PNL-5225

UC-98F

INTERIM REPORT

ISTUM PC: Industrial Sector Technology Use Model for the IBM-PC

J. M. Roop
D. T. Kaplan

September 1984

Prepared for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy by Battelle Memorial Institute

Battelle

PNL-5225

PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America
Available from
National Technical Information Service
United States Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

NTIS Price Codes
Microfiche A01

Printed Copy

Pages	Price Codes
001-025	A02
026-050	A03
051-075	A04
076-100	A05
101-125	A06
126-150	A07
151-175	A08
176-200	A09
201-225	A010
226-250	A011
251-275	A012
276-300	A013

PNL-5225
UC-98F

INTERIM REPORT

ISTUM PC: INDUSTRIAL SECTOR TECHNOLOGY USE MODEL FOR THE IBM-PC

J. M. Roop
D. T. Kaplan

September 1984

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

ABSTRACT

A project to improve and enhance the Industrial Sector Technology Use Model (ISTUM) was originated in the summer of 1983. The project had six identifiable objectives: update the data base; improve run-time efficiency; revise the reference base case; conduct case studies; provide technical and promotional seminars; and organize a service bureau. This interim report describes which of these objectives have been met and which tasks remain to be completed.

The most dramatic achievement has been in the area of run-time efficiency. From a model that required a large proportion of the total resources of a mainframe computer and a great deal of effort to operate, the current version of the model (ISTUM-PC) runs on an IBM Personal Computer. The reorganization required for the model to run on a PC has additional advantages: the modular programs are somewhat easier to understand and the data base is more accessible and easier to use. A simple description of the logic of the model is given in this report.

To generate the necessary funds for completion of the model, a multiclient project is proposed. This project will extend the industry coverage to all the industrial sectors, including the construction of process flow models for chemicals and petroleum refining. The project will also calibrate this model to historical data and construct a base case and alternative scenarios. The model will be delivered to clients and training provided.

ACKNOWLEDGEMENTS

The authors of this report would like to acknowledge the support, encouragement and able assistance of a number of key contributors to this project. From the Office of Industrial Programs, Department of Energy, several names need to be mentioned. A special debt of gratitude to the contractor monitor, Harry Lane, and others in the Office of Industrial Programs: especially Tyler Williams and Thomas Gross. At PNL, our greatest debt is to Mary Clement, Project Manager, for ideas and many other contributions to this effort. Special programming assistance was received from Carol Winter, at the Battelle Washington Office and Diann Hitzel here at PNL.

CONTENTS

TABLES

FIGURES

1.0 INTRODUCTION

ISTUM (the Industrial Sector Technology Use Model) is a means of projecting the future composition of the stock of industrial equipment. Such projections may be of interest for many reasons. Available stock can be used to forecast energy demand in the industrial sector, to study the response of energy demand to changes in fuel prices or the introduction of new technologies, to estimate the potential market for new (or old) technologies, to assess the effect of changes in industrial processes on energy usage or the purchase of new equipment, or to examine the financial health of industries. This document reports the status of efforts to convert a previous version of ISTUM to a workable microcomputer model which is called ISTUM-PC.

This introduction describes the current project, and introduces ISTUM as a concept. The second chapter explains what industries and technological processes are included in ISTUM-PC, how the four major components are organized into the computer program and describes the ISTUM-PC computer program. The third chapter discusses the methods used in ISTUM-PC--the stock of industrial equipment and how it changes, and the relationship between economic competition models and engineering flow models in ISTUM-PC. The final chapter gives the status of the project to date and describes the remaining work to be undertaken.

1.1 DESCRIPTION OF THE CURRENT PROJECT

The current modification to ISTUM began in the summer of 1983, when the Office of Industrial Programs, Department of Energy (DOE), requested that the Pacific Northwest Laboratory undertake the management of a modest final effort to make ISTUM readily available to the public. A number of tasks appeared necessary if this objective was to be accomplished. To begin, the then-current ISTUM-II version of the model, which was available on the Energy Information Agency (EIA) computer of DOE, would have to be made more efficient. A second task was to update the data base, to the extent that data sources allowed, from the 1976 base year of ISTUM-II to at least 1980. A third task was to make the model more readily available to the public, either by providing a service bureau for the operation of ISTUM and/or converting the model to run on a commercial machine. Another aspect of making the model more readily available was the simulation of a number of case studies. A final task was to publicize and distribute the improved version of ISTUM.

1.2 ISTUM: THE CONCEPT

The answer to the question "Why ISTUM?" is partly the result of historic events since the first oil price shock in the early 1970s. The initial and ensuing oil shocks increased energy costs and there occurred a shift from relatively more energy-intensive industries to relatively less energy-intensive industries. At the same time, industrial firms searched for ways to save on energy expenses by shifting some production to cheaper foreign sites, using energy-intensive byproducts more effectively, purchasing more energy-efficient equipment, or retrofitting to make energy more productive. All of these changes had implications for policy.

During this era, policy concerns focused on the changes in energy consumption, the changes in the mix of technologies, the effects of price shocks on different industries, and the impact of different policies on the economics of the changing world energy situation. These concerns proved difficult to analyze. ISTUM originated as a tool to assist policy makers in evaluating the effects of alternative policies on energy use. The idea behind ISTUM was not merely to predict industrial energy use, but to link the analysis of energy use to industrial processes and technologies which might be affected by policy or economic conditions and thus provide a tool for the detailed analysis of some of the factors influencing industrial energy use.

A number of different modeling options existed. The economic approach is one modeling strategy that could have been used. An economic model uses econometric methods such as the estimation of oroduction functions or cost functions. An alternative economic approach relies on case studies that examine, on an industry by industry basis, the economic forces that influence energy use. A problem with the economic approach is that it does not take into account the physical constraints that govern energy use. In contrast, the engineering approach considers material and energy balances at the process level, then considers the efficiency of these processes and incorporates this information into a model of the industry. A difficulty with engineering models is that the decision to purchase a particular process or plant is inherently an economic one.

A modeling method that combines the engineering and economic approaches and provides for econometric projections of future economic activity would seem to be best suited to the problem of predicting industrial energy use. ISTUM uses this combination approach. The key building block is the industrial process, but the choice of equipment is based on economic factors.

There are a number of advantages to working at the industrial process level. Information is readily available at this level on material and energy balances; on equipment, installation and operation and maintenance costs; on retrofit options available; and on industrial effluents. Moreover, at the process level, an industrial engineer can identify the competeing technologies that can be used in a given process -- continuous digesters versus batch, for example, in pulp production.

When process detail is combined with an economic decision-making framework, a number of other advantages accrue. The economic decision framework allows the introduction of tax and other policy considerations in the economic life and cost calculations of the industrial process. The process costs (capital and installation costs, operating and maintenance costs and fuel costs) and the lifetimes of the equipment are the two major economic factors that enter the decision framework. When these two factors are combined with an appropriate decision rule, ISTUM-PC can determine the purchases of new equipment, when the equipment will be replaced, etc., given the level of required output.

2.0 COVERAGE AND USE OF ISTUM-PC

ISTUM-PC covers the 27 industries whose SIC codes are listed in Table 2.1. Some industries are modeled in more detail than others. In particular, the four largest energy using industries -- petroleum refining, chemicals, paper and pulping, and iron and steel -- are modeled in the greatest detail by use of the process flow models briefly described in section 3.1.2. The industrial processes with which ISTUM deals explicitly are described in section 2.1.

The model is intended to be used by analysts with relatively simple and widely available computing facilities and to allow even inexperienced users to run the model. A general description of the computer requirements and structure of the code is given in section 2.2.

2.1 INDUSTRIAL PROCESSES COVERED BY ISTUM-PC

To model the industrial sector by focusing on separate industries would ignore many of the similarities between industries and much duplication would result. Because industries often use the same processes to produce different products, ISTUM-PC organizes the industrial sector by process type. In ISTUM-PC, the industrial sector is comprised of 52 process types, called "energy service categories." The scope of each service category is chosen to be convenient for the model's operation and to correspond to common-sense divisions in the structure of the industrial sector. For example, papermaking is a service category, as is space conditioning.

Some service categories are generic in that they apply to more than one industry: the direct steam and machine drive service categories are examples. Other service categories such as aluminum melting and papermaking apply to only one industry. The service categories in ISTUM are listed in Table 2.2. The first 21 service categories apply to more than a single industry, while the remainder generally will apply to only a single industry.

