A SIMULATION STUDY OF DECISION STRATEGIES FOR HOG PROCESSING PLANTS CONSTRAINED BY ENERGY SUPPLY REGULATIONS

Dissertation for the Degree of Ph. D.
MICHIGAN STATE UNIVERSITY
GARY A. DAVIS
1977

2/23/77
32.00

G104019

ABSTRACT

A SIMULATION STUDY OF DECISION STRATEGIES FOR HOG PROCESSING PLANTS CONSTRAINED BY ENERGY SUPPLY REGULATIONS

By

Gary A. Davis

Energy use has been rapidly rising throughout the industrialized nations since the turn of the century. With the formation of the Oil Producing-Exporting Countries' cartel in 1974, energy supplies have become uncertain and energy prices have risen relatively rapidly. The United States government has responded to this energy situation by establishing the Federal Energy Administration (F.E.A.) and charging it with the responsibility of decreasing domestic energy consumption. In addition, the Federal Power Commission (F.P.C.) has responded to relatively high demands on natural gas supplies by implementing a reduction program for industrial users.

The proposed programs by F.E.A. and F.P.C. were expected to affect hog processing plants. The F.E.A. has proposed an energy reduction goal for several industries, a goal of 12 percent had been set for the meat packing industry. The F.P.C. proposed a sequential reduction of interruptible natural gas supplies for several meat packing plants. In

some plants, the natural gas supplies could be reduced as much as 30 percent by 1980. Since many meat packing plants had modified their activities prior to these (F.E.A. and F.P.C.) regulations, further energy supply reductions were expected to cause extensive adjustments and investments.

Three strategies for adjusting production activities constrained by energy supplies were considered:

1. Change production levels
2. Change the composition of products produced, and
3. Use less energy intensive processes.

A simulation model was designed to investigate the effect of these strategies on the energy consumption and the before tax earnings of a midwestern hog processing plant. The model has five basic components that simulate and relate (a) the flow of products, (b) the plant's price and supply expectations, (c) the plant's decision criteria, and (d) energy reducing technology to the earnings of the hog processing plant.

A six-year (76-82) time horizon was simulated for three different scenarios. The first scenario simulated the affect of expected energy price increases and assumed energy reducing technology was not available. The second scenario was designed to provide the most likely estimate of the hog processing plant's situation, technology was assumed available as expected energy price increases occurred. The final

variation considered a profit maximizing criteria in place of the plant's normal production strategy.

The research results show that the F.E.A. and F.P.C. energy reduction proposals can be simultaneously met without adversely affecting the hog processing plant's before tax earnings. An initial investment of nearly $200,000 could decrease overall energy consumption about 20 percent. It was assumed, however, that sufficient fuel oil supplies would be available to replace decreased interruptible natural gas supplies. Fuel oil price increases of 300 percent were considered in the six-year analysis as other producers were also expected to increase their fuel oil demands.

Decreasing production was not found to be a financially rewarding strategy as annual earning reductions approaching 2 million dollars could occur. A profit maximizing strategy would increase earnings 20 percent if competing firms would not change their production strategies.

A SIMULATION STUDY OF DECISION STRATEGIES
FOR HOG PROCESSING PLANTS CONSTRAINED BY
ENERGY SUPPLY REGULATIONS

By

llen
Gary A. Davis

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics

1977

DEDICATION

TO JAMES J. AND BERNA M. DAVIS

ACKNOWLEDGMENTS

Many individuals and groups contribute considerable time and resources towards the completion of any dissertation. There are four main contributors that deserve recognition for their assistance in the completion of this dissertation: The George A. Hormel Company, Inc., the Economic Research Service, U.S.D.A., Dr. Larry J. Connor, and my family. All three sectors, the federal government, the state government, and private industry contributed resources and information which were vital to this research.

I would like to thank the George A. Hormel Company, Inc. for their contribution of data and personnel time. Their willingness to assist education and research was amply reflected in the warm and helpful attitudes of their staff. Particular thanks are due to Bruce Corey, Steve Wright, and Ed Gibson.

The Economic Research Service provided financial support which funded this research project and their contribution is appreciated.

Michigan State University provided the services of many capable individuals. Professor Larry J. Connor, as the major advisor, deserves a special thanks for his contributions over the years. In addition, I would like to thank

Professors John W. Allen, J. Roy Black, James T. Bonnen, Phillip L. Carter, and Thomas Pierson for their guidance and assistance.

A special thank you is given to my wife, Susan, and my children, Burton, Cindy, and Kristy, for their patience, encouragement, and understanding during the last four years. My parents, James J. and Berna M. Davis, have contributed so much for so long that a thank you seems most inadequate. Consequently, I have dedicated this dissertation to them.

Many other individuals have been very helpful. I would particularly like to thank Mrs. Louise Smith, the editor, Mrs. Linda Buttel, the programmer, and Mrs. Kathy Reed, the typist, for their invaluable assistance. Each of these people used their special skills and provided encouragement which greatly contributed to the completion of this dissertation.

Although many people have contributed to this dissertation, any errors or omissions are the sole responsibility of the author; and any such errors should not detract from the contributions of others.

* * * * *

TABLE OF CONTENTS

PAGE

LIST OF TABLES vii

LIST OF FIGURES viii

CHAPTER

I. INTRODUCTION 1

- Introduction 1
- Research Objectives 8
- Research Methodology 9
- Summary 17
- Organization of Thesis 18

II. ENERGY REGULATIONS 20

III. CONCEPTUAL FRAMEWORK 27

IV. HOG PRODUCTION PROCESSES 39

- Description of Hog Production Processes. . 39
  - Hog Slaughtering Activity 40
  - Carcass Cutting Activity 44
  - Rendering Activity 46
  - Clean-Up Activity 49
- Description of Energy Utilization in A Hog Processing Plant 49
  - Hog Scalding Energy Demands 53
  - Hog Dehairing Energy Demands 54
  - Inedible Rendering Energy Demands . . 54
  - Edible Rendering Energy Demands . . . 55
  - Blood Drying Energy Demands 56
  - Clean-Up Energy Demands 56
  - Refrigeration Energy Demands 56

V. REVENUE AND COST ESTIMATION 59

- Revenue Estimation 60
  - Wholesale Value of Hogs 61
  - Liveweight Value of Hogs 63
- Commercial Hog Supply Estimation 66
- Cost Estimation 72

CHAPTER PAGE

VI. SIMULATION MODEL 78

Description of Simulation Model 81
Expectation Component of The Simulation Model 84
Decision Component of The Simulation Model 87
Production Alternative Component of The Simulation Model 90
Description of Energy Reducing Technology 93
Validation of Simulation Model 98

VII. RESULTS 101

VIII. SUMMARY AND CONCLUSIONS 115

Summary 115
Implications 123
Suggestions for Further Research 125

BIBLIOGRAPHY 129

APPENDIX

A. Production Component Equations of The Simulation Model 132

B. Energy Demand Component Equations of The Simulation Model 135

C. Predicted U.S. Commercial Hog Supply, 1976-1982 138

D. Predicted U.S. Commercial Hog Liveweight Value, 1976-1982 139

E. Operating Procedure of Simulation Model 140

LIST OF TABLES

TABLE PAGE

1. Daily Energy Demand for Selected Hog Processing Activities 58
2. Daily Hog Processing Costs - Slaughter Cut, Render - 1974 74
3. Comparison of Hog Processing Plant Simulation Models 80
4. Expected Reduction Schedule for Interruptible Natural Gas 85
5. Expected Fuel Oil and Interruptible Natural Gas Prices 86
6. Energy Reducing Production Alternatives Considered in The Hog Processing Simulation Model 91
7. Net Present Value of Energy Reducing Production Alternatives - 1976 104
8. Results of Hog Processing Plant Simulation Model 106
9. Simulated Energy Savings From Technology Available to a Hog Processing Plant 109
10. Simulated Natural Gas and Fuel Oil Consumption for A Case Study Hog Processing Plant, 1976-1981 111
11. Simulated Energy Cost for A Hog Process Plant 112

LIST OF FIGURES

FIGURE PAGE

1. Substitution Relationship Between Fuel Oil and Natural Gas as Boiler Energy Sources 32
2. Effect of A Natural Gas Supply Constraint 33
3. Combined Effects of Energy Reducing Technology and Natural Gas Supply Constraints 35
4. Energy Reduction and Total Revenue Decreases Occurring From Changing Output Composition 36
5. Hog Slaughtering Processes 41
6. Standard Dismembering Procedure 45
7. Flow Chart of Hog Production Process 50
8. Flow Diagram of Simulation Model 92
9. Production Strategies for A Hog Processing Plant 103
10. Effects of Alternative Production Strategies On The Plant's Earnings and Energy Consumption 107

CHAPTER I

INTRODUCTION

Introduction

Energy use has been rapidly rising throughout the industrialized nations since the turn of the century. With the formation of the Oil Producing-Exporting Countries' cartel in 1974, energy supplies have become uncertain and energy prices have risen relatively rapidly. Rapidly rising oil prices have spurred oil importing countries to reduce oil consumption as their trade balances became less favorable. Governments have reacted by encouraging consumers to lower their energy usage through a multiplicity of methods. Laws have been passed, governmental agencies were formed, and moral suasion has been used.

In spite of reported energy savings which have occurred in the United States, energy consumption has not decreased. Firms have been able to reduce energy consumption in many plants by as much as ten percent[1] and residential consumers have taken voluntary actions to reduce home

---

[1] Howard Cross, Office of Energy Evaluation, Michigan Department of Commerce, Personal Correspondence, September 1975.

energy demands. But the trend of energy consumption between 1950 and 1971 has continued. Energy consumption in the United States doubled in this 21-year time span and petroleum and natural gas have borne the brunt of this increased energy demand.

By 1972, natural gas and petroleum supplied nearly 80 percent of the U.S. energy demands.[2] Our production capabilities, however, have not kept pace with our energy demands. Because of the pricing structure, the demand for natural gas has exceeded the available U.S. supply throughout the seventies and thus creating a shortage of natural gas. This shortage has grown from 0.1 trillion cubic feet in 1970 to an expected 4.0 trillion cubic feet in 1976. Similarly, crude oil imports into the United States have nearly doubled between 1972 and 1976.

Faced with rising energy consumption and rising energy prices, federal regulatory agencies and legislators begun to propose various forms of action to change the direction of the United States' energy consumption. The Federal Power Commission has established priorities on natural gas usage. "The highest priority users -- residential and small commercial customers, as well as industrial use for plant protection, feedstock, and process needs -- are the last to be curtailed in times of

---

[2] DeGolyer and MacNaughton, Twentieth Century Petroleum Statistics, September 1, 1973, p. 95.

shortage."[3] Similarly, the Federal Energy Administration has begun to adopt energy conservation suggestions proposed by legislators.

Further control and reductions of energy use are being sought by legislators. Although not having legal status at this time, the proposed legislation does indicate the position and concern of government leaders.

Congress is proposing specific energy reduction goals as evidenced in H.R. 6860.[4] This legislation is intended to reduce U.S. dependence on foreign oil within ten years. A specific schedule has been proposed which will limit the daily importation of oil into the United States. The goal is to decrease oil imports to less than 25 percent of domestic production by 1985. Additional taxes have been scheduled for natural gas, crude oil, and gasoline.

