to a particular energy service category, allows competition only among technologies that can substitute for one another or for other material or energy inputs. Where appropriate, further disaggregation within a cell can allow for consideration of product quality, marketplace safety, and minimization of environmental insult. In addition, distinctions within a cell are made for four capacity-size classes representing different product output rates (in units per year) and for four technology utilization factors representing the annual rate of unit use (in hours per year). These distinctions are made because some technologies may be technically constrained in certain size and utilization categories and because the costs per unit of output can change for technologies with different levels of output capability.

Within a model cell, basic equipment and other cost components are developed as individual building blocks, thus assuming consistent cost representation among different technologies. Each cell covers such items as process-related equipment, auxiliary equipment, and indirect costs, and is often in the form of a cost distribution, reflecting variations based on site-specific factors. For example, evaluation of a new coal-fired steam boiler involves consideration of building blocks covering site preparation and powerhouse construction, the boiler and related equipment, fuel and waste handling equipment, environmental controls, installation, and indirect capital costs.

Three steps follow completion of the nominal market share competition. First, nominal market shares, derived by minimizing lifecycle costs, are modified by the results of a behavioral analysis. This analysis takes explicit account of the fact that actual industrial decisions are not entirely economically derived. The behavioral analyses incorporate a series of noneconomic-related "behavioral lags, " thereby allowing ISTUM to model to delayed market penetration of certain energy service-providing technologies. These behavioral lags are intended to reflect a host of non-cost factors that cause investment decisions to deviate from strict cost minimization.

Second, given either nominal cost-minimum or behavioral-modified market shares, ISTUM transforms these shares into absolute levels of investment, Total demand for new equipment over a forecast period is derived from data on existing capital stock and rate of growth of product output. In addition, existing capital stock characteristics are modified to account for retrofit upgrade or replacement decisions.