A service category consists of a collection of different pieces of equipment called technologies. To give substance to the idea of a technology and to indicate the detail used in the model, Table 2.3 lists all of the technologies associated with the production of pulp included in ISTUM-PC. The types of pulpers are organized under several headings: chemical pulp, semi-

TABLE 2.1. Industry Groups and their Applicable Service Categories[a]

SIC	Name	Applicable Service Category Codes
1	Crops	7
2	Livestock	6, 7
3	Non-energy mining	5, 7, 19, 12
4	Energy mining	5, 7, 9, 12
15	Construction	5, 7, 22
20	Food	7, 11, 15, 18
21	Tobacco	9, 13
22	Textiles	9, 17
23	Apparel	9, 17
24	Lumber	9, 11
25	Furniture	9, 11, 16
26	Paper	15, 29-34
27	Printing	9, 13
28	Chemicals	48-52
29	Petroleum	35-40, 22
30	Rubber	9, 11
31	Leather	9, 13
32	Stone, clay & glass	9, 10, 11, 14, 26, 27, 28
331	Iron & steel	41-47
3334	Aluminum	9, 22-25
334	Other primary metals	9, 11, 19-21
34	Fabricated metals	9, 10, 11, 13, 16, 19, 20, 21
35	Non-electrical machinery	9, 10, 12, 13, 15, 19, 20, 21
36	Electric equipment	9, 11, 16, 19, 20, 21
37	Transportation equipment	9, 11, 16, 19, 20, 21
38	Instruments	9, 11
39	Miscellaneous	9, 11

(a) Service Categories 1, 2, 3, 4 and 8 apply to all industry groups and are not listed here.

TABLE 2.2. Energy Service Categories

Number	Name	Number	Name
1	Boiler generated steam	27	Cement making
2	Cogenerated steam	28	Glass melting
3	Machine drive	29	Pulping
4	Space, H, V, and AC	30	Bleaching
5	Electricity generation	31	Papermaking
6	Refrigeration	32	Chemical recovery
7	Transportation	33	Pulp drying
8	Lighting	34	Paper lime calcining
9	Direct steam	35	Distillation
10	Heating, dirty	36	Cracking
11	Heating, direct, clean	37	Alkylation
12	Drying, dirty	38	Hydrogen production
13	Drying, direct, clean	39	Hydrotreating
14	Lime calcining	40	Reforming
15	Concentration	41	Agglomeration
16	Paint drying	42	Ironmaking
17	Textile drying	43	Coking
18	Food drying	44	Steelmaking
19	Metal melting	45	Primary finishing
20	Forging	46	Secondary finishing
21	Heat treating, generic	47	Heating treating
22	Feedstocks	48	Organic chemicals
23	Aluminum melting	49	Inorganic chemicals
24	Aluminum heating	50	Plastics and resins
25	Aluminum electrolysis	51	Chemical fertilizers
26	Brick firing	52	Chemical feedstocks

chemical pulp, and mechanical pulp. Kraft pulp can be produced by two different types of machines--batch digesters or continous digesters. At the level of a specific technology, a batch digester can stand alone or it can operate with computer controls. It can operate with a blow heat recovery device, or it can be structured to have both conservation options apply. Collections of technologies such as this one for pulp are called service categories.

Industries are represented as collections of service categories. The paper industry (SIC 26) consists of the service categories pulping, pulp drying, bleaching, papermaking, paper drying and others. The set of service categories that comprise each of the 27 industries in ISTUM-PC are shown in Table 2.1.

Chapter 3 briefly describes the method used by ISTUM-PC in dealing with each service category. The modeling of an industry consists of the application of this method to each of the service categories in an industry. Figure 3.3 is meant to indicate the relationship between industries and service categories in ISTUM-PC. (The reader might find it helpful to refer to Figures 3.1 and 3.2 in interpreting Figure 3.3.)

2.2 OVERVIEW OF MODEL COMPONENTS

ISTUM-PC was designed -- as the name suggests -- to operate on desktop computers such as the IBM-PC. At least 512 kbytes of memory are needed. The model will run on a machine with two floppy disk drives, although the use of a hard disk considerably adds to the speed and convenience of the model.

The exact speed of execution of the model of course depends on the type of computer being used and the parameters of the model run. One of the large four industries will take about 15-25 minutes per year on an IBM-PC with a hard disk, or about 1-1.5 hours for a four year run (e.g. 1985, 1990, 1995, 2000). The smaller 23 industries can be run faster.

The cost of a model run is essentially zero since computer time on computers such as the IBM-PC is virtually free once the computer has been purchased. This is true especially since the model can be set up to run without supervision over a lunch hour or overnight.

TABLE 2.3. Technologies for Pulping in ISTUM-PC

Technology	Pulp Type	
Batch Digester, Kraft	Chemical Pulp	Pulp
Batch Digester, Kraft, with CC[a]	Chemical Pulp	Pulp
Batch Digester, Kraft, with BHR[b]	Chemical Pulp	Pulp
Batch Digester, Kraft, with CC and BHR	Chemical Pulp	Pulp
Continuous Digester, Kraft	Chemical Pulp	Pulp
Continuous Digester, Kraft with CC	Chemical Pulp	Pulp
Alkaline-Oxygen Digester	Chemical Pulp	Pulp
Alakline-Oxygen Digester with CC	Chemical Pulp	Pulp
NSSC[c] Batch Digester	Semi-Chemical Pulps	Pulp
NSSC Batch Digester with CC	Semi-Chemical Pulps	Pulp
NSSC Batch Digester with BHR	Semi-Chemical Pulps	Pulp
NSSC Batch Digester with CC and BHR	Semi-Chemical Pulps	Pulp
NSSC Continuous Digester	Semi-Chemical Pulps	Pulp
NSSC Continuous Digester with CC	Semi-Chemical Pulps	Pulp
Groundwood Pulp--Size I	Mechanical Pulps	Pulp
Thermomechanical Pulp--Size I	Mechanical Pulps	Pulp
Thermomechanical Pulp--Size I with VR[d]	Mechanical Pulps	Pulp
Groundwood Pulp--Size II	Mechanical Pulps	Pulp
Thermomechanical Pulp--Size II	Mechanical Pulps	Pulp
Thermomechanical Pulp--Size II with VR	Mechanical Pulps	Pulp
Secondary Pulp		Pulp

(a) CC: Computer Controls
(b) BHR: Blow Heat Recovery Device
(c) NSSC: Neutral Sulphite Semi-Chemical Process
(d) VR: Vapor Recompressor

Aside from the model's computer programs and data which are provided on floppy diskettes, the model requires a commercial software product, the STSC Inc. APL*Plus PC interpreter for the APL language. This interpreter is available for a number of IBM-PC compatable machines and does not require any hardware changes to the computer. (However, installation of a special character generator chip is required if the model user wishes to be able to write his or her own APL code -- something not required to operate ISTUM-PC.) It is possible to transfer ISTUM-PC to a mainframe computer at small cost if the mainframe is equipped with an STSC APL*Plus interpreter, or at larger cost if only a non-STSC interpreter is available.

The ISTUM-PC computer program is organized into four major components. The first component is a "front-end" that prompts the user for information that will determine how the model is to be solved and allows the user to alter scenario assumptions. The second component is called the "master module" and handles the bulk of the computations--market share calculations, stock turnover calculations, and other computations that are the topics for discussion in Chapter 3. The third component is a report writer that uses the results from the master module to organize, calculate and produce the reports requested by the user. A fourth component consists of the industry data files and the storage of results. The logic of ISTUM-PC can best be described by reference to these four components shown in Figure 2.1.

The data manager for ISTUM-PC is the first component that the user sees. In Figure 2.1 this component is labeled "Define Simulation Parameters," which is one of the major functions of the front-end. By query, a number of options are chosen, including the industries selected and the dates for which the model is to be run. When all the parametric information is obtained to run the model, the user is given a choice of altering input assumptions or proceeding directly with the simulation. If assumptions are to be changed, then the user is allowed to alter either fuel prices or industry growth rates or both. The simulation parameters and input assumptions are then stored, and control is passed to the master module.