Legislation, such as H.R. 7014, is intended to include all major energy consuming industries which utilize at least one trillion British thermal units (B.T.U.) of energy per year. Energy conservation goals for each industry will probably be established by the Federal Energy Administration for at least the ten most energy consumptive industries. Corporate officers of high energy consumptive

---

[3] Federal Energy Administration, The Natural Gas Shortage: A Preliminary Report, August 1975, p. 8.

[4] U.S. Congress, House, Energy Conservation and Conservation Act of 1975, H.R. 6860, May 9, 1975, 93rd Congress.

firms will be expected to report improvements in energy efficiency to F.E.A. on an annual basis. As a minimum, any group of corporate officers which refuses to report can be held in contempt of court.

The Federal Energy Administration has taken the proposed legislation as an indication of the intent of Congress. Consequently, F.E.A. has begun to meet with several industries to establish reasonable energy reduction goals. In addition, several research studies have been funded by F.E.A. to study energy reduction potentials in several industries.

F.E.A. provided funds to initiate energy research in the food processing area by means of a survey for 12 of the 44 food and kindred products industries.[5] This research was designed to: estimate types of energy use, to determine variations in energy use among plants, to identify conservation potentials, and to determine key constraints on current operations.[6] The industries included within this study were: meat packing, sausage and other prepared meats, fluid milk, canned fruits and vegetables, frozen fruits and vegetables, animal feeds, wet corn milling, cane sugar refining, beet sugar, malt beverages,

---

[5] Development Planning and Research Association, Inc., Industrial Energy Study of Selected Food Industries, March 22, 1974, F.E.A. Contract No. 14-01-0001-1652.

[6] Ibid., p. I-2.

animal and marine fats and oils, and manufactured ice. Each industry was defined according to the SIC classification of the U.S. Bureau of Census.

The meat packing industry ranks as the most important of the industries studied. It has the highest value of shipments, the most employees, and is the largest single user of energy. Over 100 trillion B.T.U. are used annually by the meat packing industry.[7]

Meat packing and the associated plant processing utilized more gross energy than any other food industry processor. Almost ten percent of the total food processing energy was used in the meat packing-processing area. The major portion (80%) of their annual energy requirements were derived from red meat and by-product processing. The remaining 20 percent was utilized for processing prepared meats at the slaughter house premises.[8]

Nearly half of the meat packing industry's energy needs were provided by natural gas and about a third were supplied by electricity. Petroleum derivatives, such as residual oils and middle distillates, along with coal each provided ten percent of their energy demands. Although propane provided only two percent of the industry's energy

---

[7] Ibid., p. II-1, II-4.

[8] Foster D. Snell, Inc., Energy Conservation in The Meat Packing Industry, F.E.A. Contract No. C-04-50090-00, January 1975.

needs, the meat packing industry consumed one-fourth of the propane utilized by the twelve industries surveyed.[9]

These simple averages of energy use patterns in the meat packing industry can be misleading. Energy consumption between plants and geographical regions is quite diverse. Natural gas provides about 40 percent of the Mid-Atlantic region's meat packing energy needs; but, in the Pacific region, it provides nearly two-thirds of the industry's energy needs. Since electrical energy provides between 29 and 34 percent of industry's energy demands, fuel oil and coal must offset the natural gas variances between geographical regions.[10] Energy consumption between plants within a region shows more diversity than regional research[11] which revealed that the energy required per pound of liveweight processed could vary between plants by as much as 400 to 2,700 B.T.U. This difference has been attributed to the type of animal processed, the degree of by-product processing, and the final form of the products sold.

The energy research studies funded by F.E.A. have reported conflicting opinions on energy reduction potential in the meat packing industry. One reports that a five

---

[9] Development Planning and Research Association, Inc., <u>Industrial Energy</u>, Exhibit II-4, II-5.

[10] Ibid., Exhibit III-2.

[11] Ibid., Exhibit III-13.

percnet energy reduction goal would necessitate a reduction in output.[12] Another considers a 30 percent overall energy reduction goal as reasonable.[13] An immediate short-run reduction of 13 percent is possible and an additional 13 percent could occur in the long-run if considerable investment were undertaken. A further intermediate adjustment to reduce energy demand another 6 percent would reduce total energy demands more than 30 percent.

The Federal Energy Administration is negotiating with major meat packing firms to reach a mutually acceptable energy reduction goal. While the F.E.A. advocates the 30 percent reduction goal, many of the major firms believe that a large number of energy reduction adjustments have already been undertaken and an additional 30 percent reduction is unreasonable. Secondly, they claim that F.E.A. research indicated energy reduction potentials without assessing economic and political feasibility. Energy reductions brought about by modifications of U.S.D.A. sanitation regulations were particularly questioned by the meat packing industry.

---

[12] Ibid., Exhibit III-16.

[13] Foster D. Snell, Inc., Energy Conservation, Exhibit V-9.

Research Objectives

The meat packing industry is concerned about future energy supplies and costs. "Petroleum products are under allocation controls caused by their short supply, (and) the industry is faced with significant cutbacks in the supply of natural gas."[14] In addition, the F.E.A. has been granted the authority to establish energy conservation goals and to withhold energy supplies if those goals are not met.

Several questions have been raised regarding the effect of energy supply constraints even though the constraints have not been fully identified.

Major energy questions which require answers are:

1. What are the various energy demands in meat packing plants?
2. What production adjustments, equipment, or technology are feasible to reduce energy demands?
3. What effect will further energy price increases have on the future financial health of the industry?

The purpose of this research was to evaluate the effect of energy supply constraints and rising prices on a

---

[14] Development Planning and Research Association, Inc., Industrial Energy, p. III-17.

hog processing plant. To accomplish this purpose and to provide a tentative answer to current energy questions, the following specific research objectives were proposed:

1. To describe the hog production processes
2. To delineate mass-energy flows for production processes which utilize natural gas and fuel oil
3. To identify and evaluate production adjustments and technologies which might reduce energy flows
4. To estimate the effect of alternative production strategies on the financial position of the firm
5. To evaluate the financial impact of a 12 percent reduction in total energy utilization.

Research Methodology

Meat packing plants are located in several areas of the United States and they have been constructed and modified considerably over the last 100 years. Each area has changed over time as population, agricultural production, and transportation facilities grew and adjusted to our nation's needs. Many members of the meat packing industry have indicated that a classification system to identify typical or representative plants would be nearly impossible to develop.[15] Changing technology and a myriad of production processes of varying size, which would be organized in

---

[15] Foster D. Snell, Inc., Energy Conservation, p. III-2.

many ways, seem to pose an array of firms which cannot be classified in a representative manner.

The generalizations which appear acceptable to the industry are (1) that the major portion of the meat animals slaughtered are processed in plants with a rated hourly capacity in excess of 75 head[16], and (2) the most numerous groups of meat packing plants will slaughter, process, bone, and render edible and inedible fats.[17]

A single plant analysis was chosen as the best means to consider the effect of energy constraints and rising prices on the meat packing industry. It was determined that the analysis of one plant could provide specific information which would be preferred to an analysis of several firms, which would not be considered representative. A hog processing plant was also preferred to beef, veal, or sheep since the energy required per pound of hog product is considerably greater. Consequently, the proposed energy supply constraints were hypothesized to be more acute for hog processing than for other red meat processing plants.

A midwest hog slaughtering plant agreed to cooperate on this research. The plant was sufficiently large (over 75 head per hour) to include many of the processes performed by other meat packing plants. Other livestock

---

[16] Allen J. Baker, Personal Correspondence, Economic Research Service, U.S.D.A., November 4, 1975.

[17] Ibid.

were not processed at the plant.

The hog processing plant was expecting federal regulations which would force a decrease in total energy usage. In addition, a major proportion of its natural gas supplies would be eliminated. The plant manager has been informed that the natural gas supply limitation will be effective in 1980 and that the energy reduction goal must be met by 1982. As other industries are also forced to replace natural gas by other energy sources, the price of these sources were expected by the plant to rise rapidly.

The management of the hog processing plant was concerned with selecting a course of action when the constraints were unclear, when future prices were unknown, and when technically feasible production adjustments had not been assessed for economic feasibility. Two questions which emerge from this uncertain situation are:

1. What decision strategies will the firm most likely follow? and
2. What decision strategies should the firm follow?

Simulation has been selected as an appropriate technique to approximate the firm's behavior. This technique allows the cause and effect information to be traced over time without actually changing the plant's operations. "A mathematical model of decision rules, information sources, and other interactions among the components of an organization are formulated, and the model's behavior through time is generated on a digital computer."[18]

The components of the simulation model were:

1. Production processes component
2. Energy demand component
3. Expectation component
4. Decision strategies component
5. Production alternative component

The production processes component was designed to simulate the flow of intermediate and final products through the plant. The hog processing plant was initially contacted to describe the production processes and general operational procedures. Production activities were defined as slaughter, cutting, rendering, and clean-up. The stages of slaughtering consisted of stunning, bleeding, scalding, hair removal, singeing, eviscerating, and carcass chilling. Stages of the cutting process includes blood drying, edible and inedible products. Plant clean-up was one activity that transcended across all production areas.

Data concerning the quantities of hog components entering and exiting each stage of production was obtained from the firm's records. Production coefficients were ascertained by computing simple averages over the most

---

[18] Halter, A. N., and Dean, G. W., "Use of Simulation in Evaluating Management Policies Under Uncertainty: Application to A Large Scale Ranch," Journal of Farm Economics, August 1965, Vol. 47, No. 3, p. 557.

recent 250 production days (one year equivalent).

Energy utilization within a hog processing plant was needed for heating and cooling. Steam was commonly used as the major heat source and required nearly 80 percent of the total energy usage in a hog processing plant.[19] The steam boilers have generally been equipped to utilize either natural gas or fuel oil interchangeably. The refrigeration processes utilize natural gas, propane, and electricity. About half the refrigeration energy demands and all of the steam boiler energy demands have been provided by natural gas. These energy demands are the most affected by natural gas limitations and rising prices of substitute energy sources.

Energy demands for refrigeration and boiler steam were studied in the hog processing plant. Mass-energy flows were determined for each production process which utilized boiler steam and required cold storage. Various tests were combined with standard engineering methods by the cooperating firm's engineers to determine the energy use within the packing plant.

Total plant energy utilization was estimated from linear regression equations derived from engineering studies of hog packing plants.[20] Derived energy demands for hog

---

[19] Johns-Mansville, Inc., "How Pork Plant Rates On Energy," National Provision, January 31, 1976, p. 30.

[20] Ibid., p. 34.

scalding, hair removal, blood drying, edible rendering, and clean-up were obtained from the plant personnel. Refrigeration energy demands were determined for the carcass chill cooler, the carcass cutting floor, the loin cooler, the fresh meat cooler, the offal freezer, and the shipping area.

The expectation component of the simulation model reported monthly costs and revenues. Production cost estimates were derived from two data sources. The actual costs of production were obtained from the plant. One year's data was utilized to ascertain processing costs over a wide range of production; and an appropriate functional form was fitted to the data. Secondary data based on a 1974 Corn Belt-Lake states survey[21] of hog slaughter plants was utilized to shift the functional form vertically. The secondary data was from plants of approximately the same size as the case study plant. Shifting the firm's actual cost function prevented disclosure of the firm's proprietory information.