The master module is the main computational segment of ISTUM-PC. When control is first passed to this segment, appropriate files are allocated, the environment is structured appropriately for the run, and the work

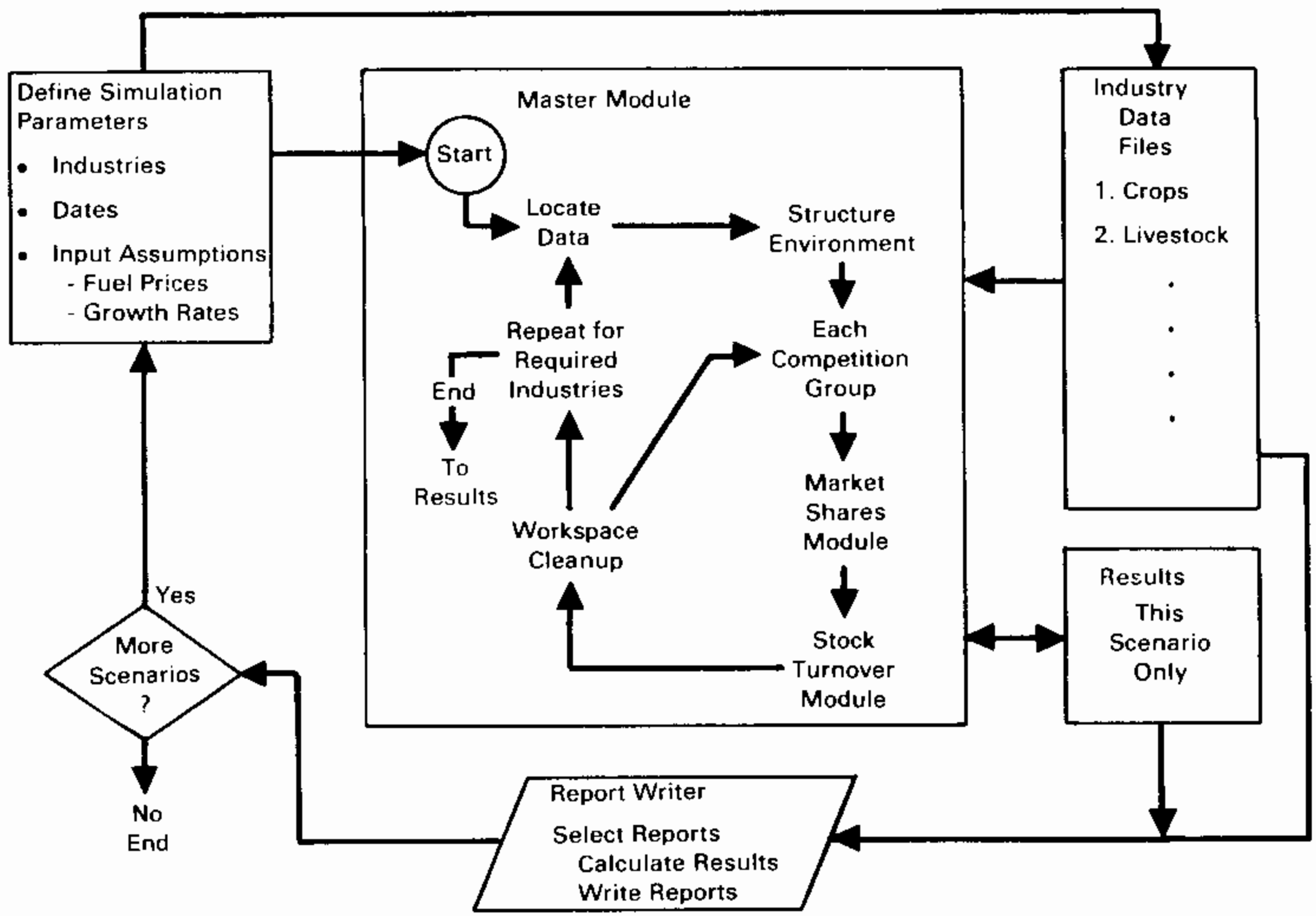

FIGURE 2.1 Overview of Model Components

begins. First market shares are calculated for the competition groups that apply to this industry or block of industries in the market share module. Then stocks are updated in the stock turnover module and the results of these calculations stored. At this point the working area is purged of extraneous variables and data and the program determines if further calculations are to be oerformed. This is done for all competition grouos in an industry (or industry block), all industries, for each time period requested until all calculations are complete and the results stored. Then control is transferred to the report writer.

The report writer determines what reports are to be constructed by a query system similar to the query system used initially to define simulation parameters. The data needed to calculate the requested information is then drawn from the industry data and output files. Finally, it constructs the requested reports. These can either be saved or immediately written to a printer. Report writing capabilities in ISTUM-PC have been structured so that the results of a model run can be saved on floppy diskettes for later use or comparison with later runs of the model. Although the exact amount of diskette soace required for the results of a model run depend on the parameters used for that run, tyoically one of the large industries can fit on a single diskette, and all 27 industries on three to four diskettes.

Fundamental to these first three components are the data. The basic data for all industries are stored in 9 blocks. Some of these blocks contain a single industry, others, several industries. Blocks are structured to contain approximately the same number of technologies, regardless of the number of industries included. Thus there are six blocks with a single industry because these industries use a considerable number of industry soecific technologies that are not used in other industries. Any of the blocks easily fit on a singe floppy diskette, and multiple copies of block data can be made so that data can be changed for some model runs when appropriate.

3.0 THE ISTUM-PC METHOD

The purpose of ISTUM-PC is to predict the future composition of industrial stock, and hence calculate industrial energy use and effluent discharges. In order to do this, it is necessary 1) to keep track of existing industrial stocks as they are retired or retrofitted, and 2) to determine what new industrial equipment will be acquired. In parallel with these two requirements, the calculations in ISTUM-PC are broken into two main parts: 1) the stock turnover module, and 2) the market shares module. The market shares module is a model of the competition of technologies for shares of the market for future acquisition of equipment. The stock turnover module is a model of the retirement of existing stocks and the incorporation of new acquisitions into the overall industrial stock. This chapter describes what the two modules do and how they work. Since different industries do not interact in the model, the explanation will proceed as if the calculations applied to a single industry. ISTUM-PC applies the method to each of the 27 industries that comprise the industrial sector.

3.1 THE MARKET SHARES MODULE

The main task of the market shares module is to estimate how the demand for future new industrial stock will be translated into the purchase of specific technologies. As mentioned in Section 1.2, ISTUM-PC is a combination of an economic and an engineering process approach to modeling. In the market shares module, the two approaches fit together roughly like this: the engineering approach is used to determine what will be the relative demand for the various energy service categories; and the economic approach is used to determine how the different technologies will compete to fulfill the demands specified by the engineering approach. The structure of the market shares module is shown in Figure 3.1.

3.1.1 Service Categories and the Economic Approach to Modeling

The demand for an energy service category is determined by assumptions about industrial growth or demand for final products. Once this demand is known, ISTUM-PC must determine which specific technologies will be acquired to meet that demand.

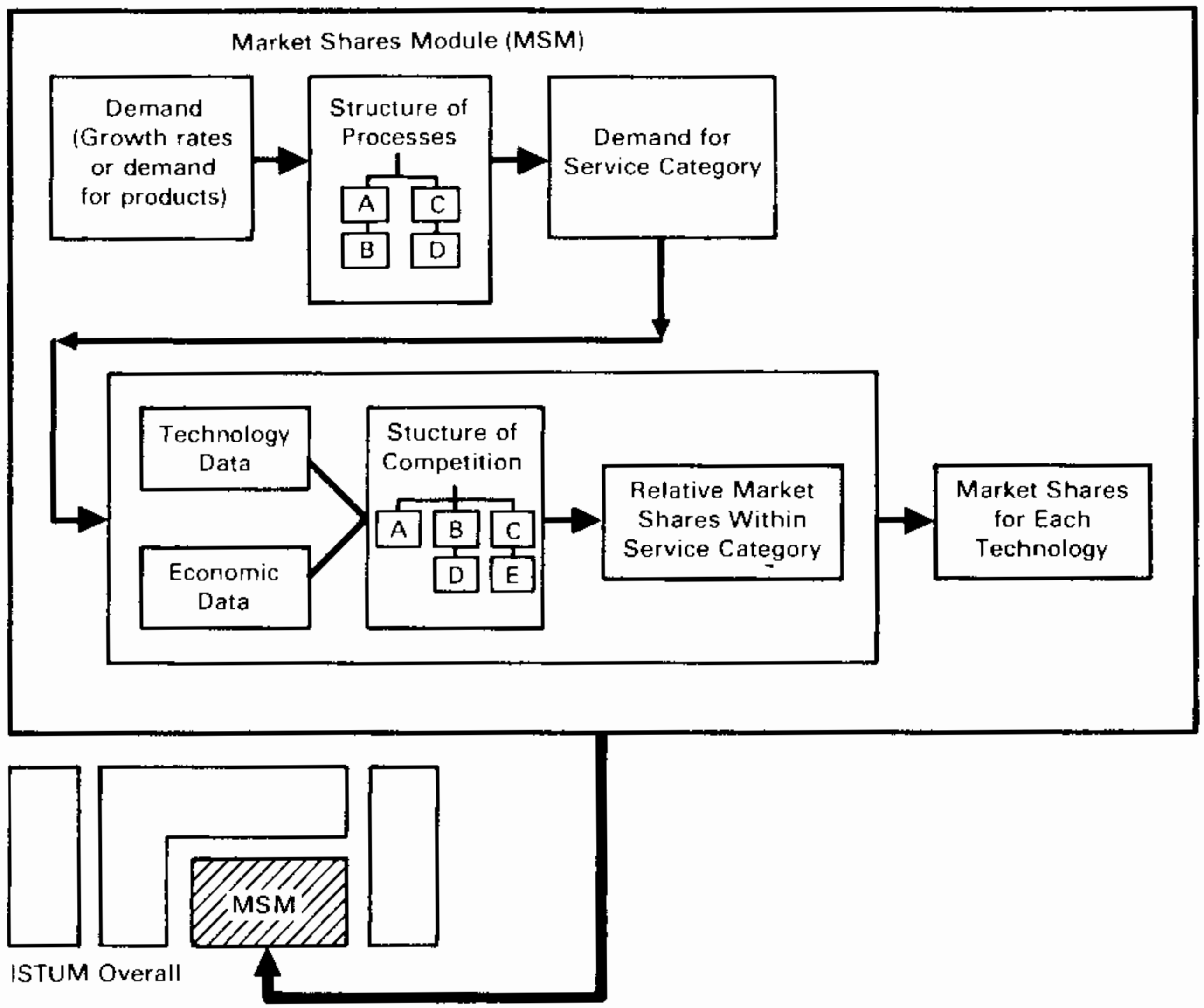

FIGURE 3.1 Structure of Market Shares Module

There are, however, an overwhelming number of technologies. It would be virtually impossible to keep track of the production capability and specific characteristics of every single type of industrial machine. Therefore, ISTUM-PC simplifies the situation by modeling only those types of machines deemed necessary to represent the variety of real world industrial processes adequately.

The success of the model in predicting changes in the composition of industrial stocks depends largely on the set of machine types represented in ISTUM and on the accuracy with which these machines are characterized (e.g., energy use per unit output, capital costs, etc.). With these two factors in mind, ISTUM-PC has been constructed so that either the set of machines or their characteristics can be fairly easily altered.

Each of the machines represented in ISTUM is called a technology. In most cases, a technology is based on an actual machine that could be bought "off the shelf." In other cases, a technology may be an idealized representation of a collection of real world machines.

A technology is a complete set of equipment that consumes energy and raw material and produces an industrial product, e.g., pulp or ammonia. Thus a batch Kraft digester with computer controls is one technology, and a batch digester with a blow heat recuperator is another technology. The computer control, however, is not itself a technology as far as ISTUM is concerned: it is merely a component of a technology. Such components have no separate existence in the model. They come into play only to the extent that they influence the operating characteristics or costs of technologies.

To illustrate the idea of a technology, Table 2.2 lists all of the technologies included in ISTUM-PC associated with the production of pulp. The types of pulpers are organized under several headings: chemical pulp, semi-chemical pulp, and mechanical pulp. Kraft pulp can be produced by two different types of machines--batch digesters or continuous digesters. At the level of a specific technology, a batch digester can stand alone, can operate with computer controls, can operate with a blow heat recovery device, or can be structured to have both conservation options apply.

The basic assumption of ISTUM-PC is that technologies compete on the basis of life cycle cost (LCC) per unit output. Life Cycle Cost is the sum of capital costs, operating and maintenance cost and energy cost. It takes into account interest rates, investment tax credits and the expected lifetimes of the equipment. Energy costs are calculated from engineering data on fuel used per unit output and fuel prices. Capital cost and operating and maintenance cost for each technology are included int the ISTUM-PC database.

The LCC for each technology is assumed to have a probability distribution. The market share for a technology in the model is the probability that it has a lower life cycle cost than all other competing technologies. In most cases, therefore, the single "lowest cost" technology will not be the only one purchased. Typically, the several competing technologies will each take a share of the market, with the market share for each technology being determined by the life cycle cost.

The market shares module was designed to be flexible. The model currently uses cost per unit output as a basis for evaluating the competitiveness of a technology. We expect that this will be the variable chosen by most users of ISTUM-PC. However, it is possible to apply alternative criteria to determine the competitiveness of technologies. For example, one might wish to use a combination of cost per unit output and pollution per unit output to evaluate the competitiveness of technologies. This would allow the analyst to use ISTUM-PC to simulate various pollution regulations.

In actual practice, not all users of a particular technology will desire equipment of the same size nor will the equipment receive the same use. Obviously, the cost per unit output of the equipment will depend both on how intensively it it used and how large it is. Therefore, given the same economic conditions, users will tend to make different choices when acquiring equipment. A low capacity user, for example, may tend to purchase equipment with low capital cost, but perhaps high energy cost. A high capacity user might be more willing to trade higher capital cost against reduced energy use.

In order to account for differences in equipment choice, ISTUM-PC calculates relative market shares for every technology for two size and two capacity utilization rates. The two size and two capacities for four size-capacity utilization categories (S/CU categories) that are defined for each technology based on technical considerations and actual industry practice. The market share calculations are undertaken, individually, for each of the four S/CU categories, with no interaction among the S/CU categories.

In many cases, the same basic technology is represented more than once in ISTUM-PC in order to include the possibility of adding on different conservation options or using different fuels. For example, in Table 2.3, the NSSC batch digester is lised four times while the alkaline oxygen digester is listed twice. For the NSSC digester, the second through fourth entries repeat the first digester with different convervation options added. The second alkaline oxygen digester adds a single conservation option, computer controls. But there is a difficulty with repetitions of technologies. In probabilistic models, the more occasions the technology appears, the more likely it will garner a larger market share. In order to avoid this tendency, ISTUM-PC structures the competition of technologies so that similar technologies are competed against one another before they compete against less similar technologies.

3.1.2 Flow Models and the Engineering Modeling Approach

The total size of the market in ISTUM-PC is specified in terms of industrial growth rates or alternatively in terms of the demand for final products (e.g., the total demand, in tons, for paper of all sorts). In order to transfer these to a demand for industrial equipment and set the stage for the economic model described in section 3.1.1, it is necessary to determine how industrial growth rates or demands for final products affect the demand for the service categories.

If total demand is given in terms of industrial growth rates then a very simple method is used. For each of the service categories a demand is specified, either directly or as a function of the assumed growth rate of the industry. These growth rates, by industry, are assumptions that are inputs to the model. The service category demand is expressed as the capacity needed of output (e.g., so many million Btu of steam in the food processing industry). This number is usually calculated by multiplying the growth rate of the industry times the base period stock of steam generating equipment. In other words, one assumes that as output increases, the requirements for steam grows in lockstep with that growth in output. This targets a level of capacity for each service category that is included in a particular industry. The drawback to this simple approach is the assumption that all service categories grow at the same rate as industry output. In some cases, the demand for service categories may depend strongly on factors peculiar to an industry such as the supply of scrap steel or changes in the demand for the slate of petroleum products.

In the case of the four largest industrial energy users -- petroleum, chemicals, pulp and paper, and iron and steel -- the total size of the market is specified in terms of demand for final products. In these cases, a process flow model is constructed which determines what will be the demand for the various energy service categories by tracing material flows from one process to another. Characterizing an industry with a flow model begins with a description of the sequence of processes that comprise an industry. A simplified example is given for the paper industry as follows: the pulping process yields pulp which is bleached and then washed and subsequently sent to papermaking stage which consists of web formation, pressing, and drying. There are a variety of complications that must be represented in the flow model. For example, not all types of pulp can be used in the production of all types of paper, pulp from continuous digesters is usually not dried, etc. Fully characterizing the paper industry requires that other process sequences, such as chemical recovery and production of steam be included. Many of these processes can be organized as parallel flow models.