Labor costs were maintained as a separate cost item in the accounting procedures due to the peculiarity of the industry-union contract. The plant's union contract guaranteed 36 hours of wages to the employees regardless of the hours worked. If the employees worked less than 144

---

[21] Food Manager, Inc., Cost Component - Cattle and Hog Slaughter Plants, U.S.D.A., E.R.S. Contract No. 12-17-03-5-943, October 1974.

hours a month, the difference between hours paid and hours worked was carried over to the following month. The labor hours carried over were credited against any overtime hours worked in the following month. This provision allowed the plant to essentially store labor costs for 30 days while guaranteeing a minimum income level to the employees. Consequently, production decisions were influenced by the amount of labor hours carried over from the previous month.

Revenue for the firm has been determined by the product price and the quantity of product sold. Although a hog processing plant does produce a multiplicity of products, it is fortunate that the products sold are a linear combination of the basic input - the live hog. By extending the composite wholesale price per unit of live hog published by the U.S.D.A.[22], an estimate of total revenue was obtained.

Total revenue for the hog packing plant was estimated by extending the composite monthly wholesale hog price six years into the future. This extension required three separate estimation steps:

1. Estimate the U.S. monthly commercial hog supply by a harmonic Fourier Series approximation of the four-year hog cycle
2. Hog slaughter price estimation by linear regression

---

[22] U.S. Department of Agriculture, Livestock and Meat Statistics, S.B. No. 522, ERS, SRS, AMS, July 1973, p. 28.

3. Estimate the wholesale price - slaughter price relationship as a linear function of the U.S. hog supply.

The composite output price was estimated by multiplying the hog slaughter price by the wholesale slaughter price ratio. Subsequently, monthly revenue was determined by a composite output price and the quantity of hogs slaughtered.

The short-run decision component of the simulation model was designed to select the best level of production for each month. The decision criteria for the firm was ascertained and was used to determine the hog slaughter rate for each month. The decision criteria proposed by economic theory and profit maximization was also considered. A comparison of these two criteria was utilized to determine the effect of these decision criteria.

The long-run decision component was concerned with annual decisions regarding energy utilization adjustments. The production adjustments which were selected for economic analysis are:

1. Shell and tube ammonia condensers
2. Continuous cooker heat reclamation
3. Low temperature rendering
4. Hog singer heat-exchange equipment
5. Centrifuge blood drying
6. Selling whole blood

The firm's decision criteria for selecting production alternatives was based upon the plant's internal rate of return (15%) and expected energy prices. The net present value approach was included within the model.

The firm had considered the possibility of converting to other energy sources such as coal. Their analysis eliminated coal as a substitute energy source. The production alternatives listed above will be adopted as they meet the firm's criteria. If none were selected by 1982, the firm would select a sufficient number of alternatives that would result in a 12 percent overall energy reduction. This total energy reduction goal by management was deemed essential to maintain federal assurance of sufficient fuel oil supplies beyond 1982.

Summary

The hog processing plant has three decision strategies from which it can choose, either singularly or in combination:

1. Reduce output
2. Change output composition
3. Change energy use by utilizing less energy intensive processes.

This research was intended to appraise the best strategy for the plant as energy constraints were imposed and as energy prices increased. The decision criteria of the firm was compared with the decision criteria proposed by economic theory.

Simulation was selected as an appropriate technique to approximate the behavior of the plant over a six-year time horizon. Although specific plant peculiarities exist, the same energy constraints are being imposed on other meat processing plants. In addition, many hog processing plants utilized the same energy processes as the selected mid-western hog plant. Consequently, the evaluation of various energy reduction technology and decision strategies should be readily applicable to other meat processing plants.

Organization of Thesis

The hog processing plant has been forewarned that natural gas usage and total energy usage must be decreased. Following this introduction, the regulatory power granted to the Federal Energy Administration and the Federal Power Commission is reviewed. Production theory was re-examined in regards to energy constraints and rising energy prices in Chapter III - Conceptual Framework.

The physical production processes of the hog plant were described in Chapter IV. The description starts with a live animal in the holding pen and proceeds in the same order as a hog would be processed. The derived energy demands of the production processes were enumerated in the same order as the physical processes occur.

Revenue and cost estimation procedures are elucidated in Chapter V. Input supply and price estimation procedures were developed in the first section, and cost estimations were derived from the level of input use.

The simulation model was explained in Chapter VI. Here the decision strategies and expectations of the firm were integrated with the physical and financial information from Chapter IV and V. The results, summary and conclusions of this analysis are reported in Chapters VI and VII, respectively.

CHAPTER II

ENERGY REGULATION

The Federal Power Commission (F.P.C.) and the Federal Energy Administration (F.E.A.) have been given the authority by Congress to regulate natural gas and energy, respectively. Natural gas was considered an important national resource many years ago when Congress first provided for the regulation of natural gas supplies and prices with the National Gas Act of 1938. Since that time, other energy sources had escaped direct supply controls, except in times of war, until 1974 when Congress established the Federal Energy Administration. Both congressional acts granted authority of supply and price control to these regulatory bodies.

The 1938 congressional action gave the "Federal Power Commission authority for regulation of interstate natural gas companies, including the exportation or importation of natural gas, rates and charges, determination of cost of production and transportation, ascertainment of cost of property, records and memoranda, and rates of depreciation." An amendment in 1954 did remove the Federal Power Commission's authority for intrastate natural gas regulation, provided that state regulation existed.[23]

With the establishment of the Federal Energy Administration (F.E.A.) in 1974, Congress assigned 12 specific functions. The three most pertinent functions for this research are:[24]

1. "Develop and oversee the implementation of equitable and mandatory energy conservation programs and promote efficiencies in the use of energy resources"
2. "Develop plans and programs for dealing with energy production shortages"
3. "Assure that energy programs are designed and implemented in a fair and efficient manner so as to minimize hardship and inequity while assuring that the priority needs of the nation are met".

Although the F.E.A. is a young agency, it has been granted considerable powers. Initially, the F.E.A. flexed its muscles by notifying both energy users and suppliers that it could directly affect them. Suppliers of crude oil, residual fuel oil and refined petroleum products produced in or imported into the United States were notified that they must supply all end-users which purchased an allocated

---

[23] American Gas Association, <u>Gas Rate Fundamentals</u>, 1969, p. 91.

[24] U.S. Congress, House, Public Law 93-275, H.R. 11893, 93rd Congress, 1st Session, May 7, 1974.

product from them prior to January 5, 1974. This decree affected contractual relations between users and suppliers and the F.E.A. made it clear that it would use its authority to transfer energy supplies from one region to another and between industries if such action were necessary.[25]

In addition, the Federal Energy Administration has classified industries according to a priority system. If an end-user wants to maintain an established "base volume" and its priority rating, it must certify to the F.E.A. that it has an energy conservation program in effect.[26] The F.E.A. has required end-users of energy supplies to have a "base period volume" of energy consumption which was determined on a monthly basis for each of the twelve months prior to February 1, 1974. Adjustments to this base period volume may occur under "unusual growth" circumstances. Growth in excess of 10 percent in any one year can be used as an adjustment to the base period volume.

Agricultural industries which have received a priority rating (which provides 100 percent of their base period volume) are classified according to the standard industrial code numbers (Bureau of Census) in Division A, Agriculture, Forestry, and Fishing, and Division D, Manufacturing of Food and Kindred Products, Major Group 20.

---

[25] U.S. Government, Federal Register, Friday, March 29, 1974, Vol. 39, No. 62, pp. 11771-11777.

[26] Op.cit., p. 11778.

Exceptions to these general classifications have also been made by F.E.A.[27]

The Federal Energy Administration has been given the authority to withhold or assure supplies of crude oil, residual fuel oil, and refined petroleum products. Although, specific agricultural industries have been granted an allocation equivalent to their base period volume, this allocation is not assured if the end-user does not have an energy conservation program in effect.

The meat packing industry has relied upon natural gas and petroleum products to directly supply nearly two-thirds of its annual energy demands.[28] Electricity supplies another 10 percent and part of this has been generated from gas or petroleum products. Both natural gas and petroleum derived products are regulated by federal authorities and adjustments in these regulations can affect the cost and production levels of meat packing firms.

The meat packing industry has historically operated with two types of natural gas contracts. One contract specifies a quantity of natural gas which must be delivered to the firm. This is referred to as a firm gas contract.

---

[27] Specifically excluded industries are 0181, 0189, 0271, 0279, 0742, 0752, 0781, 0782, 0849, 2047, 2065, 2067, 2084, 2095, 2097. Specifically included industries are 2141, 2411, 2421, 2873, 2874, 2875, 4971.

[28] Development Planning and Research Association, Inc., Industrial Engineering, Exhibit II-4.

The second type of contract is referred to as an interruptible natural gas (I.N.G.) contract. This contract specifies a quantity of natural gas which will be delivered only if higher priority users do not require gas. Interruptible natural gas has provided half to two-thirds of the non-electrical energy demands of meat packing plants.

The past operating procedure followed by the industry has been the reduction of I.N.G. during the winter months when home heating demands are high. During these months, the industry uses other energy sources, such as residual fuel oils. In the summer months, interruptible natural gas has been plentiful. Interruptible contracts generally have specified lower per unit gas prices than the firm contracts to compensate users for the unreliable gas supply.

The relatively recent emphasis of energy conservation and the depleted natural gas supplies have changed the energy supply situation. The Federal Power Commission has established natural gas curtailment priorities, and the meat packing industry's natural gas usage fits in the lowest priority categories - boiler fuel use and interruptible usage when alternative fuel capabilities exist.[29] The Federal Energy Administration has established energy conservation goals for industries under the authority

---

[29] Federal Energy Administration, The Natural Gas Shortage: A Preliminary Report, August 1975, Table 1.

granted by Congress. The power to enforce energy conservation goals currently is derived from F.E.A.'s authority to allocate petroleum and petroleum products when energy demands exceed supplies. If energy conservation goals are not met, F.E.A. can transfer energy supplies between geographic regions and between industries.

The hog packing plant has been informed by the suppliers of natural gas that all interruptible natural gas will be completely shut off by 1981. In addition, after 1977, interruptible natural gas contracts will be limited to half of the previous years' contracted supplies. As natural gas users switch to other energy sources, those sources are expected to suffer price increases. The impact of this general anticipation is that fuel oil suppliers are limiting their contractual agreements to 30 days. Every 30 days, price and quantity will be re-negotiated.

The F.E.A. has proposed an energy conservation goal of 12 percent for the meat packing industry. All meat packing plants will most likely be required to reduce their total energy demand 12 percent below their 1974 level by January 1983. If this expected goal is not met, the firm will not be assured of more than 30 days of energy supplies. The threat of losing all energy supplies is sufficient to convince the hog packing plant to reduce overall energy demands.

The combined effect of federal regulations, F.P.C., and F.E.A. on the hog processing plant is:

1. A scheduled reduction in interruptible natural gas supplies, and
2. An overall energy reduction goal near 12 percent.

CHAPTER III

CONCEPTUAL FRAMEWORK

The meat packing industry was anticipating energy supply constraints and rising energy prices. Rising energy prices would affect all producers, but the energy supply constraints were not intended to affect all producers equally. Small producers, those using less than 50 MCF on a peak day, had a higher natural gas priority than larger producers and they appear to be exempt from natural gas curtailments. This legal distinction and the paucity of agreements on the characteristics of a representative meat processor has limited this research to investigating the decision strategies of a hog processing plant subjected to energy supply constraints.