There are four more or less separate models within the pulp and paper flow model. The one is paper, which consists of the sequence of processes mentioned above. For this model, demand is measured on the basis of tons of paper (5 percent moisture). This demand is factored into three types of paper--tissue, coated and other--because there are special drying requirements for tissue and coated paper. The drying capacity demanded to produce so many tons of paper takes into account that the paper feeding into the main (steam drum) drying process is 65 percent moisture. Similarly, the demand for pressing capacity takes into account that the formed web is over 90 percent water and loses over 30 percent of its volume as it is pressed. In similar fashion, the material balances are accounted for throughout the flow model in order to determine the capacity requirements for each type of equipment used in that competition group. Furthermore, a flow model can be constructed so that other service category demands--in this example, chemical recovery, machine drive and steam--are derived from previously calculated requirements. Capacity for recovery of the chemicals in black liquor produced by Kraft and other chemical pulping processes will clearly depend on the pulp produced by these processes. A recovery furnace in this service category (chemical recovery) produces steam by burning the lignins removed from wood during the chemical pulping process. This must be taken into account in determining the demand for steam, which is another service category in the paper industry flow model.

3.1.3 Competition Groups

The above distinction between service categories and flow models has been a little misleading in one sense, because both the economic competition between technologies and the determination of the demand for service categories are done by the same general method. There is a much more thorough integration of the engineering modeling approach and the economic modeling approach than is implied by the above description. The flow models can consider the costs of technologies in deciding between processes, and the competition between technologies within a service category can include engineering constraints.

The set of all technologies in the service categories linked together by a process flow model is called a competition group. It is possible for technologies in different service categories to compete with one another if they are in the same competition group.

3.2 STOCK TURNOVER MODULE

The stock turnover module is the second of two main components of ISTUM-PC. The stock turnover module does three main things. It keeps track of the retirement and retrofitting of old stock; it uses the results of the market shares module to determine the demand for service categories; and it calculates how much new stock must be acquired. Using this information and the results of the market shares module, it updates the stock of equipment. From this updated equipment stock, total energy use can be calculated. An overview of the processes employed in the stock turnover module is provided in the remainder of this section and illustrated in Figure 3.2.

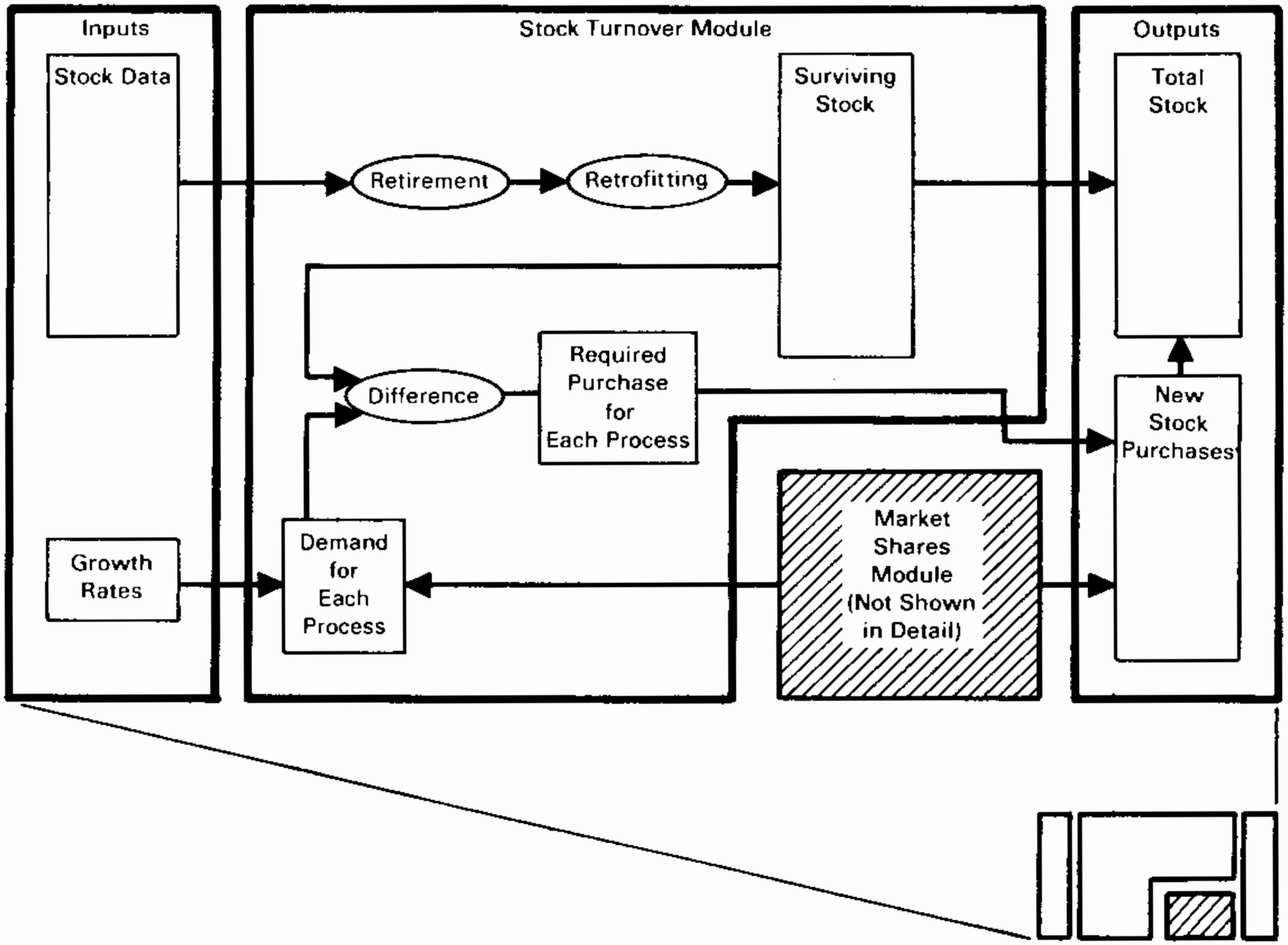

FIGURE 3.2 Structure of Stock Turnover Module

3.2.1 Tracking Stocks

ISTUM-PC measures the stock of a particular technology in units of physical output; i.e. the stock of a particular type of paper pulper is measured in tons of output per year. The way ISTUM represents stock is different from measuring stock in terms of the number of machines, or the dollar value of output, or even the total capacity of all installed machines. It is more a measure of the average capacity that can be used to produce a particular output under normal operating conditions. An ISTUM stock report is a report of physical production levels, and therefore not directly a report of the number of machines or the value of output.

The base year stock data are fundamental to the stock turnover module. The base stock is the amount of each technology (in units of physical output) that existed in the base year of the model (1980). ISTUM uses this base stock and assumptions about retirements to produce information on the total stock in each of the model years, based on new stock acquired between model years. For example, if the model is run for 1984, 1988, 1992, 1996, and 2000, projections are made for total stock in each of these years, or for the stock purchased in the intervals 1981-84, 1985-88, 1989-92, 1993-96, and 1997-2000.

3.2.2 Retirement and Retrofitting of Stock

Stock is retired for two reasons in ISTUM-PC. Economic retirement occurs when stock becomes so uneconomical to operate that it is scrapped even though it has not worn out physically. Economic retirement also occurs in ISTUM through retrofitting. Scheduled retirement occurs when stock has reached the physical limits of its useful life. Stock may be retired either because it has worn out and stopped operating, it has become unsafe or obsolete, or because it has become too expensive to maintain in working order. The best distinction between economic retirement and scheduled retirement is that scheduled retirement is due solely to thhe nature of the equipment, while economic retirement is caused by changes in economic conditions (e.g. fuel prices).

The stock turnover module is concerned primarily with scheduled retirement. Typically, not all the stock of a particular technology acquired in a given year is retired at the same tiime. Some equipment breaks down or is destroyed early in its life while other equipment of the same type may be kept running long past its predicted life. The probability that a piece of equipment will have been retired by a certain time is contained in survival curves which can be specified individually for each technology. ISTUM-PC makes the reasonable assumption that the same curve applies to a given technology whenever it is purchased. Thus, the same survival fraction applies to 1985-vintage equipment in 1995 as applies to 1990-vintage equipment in the year 2000.

Base stock is treated slightly differently when being retired. Rather than keep track of the different vintages of base stock (which would be computationally expensive and for which no solid data exist) a separate retirement curve is maintained for base stocks which represents the vintages of base stock.

Economic retirement of stock occurs when economic conditions change to the point where it is worthwhile to discard equipment before it is worn out, or to retrofit the equipment. In ISTUM-PC, retrofitting means converting one technology to another. This is handled by a logic very similar to the described for new equipment market shares in section 3.1.1. A technology is retrofitted to another when it is possible to do so and the life cycle cost of carrying out the retrofit (the sum of capital expense and changes in fuel and operating and maintenance costs) is less than zero. As with the market share calculations, retrofit life cycle cost calculations are done probabalistically.

3.2.3 New Purchases of Stock

Given the base year's stock, stock purchased in previous model years, and retirement and retrofitting, the amount of surviving production capacity in each service category can be calculated. The demand for each service category is determined in the market shares module (see section 3.1.2), and the difference between this demand and the surviving production capacity is the amount of new equipment which must be purchased. (Actually, the demand for and supply of stock is not calculated at the service category level, but at the finer level of groups of technologies which can directly substitute for one another.) This amount is allocated among specific technologies according to the market shares determined in the Market Shares Module. The result is stored both in terms of new stock purchased, and total stock in production.

In the event that surviving stock in a particular category exceeds demand for stock, no new stock is purchased in that category and the total stock in production reflects the actual production level rather than the amount of surviving stock. Thus, ISTUM-PC can, to a limited extent, incorporate the mothballing of stocks.

3.2.4 Modules and Service Categories

The relationship between the market shares module and the stock turnover module is indicated in Figures 3.1 and 3.2. The market shares module is more or less independent of the stock turnover module, however, the stock turnover module uses the results of the market shares module in determining the size of the market for service categories. The relationship between the service categories and the industries for which the model is being run is shown in Figure 3.3. Whenever two or more industries are being run and they share a service category, the calculations for both industries for that service category are done at the same time.

3.3 OUTPUTS OF THE MODEL AND ENERGY USE

The two major outputs of the stock turnover module are the amount of new stock purchases and the total stocks of equipment in use. Both of these are given for each technology for each year of the model run.

Energy use is calculated during the printing of reports on energy use. It is calculated by multiplying the stock in use of each technology by the amount of fuel of different types used by that technology. Thus, it is possible to get energy use reports of different detail -- energy used by fuel in each industry, energy used in each process, and energy used by each technology. It is also possible to get reports on the effluents discharged, and on intermediate fuel produced and used in an industry (e.g. black liquor in the paper industry or blast furnace off gas in the iron and steel industry).

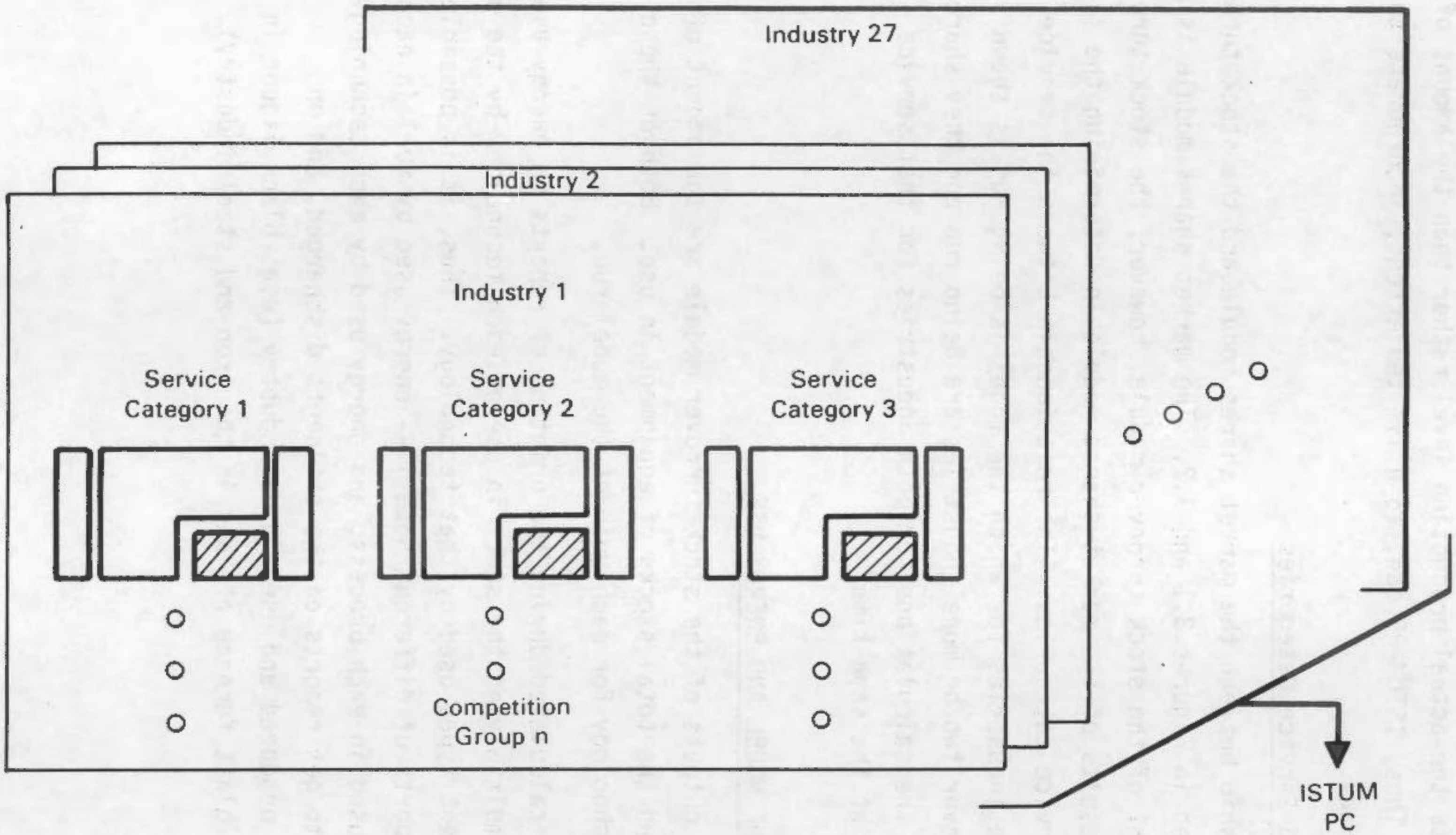

FIGURE 3.3. How Competition Groups Fit Into Industries

4.0 PROJECT REPORT: STATUS AND REMAINING TASKS

The current project that has led to the development of ISTUM-PC has not, at this juncture, been completed. Although cosiderable progress has been made on the ambitious set of tasks outlined originally, funding has simply not been adequate to complete ISTUM-PC. But work toward that goal is proceeding, and a method of funding the remainder of the work has been agreed upon. This chapter will describe the current status of the project--the topic covered in the section 4.1. Section 4.2 describes the remaining tasks to be completed over the next several months. But even this further work will not see the model completed. The final section of this chapter details the proposed method of providing for the transfer of the model to potential clients--industry planning groups, trade and industry associations, research institutions and public institutions.

4.1 CURRENT STATUS OF ISTUM-PC

The project that originated in the summer of 1983 had six identifiable objectives: update the data base, improve run-time efficiency, revise the reference base case, conduct case studies, provide technical and promotional seminars, and organize a service bureau. While some of these objectives have been met, others have been only partially achieved. The most dramatic achievement has been in the area of improving run-time efficiency. From a model that required a large proportion of the total resources of a main-frame computer and a great deal of effort to operate, ISTUM-PC currently runs on an IBM Personal Computer. Moreover, the organization of the supporting data base and program files allows the model to comfortably operate in that environment, and simplifies both the updating of the data and changes to the structure of the model. The last two objectives--conducting seminars and organizing a service bureau--have also been partially achieved.