A midwestern hog processing plant was anticipating energy supply constraints which were to be imposed by the F.E.A. and F.P.C. Natural gas, used in boilers to produce steam, was scheduled to be incrementally decreased between 1976 and 1980. After 1980, natural gas would no longer be available for use in steam boilers. In addition, a 12 percent energy conservation goal was being imposed by the Federal Energy Administration. Failure to meet this 12 percent energy reduction goal could jeopardize the agricultural priority of the hog processing plant and could subsequently result in losing federal assurance of future energy supplies.

This research was primarily concerned with identifying and evaluating the decision strategies available to the hog processing plant. The nature of the constraints imposed upon the plant, however, were important in the identification of possible strategies. The imposed energy constraints were scheduled to be implemented during the next six years. Consequently, decisions could be implemented during different time periods or prior decisions could be reversed in a later time period. In addition, the hog processing plant had a production constraint imposed upon it by the parent firm. Consequently, the decision strategies available to the plant were constrained by time, the parent firm, and energy supplies.

An important distinction must be made concerning the analysis of this hog processing plant and the analysis of a firm or an industry. In many respects, the hog processing plant could be considered a firm, but sufficient differences exist which deserve amplification. First, the plant does not fit the neo-classical definition of a firm and it does not attempt to maximize profits. The plant is not an individual business, and its production goals and output prices were established by the plant's parent firm.

Similarly, the plant, per se, can not be considered representive of the industry nor any major segment of the industry. The plant is assumed to operate in a market situation where its actions will not change the market behavior of other plants, firms, or the industry. Although the energy constraints imposed on the plant are also being imposed on most other plants, the possible effect of several industry adjustments are not included in this study. It was assumed that the market behavior of competitive plants would remain unchanged. The only industry and national adjustment that affect the plant is the plant's energy price expectations, which subjectively accounts for energy use adjustments. The hog cycle is expected to continue and hog prices are assumed to follow historical patterns.

It is true, however, that many meat packing plants will be subjected to both the F.E.A. and F.P.C. energy constraints. Since this study concentrated on hog processing activities, it is applicable to other meat packing plants which use similar rendering and by-product processing methods.

Firms may utilize this analysis to provide an indication of the impact of modified production goal criteria by assuming the absence of any change in the behavior of its competitors. Similarly, any conclusions concerning industry adjustments must be modified to conform with the assumptions imposed on the plant analysis. Since the analysis assumed that the plant's behavior would not modify the behavior of other plants, then it must also be assumed that the joint behavior of several plants would not be significantly changed. Ignoring this assumption could cause misleading implications about industry behavior.

Production theory appeared more germaine to this analysis than the traditional theory of the firm. The energy constraints could be considered and adjustments for the plant could be hypothesized without imposing a profit maximizing goal. In addition, the time factor could be considered in the short-run and long-run as various decision strategies were investigated.

The production function of the hog processing plant was described by the neo-classical production function,

$$Q = F\,(X_1, X_2, X_3 \ldots X_l \ldots X_r/X_t \ldots X_n)$$

where

Q = output

X_1 = natural gas as a boiler energy source

X_2 = fuel oil (#5 or #6)

$X_3 \ldots X_l$ = possible energy saving technology currently at a zero level of usage

$X_l \ldots X_r$ = other variable factors

$X_t \ldots X_n$ = embodies all other fixed factors of production.

Since a sufficiently long time horizon was being considered, the number of variables which were to be considered increased from X_1 to X_2, which were normally considered short-run variables to X_3 through X_r.

The variables X_1 and X_2 fit the economic definition of perfect substitutes when they are used as boiler energy sources. After they are ignited to produce heat, fuel oil and natural gas could be considered as the same commodity. Fuel oil and natural gas are commonly measured in gallons and thousand cubic feet (MCF), respectively. In these units of measurement, about five gallons of fuel oil produce the same quantity of heat (B.T.U.) as one MCF.

Since both energy sources produce B.T.U.'s, a cost minimizing plant would prefer to use the input which had the lowest price per B.T.U. if a price differential existed. In this instance, natural gas has a lower cost per B.T.U. than fuel oil. This situation is depicted in Figure 1, where OB quantity of natural gas is purchased and a zero quantity of fuel oil is purchased.

The effect of the constraint on natural gas boiler supplies becomes more obvious in the framework of economic theory. From Figure 1, it is clear that the firm will prefer natural gas until fuel oil prices become less expensive relative to natural gas prices. Since fuel oil prices have not changed in this manner, a regulatory constraint would force the plant to use fuel oil if it wanted to maintain its level of production. Given the price relationship in Figure 1, the plant utilized only natural gas as a boiler energy source.

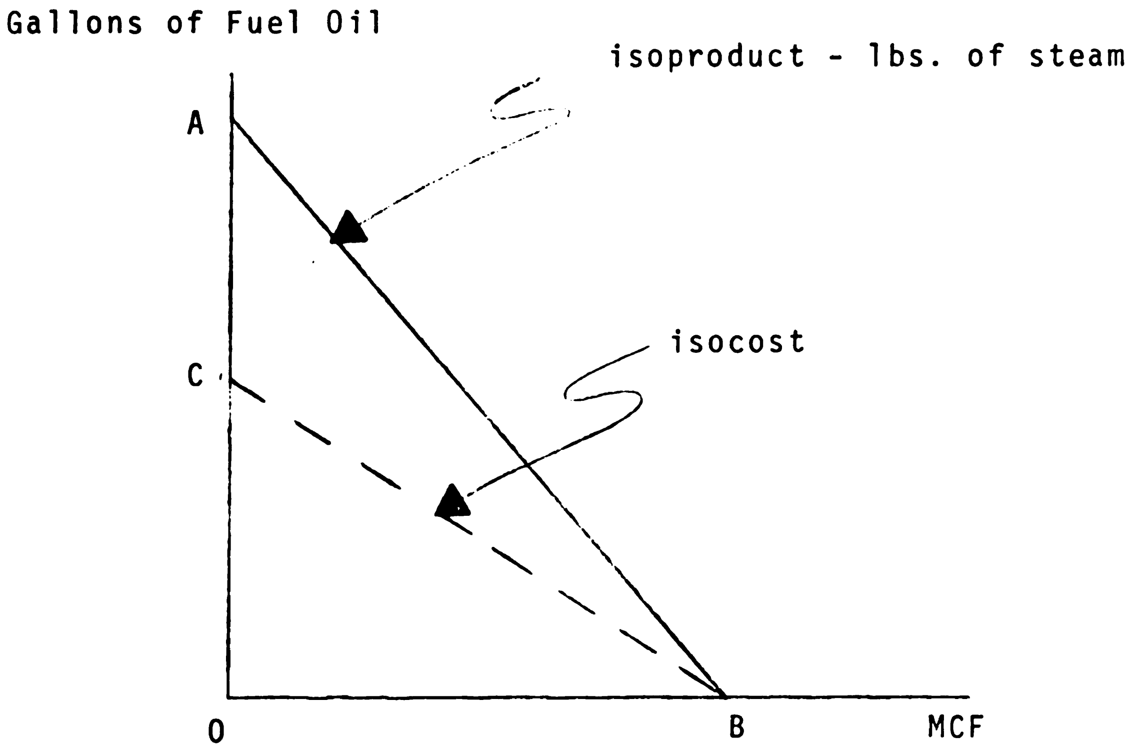


FIGURE 1. SUBSTITUTION RELATIONSHIP BETWEEN FUEL OIL AND NATURAL GAS AS BOILER ENERGY SOURCES

By imposing a supply constraint of OR, as shown in Figure 2, the plant is forced to use OX quantity of fuel oil and OR quantity of natural gas to maintain the same quantity of steam production as OB units of natural gas would produce. Energy cost increases were shown in line CB, shifting outward to position DE since fuel oil costs per B.T.U. are higher than natural gas costs.

It is necessary to note that the isoproduct line in Figure 2 becomes discontinuous at point S. The imposition of the energy constraint (OR) removes line segment SB fr

wi

wi

Fu

FIG

fuel

ship

crea

are

allow

reduc

The in

shift

from a previously existing substitution relationship. Even with production decreases, fuel oil usage would increase without increasing total energy costs.

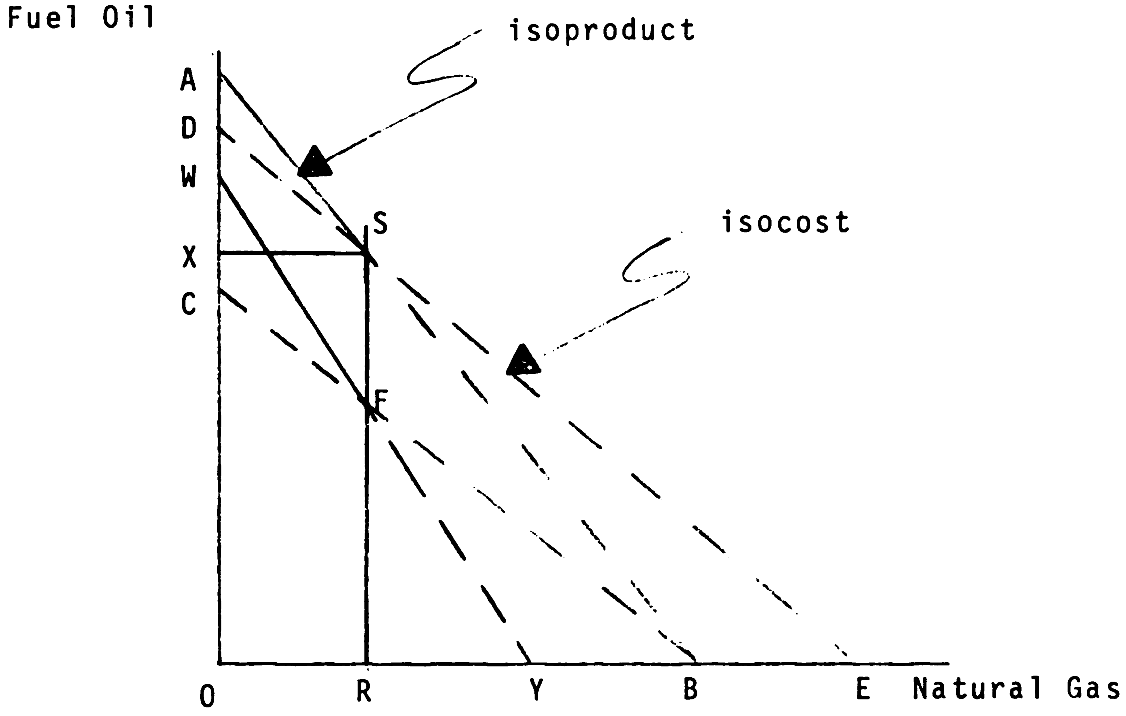


FIGURE 2. EFFECT OF A NATURAL GAS SUPPLY CONSTRAINT

When only considering the effect of substituting fuel oil for natural gas under the given price relationship, it is clear that either total energy costs will increase or production must decrease as natural gas supplies are constrained (Figure 2).

The time horizon under consideration, however, allows for other factors of production to vary. Energy reducing technology can enter the production function. The introduction of this technology would actually cause a shift in the production function and the isoproduct curves would subsequently shift downward. Figure 3 shows a shift that could occur due to a change in the production function. Isoproduct line AB represents 1,000 units of steam produced in time period t-1 and line JK represents the same units of steam produced in time period t when new technology is used.