The main shortcomings in achieving all the objectives of the original project are in the industrial coverage of the current version of ISTUM-PC, the calibration to historical data, and in some technical attributes of the program. Of the 27 industries that comprise the industrial sector, ISTUM-PC currently includes 16 minor industries (from an energy use perspective) and a flow model of the pulp and paper industry. That leaves three other major energy consuming industries for which there are no flow models, and seven minor industries yet to be included. From the perspective of technical model development, ISTUM-PC is currently short the capability to retrofit equipment stocks, which are a major mechanism by which industry improves the productivity and energy efficiency of equipment. Finally, credibility of ISTUM-PC requires that the model be calibrated to historic energy use data. Progress over the summer will solve the retrofitting problem, add to the coverage of the model, and organize a project that will see the work completed.

4.2 WORK IN PROGRESS

Work in progress over the summer of 1984 will see the completion of four tasks. ISTUM-PC will be expanded to include the retrofitting of technologies; a process flow model of the iron and steel industry will be constructed; documentation of ISTUM-PC will be drafted for review; and a more user friendly front-end will be developed. In addition to these tasks, the groundwork will be established for a multiclient project which will see ISTUM-PC completed.

The retrofitting of technologies in ISTUM-PC is critical to the model's ability to track energy use. Even in periods of economic recession, when new plant and equipment purchases are severly curtailed, retrofitting that is cost effective is carried out. These cost saving measures can dramatically improve the energy efficiency of production processes, and significantly change the energy-output ratios. Clearly if a model is to replicate industrial energy use, it must account for the retrofitting of technological stocks. By the end of FY 1984, ISTUM-PC will account for retrofitting. As of this report, the design phase of the retrofitting changes to the model have been made, and the computational algorithms have been worked out. What remains is the computer coding of the algorithms, testing and debugging, and implementation into the model.

Work is currently in progress on two other tasks: the design of the front-end to ISTUM-PC and constructing of a model of the iron and steel industry. An earlier description of the model (Section 1.3) explained how the front-end of ISTUM-PC would work. That portion of the program is currently being translated into computer code. The iron and steel flow model will begin with the model developed previously for ISTUM-II, but will take into account the dramatic changes that have occured in this industry over the past several years.

Additional documentation will also be completed by the end of the summer. This document serves as an overview of ISTUM-PC. To follow are three other volumes that will provide more detail concerning the struture of the model, a user's guide to explain how to use ISTUM-PC, and more technical documentation of the model, itself. Currently drafts of all these documents exist in various stages of completion and are being revised.

4.3 TECHNICAL TRANSFER OF ISTUM-PC

When the above tasks have been completed, ISTUM-PC will be have a demonstrated set of capabilities that industrial planning groups and other potential clients will find attractive. Yet ISTUM-PC will not be complete. Funding for the remaining work, logically, should come from the primary beneficiaries. Our strategy for soliciting these funds is to propose a multiclient project that will provide ISTUM-PC to the prospective client with several further tasks completed. Foremost among the deliverables will be a completed model--flow models for petroleum refining and chemicals would be constructed and the seven minor industries would be added. Once the model is complete, some considerable effort would be devoted to calibrating the model to actual, historic, energy use by industry. A final deliverable would he a training program for ISTUM-PC users.

5.0 REFERENCES

U.S. Department of Energy. October 1979. Industrial Sector Technology Use Model (ISTUM): Industrial Use in the United States, 1974-2000. Final Report DOE/FED/2344-1, 2 volumes. Washington, D.C.

U.S. Department of Energy. February 1983. Industrial Energy Productivity Project - Final Report. DOE/CS/40151-1, 9 Volumes. Washington, D.C.

DISTRIBUTION

No. of
Copies

OFFSITE

Peter Back
U.S. Department of Energy
Alcohol Fuels
Forrestal Building
1000 Independence Avenue
6th Floor - Mail Stop CE-82
Washington, DC 20585

Richard Barnes
Oak Ridge National Laboratory
P.O. Box X, Mail Stop H-32
Oak Ridge, TN 37831

Robert Benny
U.S. Department of Energy
Mail Stop PE-142
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

Mark Bragen
Argonne National Laboratory
Building 362-EES
9700 South Cass Avenue
Argonne, IL 60439

John J. Brogan, Director
U.S. Department of Energy
Office of Energy Systems
Research
Mail Stop CE-14
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

Cal Burwell
Oak Ridge Associated Universities
PO Box 117
Oak Ridge, TN 37830

John Cadogan
U.S. Department of Energy
Mail Stop CE-331
Forrestal Building
1000 Independence Avenue
Washington, DC 20585

No. of
Copies

OFFSITE

Elton Cairns
Associate Laboratory Director
Lawrence Berkeley Laboratory
Berkeley, CA 94720

Lynda T. Carlson
Director of Energy End Use
U.S. Department of Energy
Energy Information Administration
Mail Stop EI-65
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

Joseph A. Carpenter
Oak Ridge National Laboratory
P.O. Box X
Oak Ridge, TN 37830

Bob Copeland
Industrial Energy Division,
EM&R Canada
580 Booth Street
Ottawa, CA K1A 0E4

John Corliss
U.S. Department of Energy
Policy, Safety and Environment
Mail Stop PE-33
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

Bruce Cranford
Office of Planning & Environment
U.S. Department of Energy
Mail Stop FE-13
Germantown, MD 20545

Robert Creese
Industrial Engineering Department
West Virginia University
721 Engineering Science Building
Morgantown, WV 26506

No. of Copies

OFFSITE

Patrick Crowley
Federal Energy Regulatory Commission
U.S. Department of Energy,2c-874
825 N. Capital Street
Washington, D.C. 20426

Peter Davis
Joint Tax Committee
U.S. Congress
Washington, DC 20515

Robert H. Drake
Group Leader - Economics
Los Alamos National Laboratory
PO Box 1663 M/S F605
Los Alamos, NM 87545

Richard L. Durham
U.S. Department of Energy
Bonneville Power Administration
1002 N.E. Holladay Street
PO Box 3621
Portland, OR 97208

Bruce Dwyer, Director
Planning and Evaluation
Office of Planning & Resources
Energy Information Administration
U.S. Department of Energy
Mail Stop EI-32
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

Dr. James J. Eberhardt
U.S. Department of Energy
Division of Energy Conversion
and Utilization Technologies
Mail Stop CE-142
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

Joyce Economous
Bonneville Power Administration
Office of Conservation
Division of Program Design
1002 N.E. Holladay Street
Portland, OR 97232

No. of Copies

OFFSITE

Ev Ehrlich
Congressional Budget Office
Room 410, House Annex 2
U.S. Congress
Washington, DC 20515

J. Erich Evered
Administrator
U.S. Department of Energy
Energy Information Administration
Mail Stop EI-1
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

Dwight French, Director
Office of Energy Markets and End Use
Energy Information Administration
U.S. Department of Energy
Mail Stop EI-651
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

William Fulkerson
Director, Energy Division
Oak Ridge National Laboratory
PO Box X, Bldg. 4500N
Oak Ridge, TN 37831

J. Paul Galliker, Chief of Transportation
Industrial & Model Coordination
Office of Energy Markets & End Use
Energy Information Administration
U.S. Department of Energy
Mail Stop EI-631
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

Earl Gavett
U.S. Department of Agriculture
Administration Building Room 144E
14th. & Independence Avenue S.W.
Washington, DC 20250

John Gibbons, Director
Office of Technology Assessment
Congress of United States
Washington, DC 20510

No. of
Copies

OFFSITE

Mohindis Gill
USDA/ERS/NREO
Room 408- GHI
500 12th. Street S.W.
Washington, OC 20250

Dr. John W. Green
Economics Department
Colorado State University
Ft. Collins, CO 80523

Tom Gross, Director
Division of Improved Energy Productivity
Office of Industrial Programs
U.S. Department of Energy
Mail Stop CE-122
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

Marvin Gunn
U.S. Department of Energy
Division of Energy Conversion and Utilization Technologies
Mail Stop CE-142
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

Joseph Gustaferro
Senior Energy Analyst
Room 4881, Main Commerce Building
U.S. Department of Commerce
14th between E & Constitution N.W.
Washington, DC 20230

Donald Hanson
Argonne National Laboratory
9700 South Cass Ave
Bldg 362
Argonne, IL 60439

Dr. James Hartnett
Energy Resources Center
University of Illinois
Chicago, IL 60860

No. of
Copies

OFFSITE

Alex Haynes
Office of Policy, Safety and Environment
U.S. Department of Energy
Mail Stop PE-33
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