The combined effect of shifting production functions and a natural gas supply constraint can be elucidated but cannot be determined a priori for any time period. Once the energy reducing technology is adopted by the plant, a reduction in natural gas supplies would not increase energy costs above the original costs outlay until less than OI units of gas were available. By 1980, however, all natural gas for steam boiler use will be eliminated. Consequently, the effect on the plant's energy costs depends on whether or not the isoproduct line AB will shift below line EB (isoproduct t-1) as a result of adopting energy reduction technology (Figure 3).

The plant could reduce its energy consumption by changing the form of its product instead of reducing the number of hogs processed or adopting energy reducing technology. The plant has the option of selling intermediate products such as raw fat or whole blood to rendering firms rather than processing them into finished products such as lard and animal feed. All plants within this industry would not have this option due to their proximity to rendering plants. This option, if exercised, would necessitate changing the production relationship in the plant.

Total output would change in form and value as energy demands were reduced.

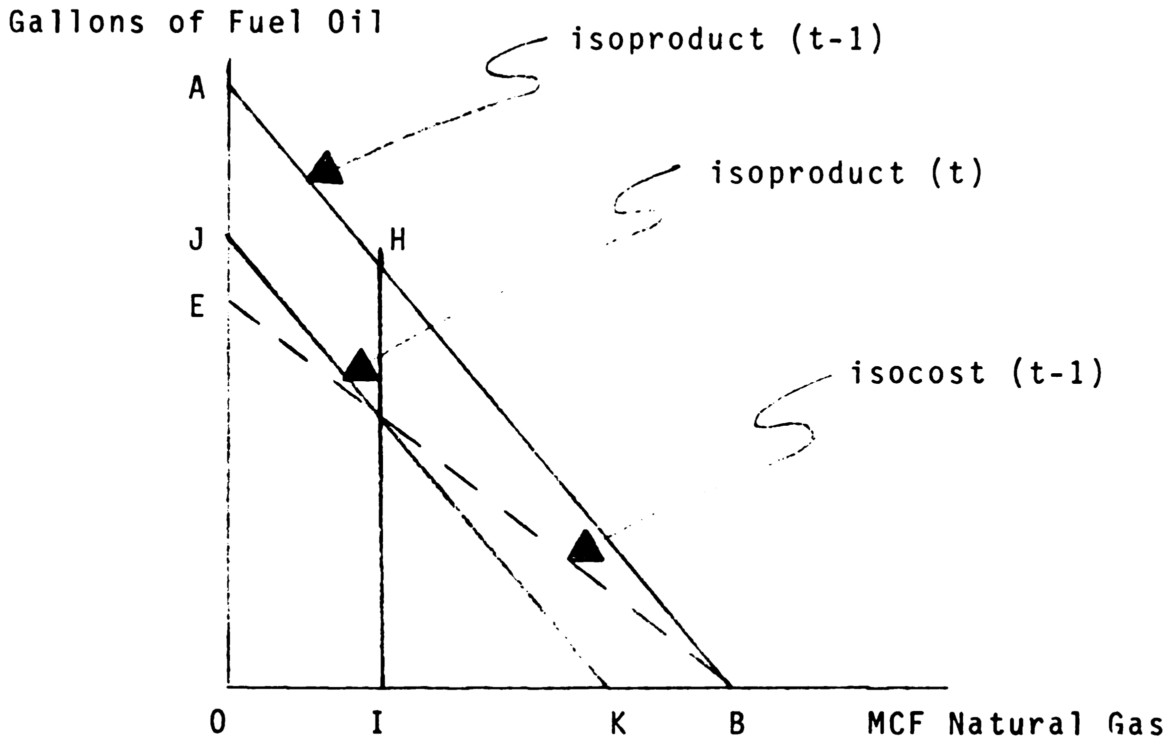


FIGURE 3. COMBINED EFFECTS OF ENERGY REDUCING TECHNOLOGY AND NATURAL GAS SUPPLY CONSTRAINTS

The impact of changing output composition was twofold, the total revenue to the plant would decrease and energy consumption would decrease as shown in Figure 4. Energy consumption would decrease by amount EF and total revenue would also decrease by amount LM. The effect on earnings of the plant would be determined when the magnitude of the total revenue decrease was compared against the energy cost decreases. The energy cost decreases were determined by multiplying the energy reduction by the appropriate energy prices.

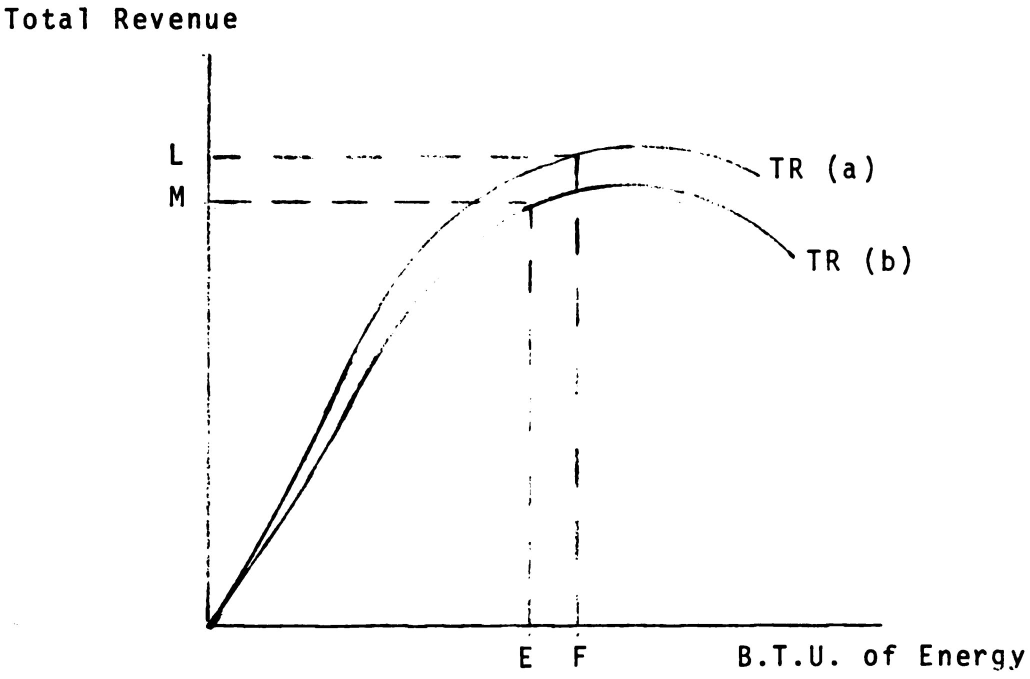


FIGURE 4. ENERGY REDUCTION AND TOTAL REVENUE DECREASES OCCURRING FROM CHANGING OUTPUT COMPOSITION

Economic theory has provided an indication of the possible decision strategies available to the hog processing plant. The F.P.C. regulation required a reduction in natural gas use in steam boilers and fuel oil was identified as a perfect substitute. The additional imposition of the F.E.A.'s 12 percent energy reduction goal, however, limited the quantity of fuel oil which could be substituted for natural gas. Consequently, other methods of reducing energy were considered.

The plant could attempt to meet the energy supply constraints by:

1. Reducing production levels
2. Adopting energy reducing technology

3. Changing the output composition of the products produced.

It should be noted that the first means to reduce energy consumption within the plant would violate the production goal imposed by the parent firm. Under changing energy supply conditions, it was hypothesized that the parent firm might adjust its means of establishing production goals. Consequently, for investigative purposes, the production level was allowed to change in two ways. First, the output could be reduced as the only means of reducing energy consumption. Secondly, output was allowed to be determined according to a profit maximizing goal.

The hog processing plant's production, energy consumption, and earnings were simulated over a six-year time horizon. Plant production levels could be determined by one of three firm criteria on a monthly basis. A monthly basis was chosen to accomodate the form of available energy consumption data. Energy reducing methods were evaluated annually by utilizing a net present value discounting technique.

Future energy reductions were multiplied by the appropriate expected energy prices to compute future cost savings. Maintenance costs for the respective time periods were subtracted from the energy cost savings to determine the net future cost savings. The appropriate 15 percent discount factor was applied to the net cost reductions and salvage value to compute the present value of future "incomes". The net present value was obtained by summing the present values over the life of the alternative and subtracting from them the acquisition cost.

Technology or production adjustments with a positive net present value were adopted in the first time period that a positive net present value occurred. A 15 percent discount factor was utilized. Decision strategies were evalued according to their impact on the before tax earnings of the hog processing plant.

CHAPTER IV

DESCRIPTION OF HOG PRODUCTION PROCESSES

The midwestern hog packing plant selected for this research slaughters a maximum of 4,500 hogs daily. The plant activities are limited to hog processing only. No other livestock are slaughtered.

All hogs are purchased by buying agents located within one state. Truck transportation is used exclusively to move the hogs from the buying stations to the plant's 5,000 head capacity livestock yards. Generally, hogs are delivered to the plant within four hours of the scheduled production time to reduce the possibility of injuries and to minimize feed and labor costs.

The plant has nearly 200 employees working directly in the production processes. Approximately 45 percent of the employees are allocated to the slaughtering activities and nearly one-third are involved with the cutting processes. The remaining employees are involved with rendering, clean-up, and miscellaneous activities.

Four major production activities occur within the plant:

1. Slaughter
2. Cutting

3. Rendering fats
4. Clean-up.

Each activity is sub-divided into individual stages. The slaughtering activity includes stunning, bleeding, scalding, hair removal, singeing, eviscerating, and carcass chilling as shown in Figure 5. Stages of the cutting activity are dismembering, boxing, and cooling meat. The rendering activities consist of blood drying and processing edible and inedible by-products. The distinction between edible versus inedible animal body parts are defined by governmental regulations. The clean-up activity transcends across all production activities and is considered as one separate activity.

Hog Slaughtering Activity

The daily slaughter activity normally starts at seven a.m., one hour after the hog cutting activity begins. Hogs are brought from the livestock pens or directly from trucks to a V-shaped hog chute. As the hog enters the chute, a revolving floor carries the animal forward in a manner similar to an escalator. The chute floor angles down relative to the sides and, as the hog moves forward, his shoulders and hams are wedged between the V-shaped sides of the chute. As the floor continues to drop away, the hog is moved forward by the sides of the chute as they revolve.