Christopher Hill
Massachusetts Institute of Technology
E40-227
Cambridge, MA 02139

Bill Hockheiser
Office of Fossil Energy
U.S. Department of Energy
Mail Stop FE-13
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

R.B. Hoffman, Director
Structural Analysis Oivision
Statistics Canada
Tunney's Pasture
Ottawa, Ontario K1A 0T6

Robert Holtz
Argonne National Laboratory
Building 330
9700 South Cass Avenue
Argonne, IL 60439

Joseph Iannucci
Sandia National Laboratory
PO Box 969, Division 8454
Livermore, CA 94550

James S. Kane, Deputy Director
Office of ENergy Research, ER-2
U.S. Department of Energy
1000 Independence Avenue
Washington, D.C. 20545

Robert L. Kieschnick, Economist
Texas Energy & Natural Advisory Council
411 West 13th Street, Room 902
Austin, TX 78701

No. of
Copies

OFFSITE

Ben Kjelshus
City of Kansas City
City Development Department
15th Floor, City Hall
Kansas City, MO 64106

Chris Kondrat
Bonneville Power Administration
Office of Conservation
Division of Planning and Evaluation
PO Box 3621
Portland, OR 97232

Andrew Krantz
U.S. Department of Energy
Photovoltaics Energy Division
Mail Stop CE-333
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

Richard Kropschot
Basic Energy Sciences
U.S. Department of Energy
Mail Stop ER-10
Germantown, MD 20454

25 Harry Lane
Office of Industrial Programs
U.S. Department of Energy
Mail Stop CE-122
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

Terry M. Levinson
U.S. Department of Energy
Mail Stop CE-142
Forrestal Building
1000 Independence Avenue, S.W.
Washington, DC 20585

Andres Liebenthal
Energy Department
The World Bank
1818 H Street, N.W.
Washington, DC 20433

No. of
Copies

OFFSITE

Ernest Loeb
Office of Industrial Programs
U.S. Department of Energy
Mail Stop CE-122
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

Ruth Love
Bonneville Power Administration
Office of Conservation
Div. of Marketing & Techninal
Assistance
PO Box 3621
Portland, OR 97232

Charles Macal
Argonne National Laboratory
Building 362-EES
9700 South Cass Avenue
Argonne, IL 60439

Charles R. Mandelbaum
Office of Energy Research
U.S. Department of Energy
Mailstop ER-32
Germantown, MD 20545

Robert L. San Martin
U.S. Department of Energy
Deputy Assistant Secretary
for Renewable Energy
Conservation and Renewable Energy
Mail Stop CE-30
Forrestal Building
1000 Independence Avenue, S.W.
Washington, DC 20585

Barry McNutt
U.S. Department of Energy
Policy, Safety and Environment
Mail Stop PE-43
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

William Marcuse
Dept of Applied Science, Bldg 179A
Brookhaven National Laboratory
Upton, NY 11973

No. of
Copies

OFFSITE

Robert Marlay
U.S. Department of Energy
Mail Stop CE-10
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

David Meyer
Office of Policy, Safety and Environment
U.S. Department of Energy
Mail Stop PE-20
Forrestal Building
Independence Avenue S.W.
Washington, DC 20585

Robin Miller
Alliance to Save Energy
Suite 206
1925 K Street N.W.
Washington, DC. 20006

Michael Mohr
Office of Business Analysis,
ITA Room 4527
Main Commerce Building
U.S. Department of Commerce
Washington, DC 20230

E.W Morrissett, Director
Library
Montana College of Science and Technology
Butte, MT 59701

Anthony M. Opyrchal
Division of Economic Analysis
U.S. Bureau of Mines
2401 E Street, N.W.
Washington, DC 20241

Dr. Jerry Pell
Office of Coal Utilization Systems
Fossil Energy, FE-23
U.S. Department of Energy
Washington, DC 20545

No. of
Copies

OFFSITE

Marylynn Placet
Argonne National Labs
444 N. Capital St
Suite 611
Washington, DC 20001

Peggy Podolok
U.S. Department of Energy
Office of Policy, Safety and Environment
Mail Stop PE-40
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

James Quinn
Office of Energy Systems Research
U.S. Department of Energy
Mail Stop CE-14
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

Michael Reid
Sr Program Officer
Alliance to Save Energy
Suite 206
1925 K Street, N.W.
Washington, DC 20006

David Reister
Institute for Energy Analysis
P.O. Box 117
Oak Ridge, TN 37830

Marvin Robertson
Assistant Professor of Business
Harding University
Station A. Box 774
Searcy, AR 72143

C.W. Robinson
Division 8352
Sandia Laboratories
PO Box 969
Livermore, CA 94550

Marc H. Ross
Physics Department
University of Michigan
Ann Arbor, MI 48109

No. of Copies

OFFSITE

Michael Rothkopf
Program Leader, Energy Analysis
Building 90/3125
Lawrence Berkeley Laboratory
Berkeley, CA 94720

James Ryan
Energy and Materials Program
Office of Technology Assessment
U.S. Congress
Washington, DC 20510

Garland Samuels
Energy Division
Oak Ridge National Laboratory
PO Box X, Bldg. 4500N
Oak Ridge, TN 37830

Gordon Sande, Sr. Research Officer
Structural Analysis Division
Statistics Canada
Tunney's Pasture
Ottowa, ONT K1A 0T6

Jayant Sathaye
Deputy Head of International Studies Group
Lawrence Berkley Laboratory
Berkeley, CA 94720

Lee Schipper
International Studies Group
Bldg 90, Room 3125
Lawrence Berkley Lab.
Berkeley, CA 94720

Gerald Schluter
ERS/NED/OEAD
U.S. Department of Agriculture
Washington, DC 20250

Alan Schroeder
Office of Industrial Programs
U.S. Department of Energy
Mail Stop CE-121
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

No. of Copies

OFFSITE

Alan J. Streb
Deputy Assistant Secretary for Conservation
Conservation & Renewable Energy
U.S. Department of Energy
Mail Stop CE-10
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

Caren Sullivan
Mississippi Dept. of Energy & Transportation
510 George Street
Watkins Bldg.
Jackson, MS 39211

William Thielbar
U.S. Department of Energy
Idaho Operation Office
550 Second Street
Idaho Falls, ID 83401

Richard Thoreson
Congress of the United States
Office of Technology Assessment
Washington, DC 20510

David Vogt
Group Leader - Resource & Environmental Analysis Div.
Oak Ridge National Laboratory
PO Box X, Bldg. 4500N,G20
Oak Ridge, TN 37830

Charles Waite
Office of the Chief Economist
U.S. Department of Commerce
Washington, DC 20230

Kung-Lee Wang
Chief, Quantitative Economics
Bureau of Mines
U.S. Department of the Interior
2401 E. St., N.W., Rm 833
Washington, DC 20241

No. of
Copies

OFFSITE

Robert Wendling
Office of Business Analysis
Room 4527
Main Commerce Building
Department of Commerce
Washington, DC 20543

Dr. Malcom Weiss
E40-455
Massachusetts Institute of Technology
Cambridge, MA 02139

Paul Werbos
Lead Analyst
Industrial Energy Demand
Energy Information Administration
Mail Stop EI-621
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

Mr. James Wiete
Program Coordinator
Energy Systems Center
University of Illinois
Chicago, IL 60860

Robert Williams
Center for Energy and Environ. Studies
Princeton University
Princeton, NJ 08544

Tyler E. Williams, Jr.
Office of Industrial Programs
U.S. Department of Energy
Mail Stop CE-12
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

T. Gary Williams
Miss. Dept of Energy & Trans
510 Watkins Bldg.
Jackson, MS 39211

No. of
Copies

OFFSITE

William B. Williams, Director
Office of Industrial Programs
U.S. Department of Energy
Mail Stop CE-12
Forrestal Building
1000 Independence Avenue S.W.
Washington, DC 20585

Philip A. Yannarella
Library Documents
Northern Kentucky University
Highland Hights, KY. 41076

27 DOE Technical Information Center

ONSITE

DOE Richland Operations Office

A. G. Flemming

266 Pacific Northwest Laboratory

W. B. Ashton
D. B. Belzer
C. A. Counts
J. W. Currie
R. M. Fleischman
R. G. Rivera
J. M. Roop (250)
Economics Library (3)
Publishing Coordination (2)
Technical Information (5)