The hog chute restrains and propels the live

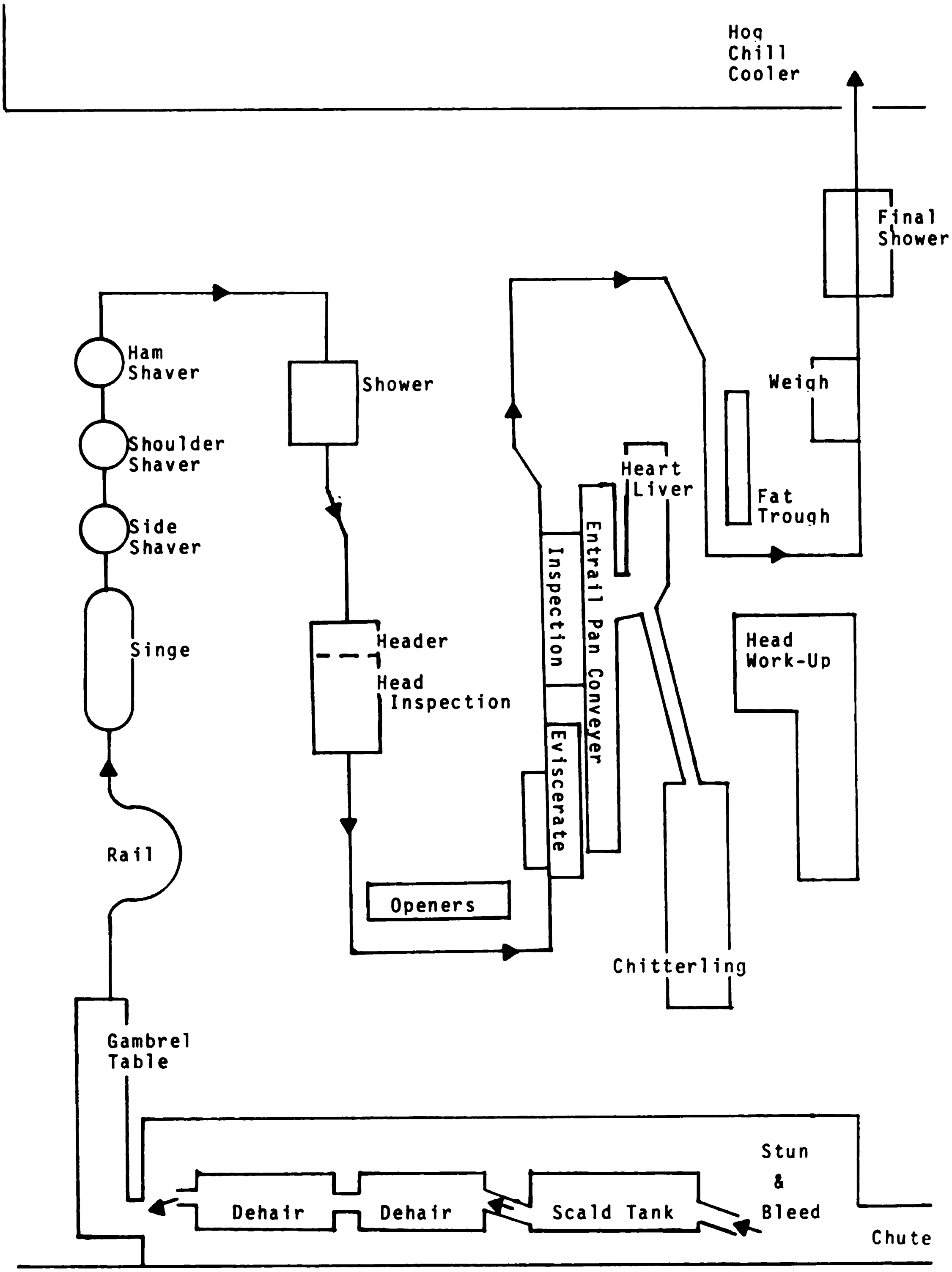


FIGURE 5. HOG SLAUGHTERING PROCESSES

animal forward to an electrical stunning area. There an electric shock is applied via a T-shaped instrument which is placed on the back of the hog with contact being made at the base of the skull and along the backbone. The stunning process is immediate, after which the hog is placed on a conveyor belt and readied for slaughter. As the hog is placed on the conveyor belt, a knife is inserted into the animal's jugular vein. As the hog is conveyed toward the scald tank, the raw blood, approximately eight to ten pints per hog, is collected in a trough along side of the conveyor and is drained into a storage area.

Hog carcasses are scalded to facilitate the removal of their body hair. The scald tank contains approximately 13,000 gallons of water heated to 148° where each hog carcass is immersed for approximately six minutes.

Immediately after scalding, the hog is placed in a dehairing machine which is basically a rotating drum with scrapers welded to the inside of the drum. The high speed at which the drum rotates plays a major part in removing the hog bristles. Two dehair machines are employed in sequence to remove the bristly hog hair. Each machine utilizes warm water to wash the carcass and to float the hair particles to a storage area.

The hog carcass is prepared for evisceration by scraping, singeing, and washing. After the dehairing activity, the hog is hung by its hocks (called gambreling) to an overhead rail. The animal is then passed through natural gas burners which singe the lighter and more flexible hair not removed in the dehairing machines. To complete the process, the hog carcass is dry shaved by employees with razor sharp knives. Prior to evisceration, the carcass receives a thorough final washing.

Each hog is scrupulously inspected by professionally trained personnel to assure that no diseased or contaminated animal is sold for human consumption. The main inspection areas prior to evisceration are the head and head glands. A second inspection follows the evisceration sequence.

When the carcass is eviscerated, several glands, entrails, etc. are removed for further processing and eventual sale. Fat is removed and directed to either edible or inedible rendering areas to be processed into lard and greases. The small intestines can be used to make chitterlings. Extracts for pharmaceutical products come from several glands: the most common of these are pancreas, thyroid, ovaries, liver, and the pituitary. Insulin, heart stimulates, asthma remedies, and anti-anemia preparations are made from the glands.[30]

The hog carcass is weighed and given a final shower of water before being placed in the chill cooler. Carcasses are stored about 15 hours in the cooler where

---

[30] American Meat Institute, By-Products of The Meat Packing Industry, Institute of Meat Packing, (University of Chicago), p. 279.

the carcass temperature is lowered about 68 degrees. The chilling process retards bacterial growth in addition to firming the carcass muscles to facilitate the hog cutting activity.

Carcass Cutting Activity

The hog cutting activity is started an hour before the slaughter activity to provide refrigeration space for the warm hog carcasses. The standard hog carcass dismembering procedure is shown in Figure 6.[31]

The hog cutting floor is the scene of the major cutting and dismembering operations. Each carcass is dismembered by the following procedure.

1. Hams are removed
2. Shoulders are removed
3. Feet are removed
4. Jowl and Boston Butt are removed
5. Shoulders, butts, bellies, back, and hams are trimmed
6. Ribs are scribed, and
7. Belly and back are separated.[32]

After dismembering the carcass, parts are stored or packed

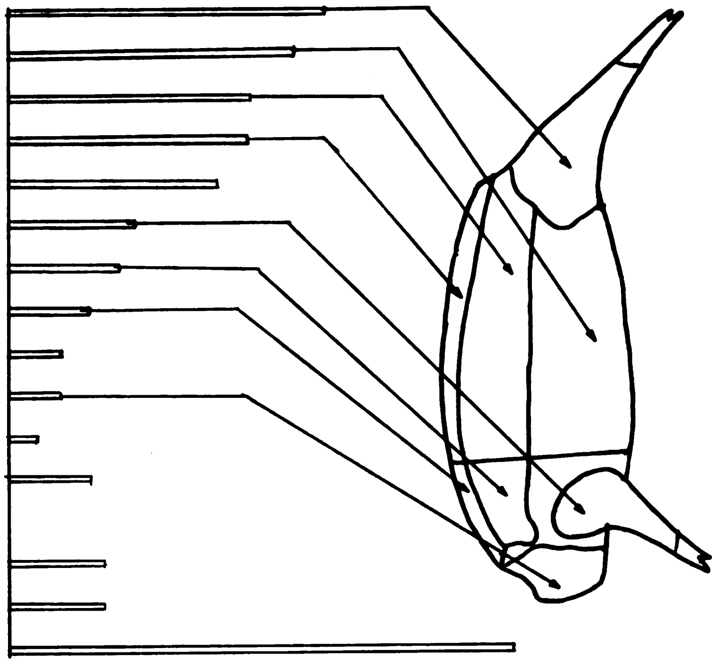
---

[31] American Meat Institute, Pork Operations, Institute of Meat Packing, 5th revised ed., (University of Chicago, 1954), p. 211.

[32] Ibid., p. 139.

	PER CENT
Hams, Smoked	13.00
Bellies or Bacon	11.75
Loins, Fresh	9.50
Fat Backs, Salted	9.50
Lard, Rendered	9.00
Picnic Smoked Shoulder	5.00
Boston Butts, Fresh	4.25
Clear Plates, Salted	2.75
Lean Trimmings, Sausage	2.25
Jowl Butts, Salted	2.25
Spareribs, Fresh	1.25
(1) Misc'l Edible Items	3.00
YIELD	73.50
(2) Edible By-Products	3.75
(3) Non-Edible By-Products	3.75
Shrinkage	20.50
TOTAL LIVEWEIGHT	100.00%

AVERAGE YIELD IN U.S. FROM AN AVERAGE HOG



(1) Including Feet, Neck Bones, Tails, Brains, Cheek and Head Meat, Nares, Lips and Snouts

(2) Including Plucks, Gullet Meat, Weasand Meat, Giblet Meat, Tongues, Kidneys and Stomach Linings

(3) Including Casings, Blood, Hair, Grease and Tankage

NOTE: Although this method of cutting is typical, proportions vary with trade requirements.

FIGURE 6. STANDARD DISMEMBERING PROCEDURE

for shipment in various coolers and freezers.

Rendering Activity

The rendering activity is divided into three separate sub-groups. These are rendering edible fats, inedible fats, and blood drying. Edible fats in hogs are the leaf and back fat, clean fatty trimmings from the viscera and fat from the edible cuts of meat.[33] The leaf and viscera fat are separated in the slaughter process while the back fat and fat from edible meat comes from the cutting floor. "Inedible fat, on the other hand, includes contaminated trimmings, visceral parts, clean-up scraps, and any other parts declared unfit for food", including hogs condemned during the inspection processes.[34]

Edible fats are cooked in cylindrical vats with a capacity of 20,000 pounds. Each vat is sealed and cooked for three and one-half hours under 60 pounds per square inch of steam pressure. Steam is entered through the bottom of the vat for two and a half hours; but, during the last hour, steam enters only from the top. The procedure, which involves changing the steam entrance point in the vat, causes the contents to settle in layers. Three definite layers are formed in the settling process,

1. Prime steam lard

---

[33] American Meat Institute, By-Products, p. 19.

[34] Ibid.

2. An emulsion
3. Tank water.

About 65 percent of the raw fat is converted into prime lard which is loaded directly into a railroad tank car. The emulsion is stored in an available processing vat for future recooking. The tank water contains about seven percent solid matter and is stored for further preparation.

About 600 gallons of tank water are derived from the cooking process and eventually is completely evaporated by steam heat. The final dehydration step requires dripping the concentrated liquid onto a stick roller, which is similar in appearance to a stainless steel rolling pin, one foot in diameter. Steam is injected into the roller and the condensed tank water is dripped onto the roller and dried almost instantly. The resulting residue is scraped off as the roller turns. This residue is processed through a hammer mill, bagged, and sold as a high protein animal feed.

The inedible rendering process receives meat and fat scraps from the slaughter and cutting floor on a continuous basis. The raw material is placed in a pre-breaker which shreds and breaks condemned parts, bone, and other scraps prior to entering a storage tank. Material from the tank is combined with steam and pumped into a continuous cooker.

The continuous cooker is a series of horizontal tubes stacked on top of each other. The raw material enters the top tube and is augered to the end where it drops to the next lower tube and is augered back. This process is repeated for about 20 minutes until the material reaches the bottom of the cooker. Approximately 10,000 pounds of material can be contained in the continuous cooker as the raw material passes through the tubes.

The cooked matter is augered to a screening and pressing machine, commonly called an expeller or a french press. The inedible grease from the material is separated by draining screens and by the presses.

Two products are derived from the continuous cooking process; these are white grease and cracklings. White grease is used in the manufacture of commerical products such as soap. Cracklings are generally sold in bulk quantities to feed manufacturers to be utilized in animal feeds.

House grease is a product used in feed manufacturing, primarily as an adhesive in the production of pellets. House grease is derived from skimming the fat and grease off the top of the water storage tank which is filled from the water drains within the plant. The skimmed material is then cooked with steam for four hours before it is readied for sale.

Whole blood is cooked approximately six hours by means of a dry cook method. The blood is piped into a jacketed container. Live steam is injected between the jacket and the container to provide the heat source which evaporates the whole blood. Dried blood is used as a high protein feed ingredient and/or as an organic fertilizer.

Clean-Up Activity

The clean-up activity is directed toward the entire plant and is not separated according to production activities. Ten employees are involved in this facet alone and 43,000 gallons of 170°F water are utilized to clean the plant. The hog production processes are shown in Figure 7.

Description of Energy Utilization In A Hog Processing Plant

Energy utilization within a meat packing plant can vary considerably. This variation has been attributed to the type of production process within the plant and the type of livestock processed. Past research[35] has shown that hog processing requires about twice as much energy as beef processing when both types of livestock are slaughtered in plants with by-product processes capabilities. Energy consumption also varies considerably between plants which process the same type of livestock but produce a different combination of products. Beef processors, which produce boxed meat, have twice the energy demand per pound

---

[35] Foster D. Snell, Inc., Energy Conservation in The Meat Packing Industry, Federal Energy Administration Contract No. C-04-50090-00, January 30, 1975.

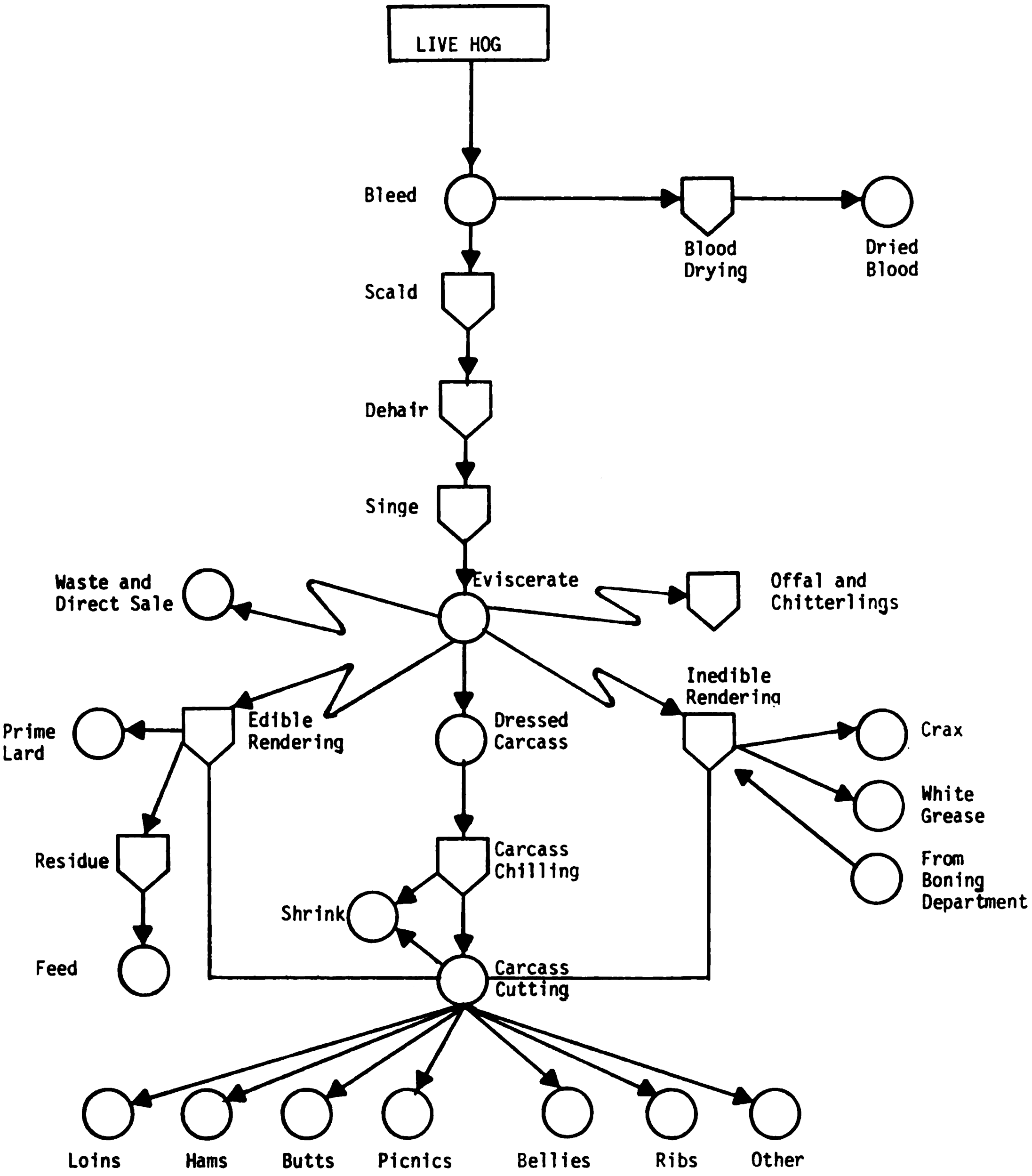


FIGURE 7. FLOW CHART OF HOG PRODUCTION PROCESS

of liveweight as beef processors which slaughter and process by-products only. Similarly, pork processing shows a wide range of energy requirements.

As interest in energy utilization increased, engineers began to concentrate on energy use within the meat processing plant. Johns-Mansville Corporation[36] studied a medium-sized (300 hogs per hour) hog slaughtering and cutting operation in Iowa. Total energy use was ascertained by months and quantified by linear regression. They estimated total energy as a function of production; the resulting equation was:

$$Y = 10{,}419 + .6975X$$

where

Y = million B.T.U. used per month

X = 1,000 pounds of production per month

Standard error for Y was $\pm 2{,}363$.

Although energy use within the plant was not correlated with various energy sources, they did ascertain that about 70 percent of the total plant energy demand was derived from the steam boiler requirements. At the mean, approximately 1,000 B.T.U. would be required per pound of live hog processed.

---

[36] Johns-Mansville, Inc., "How Pork Plant Rated On Energy", National Provisioner, Jan. 31, 1976, p. 30.

In addition, the Johns-Mansville researchers estimated that only three-fourths of the boiler steam was utilized in the production processes. The remaining 25-30 percent of the steam heat was lost or used for space heating, vacuum pumps, and etc.

This research is concerned with the derived demand for energy from each hog processing activity. Energy reducing alternatives are being proposed for specific production processes. Research, however, has lagged behind the profusion of proposed energy saving technology, and information regarding energy use versus energy reduction is not available. The current state of knowledge was limited to the Johns-Mansville study which showed that about 50 percent (70% * 75%) of the hog processing plant energy use was actually used in the production processes, per se.

The Johns-Mansville research effort was intended to be extended by this research by the addition of estimates for the derived energy demand for the following production activities:

1. Hog scalding
2. Hog dehairing
3. Inedible rendering
4. Edible rendering
5. Blood drying
6. Clean-up
7. Refrigeration.

Estimates of energy utilization were obtained from cooperating engineers with the hog processing firm. Other processing estimates were obtained by metering production activities and utilizing standard engineering tachniques. Energy consumption was ascertained by energy source and for varying levels of plant production.

Hog Scalding Energy Demands

Approximately 13,000 gallons of water are heated to 148 degrees Fahrenheit and maintained at that temperature throughout the work day. Each gallon of water requires 666 B.T.U. to raise its temperature to 148°. This energy estimate is derived from standard engineering tables which show that 79.81 B.T.U.'s are required to heat one pound of water.[37] Sixty degree Fahrenheit water is used to fill the scald tank and each gallon of water weighs approximately 8.345 pounds. In addition, the plant engineers have ascertained that approximately 1,000 pounds of steam per hour are required to maintain the scald tank temperature at 148 degrees throughout the work day. Assuming boiler efficiency is 80 percent and a five percent steamline loss occurs, 1,413,170 B.T.U. are required from the boiler energy source for every scald tank hour of

---

[37] Lionel S. Marks and Harvey D. Davis, Tables and Diagrams of The Thermal Properties of Saturated and Super-Saturated Steam, (Longsmans, Green and Company, 1920), pp. 8-10.

operation. (This estimate includes 500 B.T.U. per square foot for surface water evaporation.) The estimated B.T.U.'s of boiler energy for the scald tank is:

$$\text{B.T.U.} = 1{,}413{,}170X_1 + 876.3X_2$$

where

X_1 = number of hours scald tank is operated

X_2 = gallons of water in scald tank.

Hog Dehairing Energy Demands

The sequence of dehair machines utilized both electricity and boiler steam. Electricity is the main power source for the equipment and steam is used to heat water which washes the hogs and floats the bristles out of the machines. Two machines require 4,000 pounds of steam per hour to heat the wash water and 750 pounds of steam per hour to maintain the desired temperature. Assuming a five percent steamline loss and an 80 percent boiler efficiency rate, 7,187,500 B.T.U. per hour of operations are required at the boiler to properly operate the dehair machines.

Inedible Rendering Energy Demands

The inedible rendering process is a continuous operation which utilizes steam in a wet cooking process. The steam is injected into the equipment and directly contacts the raw material. Based on plant engineer estimates, 1.125 pounds of steam are required to render each pound of raw product. After including the steam line and boiler losses, approximately 1,293.75 B.T.U. are needed at the boiler for each pound of product processed.

Edible Rendering Energy Demands

The edible rendering process employs large conical vats which are sealed to utilize pressure as well as heat in the cooking process. This plant has eight vats for rendering edible lard. Two of these vats are used for fat from the slaughter floor, five are used for fat from the cutting floor, and one is used to render the emulsion which is a by-product of previous edible rendering activities. Approximately 3,700 pounds of steam must be injected directly into the vat to complete the three and a half hour rendering process. In addition, approximately 600 gallons of water must be evaporated to obtain the high protein animal feed from the vat tank water. The combined boiler energy requirement of the rendering process plus steamline and boiler loss were computed to be 5,598,700 B.T.U. by the plant engineers. The boiler energy required to evaporate 600 gallons of water is 1,112 B.T.U.[38] per pound plus line and boiler losses, or 7,326,000 B.T.U. for each edible rendering vat.

---

[38] Marks and Davis, Op.cit.

Blood Drying Energy Demands

The blood drying process utilized a dry cooking method. Steam is injected between the container and a surrounding metal jacket. Plant engineers attached metering devices to measure the total steam required per cooking unit. Engineers determined that steam required to evaporate the water was almost doubled due to heat radiation losses and steam condensation. After accounting for steam line loss (5%) and boiler efficiency (80%), it was found that 2,714 B.T.U. were needed to evaporate one pound of whole blood.

Clean-Up Energy Demands

The clean-up operation required 43,000 gallons of water heated to 55 degrees to 170 degrees. Utilizing standard steam tables, approximately 115 B.T.U. were required to raise one pound of water from 55 degrees to 170 degrees. Allowing for the assumed steam line and boiler efficiency, 51,582,000 B.T.U. were required for each daily clean-up operation.

One dry cooking unit was used daily to render house grease. Based upon the metering test conducted by plant engineers, 7,127,000 B.T.U. were required at the boiler for this operation.

Refrigeration Energy Demands

The refrigeration demand at the plant is currently supplied by natural gas, electricity, and propane.

Propane is used as an alternative source only when natural gas is in short supply. Normally, about 40 percent of the energy demand is provided by natural gas and the remainder is provided by electricity. Refrigeration energy demand are highly plant specific. Insulation and cool storage location relative to heat areas greatly affects refrigeration energy demands. Also, the quantity of meat processed and the time of year affect refrigeration requirements. Energy demands for six cooling areas are estimated based upon the plant conditions and the quantity of hogs processed. These are: the hog chill cooler, the hog cutting floor, the loin cooler, the fresh meat cooler, the offal freezer, and the shipping area. The shipping area energy demands were estimated with three equations which accounted for cooling losses associated with weather.

The daily energy demand for the hog processing plant is shown in Table 1. This table was derived from the case study plant's energy equations, and it was assumed that 3,300 hogs would be processed in one eight-hour day.

TABLE 1. DAILY ENERGY DEMANDS FOR SELECTED HOG PROCESSING ACTIVITIES

Hog Processing Activity	Daily Energy Consumption (1,000 B.T.U.)
Scalding	22,617
Dehairing	57,500
Inedible Rendering	139,087
Edible Rendering	77,530
Blood Drying	77,186
Clean-Up	58,710
Refrigeration and Freezing	171,600

Total energy use within the hog processing plant was estimated. Energy demands for specific energy sources and major production activities were also estimated. Energy estimated by activity and source will be simulated as production varies over the time horizon. The simulation model will be primarily concerned with the change in total energy demand to meet energy conservation goals, the feasibility of utilizing specific production alternatives as prices of energy sources change and as energy supplies are restricted.

CHAPTER V

REVENUE AND COST ESTIMATION

This research is primarily concerned with the combined effect of a total energy constraint, a natural gas supply constraint, and rising energy prices on the earnings of a hog processing plant. Revenue and costs are estimated to determine the combined effect of the energy and price changes on the plant's earnings before taxes. All cost components are related to output level changes but not all are specifically delineated. Energy supplies, energy prices, hog supplies, hog prices, product prices, and labor prices are estimated separately from other plant inputs.

Total revenue is defined as the price (P_q) per unit of output times the number of units sold (Q), i.e. $R = P_qQ$. The total revenue derived from a hog processing plant, however, is dependent upon several products, by-products, and intermediate products. Each of these have associated prices that vary according to the demand and supply relationships prevailing at any particular point in time. Consequently, total revenue (R) would, of necessity, be defined as:

$$R = \sum_{i=1}^{j} P_q^j \; q_j$$

where

J = number of different products sold

$$Q = \sum_{i=1}^{j} q_j$$

Revenue Estimation

Prices of the several products sold by a hog processing plant vary as the demand-supply relationships respond to individual market conditions. Each product's price has its own particular substitutes, complements, and price changes. The hog slaughter market does, however, influence all of the various hog product supply situations.

The combined impact of these several product prices is reported monthly by the U.S.D.A.[39] This data series reports the wholesale value of the carcass and byproducts per 100 pounds of liveweight and the average price per 100 pounds for various slaughter hog categories.

Revenue for the plant was estimated by utilizing the U.S.D.A. hog price and quantity data series. Total revenue was not estimated. Margin revenue was estimated and is defined as the difference in wholesale value and slaughter value per 100 pounds of liveweight. Linear regression was utilized to estimate the value of live hogs and the

---

[39] U.S. Department of Agriculture, Livestock and Meat Statistics, "Pork: Live Animals and Wholesale Prices Wholesale and Retail Values", Table 174, Statistical Bulletin No. 522, ERS, SRS, AMS, (1974), p. 283.

wholesale value per 100 pounds of liveweight as the slaughter hog market conditions change over time.

Wholesale Value of Hogs

Research on price spreads have been directed in several directions. Learn[40] concluded that merchants tend to maintain constant percentage markups of livestock products and, consequently as production rises, the absolute difference in prices will decrease as livestock prices fall. Hayenga[41] utilized linear regression to determine the correlation between the value of hogs and their wholesale value as the liveweight of the hog varied. Combining their research conclusions, the total quantity of hogs available for slaughter appears to have more effect on the margin between liveweight value and wholesale value than the weight of the hog.

The wholesale value of hogs has been observed by industry members to fluctuate as the liveweight value of hogs adjusts to market conditions. This relationship was quantified by linear regression to estimate the expected margin revenue as the quantity of slaughter hogs changed over time. The ratio of wholesale value to liveweight

---

[40] Learn, Elmer W., "Estimating Demand for Livestock Products at The Farm Level", Journal of Farm Economics, (1956), Vol. 38, pp. 1483-1491.

[41] Hayenga, Marvin, An Evaluation of Hog Pricing and Grading Methods, Agricultural Economics Report 192, Michigan State University, Department of Agricultural Economics, (May 1971).

value (W/S) was selected as the dependent variable, and the independent variable was the quantity of commercially slaughtered hogs (H). The monthly data (1968-1973) was found to be serially correlated and the Cochrane-Orcutt method for estimating regression equations with autoregressive disturbances was utilized to obtain the regression coefficients.[42] The estimated relationship was:

$$\underset{(.004)}{W/S = .0425} + \underset{(.00001)}{.0013H} \qquad R^2 = .85$$

where

W/S = ratio of monthly wholesale value per 100 pounds of liveweight to monthly liveweight value per 100 pounds

H = thousands of monthly U.S. commercially slaughtered hogs

Durbin Watson (D.W.) = 1.43

(xx) = standard error of coefficient.

The wholesale value of hogs per 100 pounds of liveweight was predicted with a relatively high degree of confidence whenever the slaughter price per hundred pounds and the quantity of hogs available for commercial slaughter were know.

---

[42] Kmenta, Jan, Elements of Econometrics, (MacMillan Company, New York, 1971), p. 287.

Liveweight Value of Hogs

The liveweight value or slaughter hog market price and pork prices have been estimated by economists with widely varying approaches and results. Part, but not all, of this diversity stems from the variance in research objectives. Estimates of hog demand elasticities have been made on an annual basis, monthly, weekly, and by day of the week. These estimates range from -0.46 to -5.8.[43] Annual estimates of the demand elasticity of hogs range from -0.46[44] to -2.75.[45] One monthly estimate of price flexibility was -1.6[46] (at the means) while the weekly and weekday estimates were below -2.5.

Hayenga and Hacklander estimated the monthly price of live hogs.[47] Their linear regression model accounted for approximately 97 percent of the monthly variation in hog price. Hog price was estimated as a function

---

[43] Shepherd, Geoffrey S., Agricultural Price Analysis, (Iowa State Univ., Ames, IA, 1964), 5th ed., pp. 63-64.

[44] Brandow, G. E., "Interrelations Among Demands for Farm Products and Implications for Control of Market Supply", (Pennsylvania State University, Agricultural Experiment Station , Bulletin 680, 1961).

[45] Dean, Gerald W., and Heady, Earl O., "Changes in Supply Response and Elasticity for Hogs", Journal of Farm Economics, Vol. 40, (1958), p. 539.

[46] Hayenga, Marvin L., and Hacklander, Duane, "Monthly Supply-Demand Relationships for Federal Cattle and Hogs", American Journal of Agricultural Economics, (Nov. 1970), Vol. 52, No. 4, p. 539.

[47] Ibid.

of hog slaughter, beef slaughter, stored hog supplies, changes in pork supplies, per capita income, and monthly binary variables. The hog and beef slaughter variables are based upon average slaughter per day to eliminate monthly variations as days per month differ.

The Hayenga and Hacklander model was re-estimated over a different and more current four-year time horizon. The resulting equation explained 95 percent of the price variation. The expected negative sign on the beef variable was substantiated. Many of the coefficients were nearly identical to the earlier model.

The disadvantage of using the Hayenga-Hacklander model is that five variables would have to be predicted to estimate hog prices in future time periods. To reduce the number of variables which would need to be predicted, the pork storage variable and the change in pork storage variables were eliminated from the Hayenga-Hacklander model.

Hog prices were estimated by ordinary least squares with five independent variables, hog slaughter, beef slaughter, per capita income, and monthly binary variables. Approximately 90 percent of the monthly price variation could be accounted for over the 1969-1973 time period. This model loses little explanatory power and reduces the number of variables. The daily beef slaughter variable has a mean of 133.6 million pounds and a standard deviation of only 7.15. Consequently, the monthly mean of daily beef slaughter was used, and only per capita income and daily hog slaughter estimates for future time periods were necessary. The linear regression model selected was:

$$S = \underset{(17.73)}{35.10} - \underset{(.11)}{.66X_1} + \underset{(.021)}{.16X_2} - \underset{(.10)}{.11X_3} - \underset{(2.5)}{.09M_1}$$

$$- \underset{(2.70)}{.30M_2} - \underset{(2.92)}{2.92M_3} - \underset{(2.60)}{3.04M_4} - \underset{(2.60)}{4.83M_5}$$

$$- \underset{(2.80)}{6.29M_6} + \underset{(2.75)}{3.25M_7} - \underset{(2.57)}{0.52M_8} + \underset{(2.64)}{1.15M_9}$$

$$+ \underset{(2.83)}{1.63M_{10}} - \underset{(2.79)}{1.21M_{11}}$$

$R^2 = .89$

X_1 = million pounds of pork slaughtered per month divided by the number of work days per month[48]

X_2 = monthly U.S. per capita income

X_3 = million pounds of beef slaughtered per month divided by the number of work days per month

$M_1 \ldots M_{11}$ = monthly binary variable (Feb. = 1...Dec. =11)

(xx) = standard error of coefficients

---

[48] Work days are computed as: week day, no holiday = 1 day; week day, holiday = 1/2 day; Saturday or Sunday holiday = 1/3 day.

D.W. = .98

Per capita monthly income was estimated by linear regression over time. The resulting estimate was:

$$PCI = \underset{(15.8)}{445.7} + \underset{(.374)}{3.05t} \qquad R^2 = .98$$

where

PCI = monthly personal income divided by the U.S. monthly population[49]

t = number of the months over the time horizon

t = 1 on 1/1/73

(××) = standard error of coefficient

D.W. = 2.48

Commercial Hog Supply Estimation

Hog supplies were estimated for future time periods by assuming that the repetitive nature of hog cycles would continue. Two separate studies concluded that a hog supply cycle existed and that the cycle is not solely dependent on corn production or prices. The applicability of the

---

[49] U.S. Department of Commerce, Survey of Current Business, 1969-1973.

"Cobweb Theorem" was investigated by Dean and Heady[50] in 1958. Shepherd also observed the hog cycle's occurrence even though corn prices were relatively stable.[51]

In many agricultural situations, producers adjust their outputs to price changes, but the change is not reflected instanteously in the market place. Consequently, supply response will be lagged and the market price in future time periods will reflect past decisions. Dean and Heady investigated the lagged supply response of hog producers and concluded:

> Three conditions are required for the Cobweb Theorem to explain the functioning of a commodity market; (a) producers plan in period t for output in period t+1 on the basis of prices in period t; (b) production plans once made, cannot be changed until the following time period; (c) price must be determined by the quantity sold (i.e., by interaction of a conventional demand function and a vertical supply function). The production demand and supply structure for hogs approximate these conditions. With regard to condition (a), limited research evidence points to "extension of current prices" as a dominant expectation model used by producers. Condition (b) is approximately met since once sows are bred, relatively little can be done to increase or decrease future production. Condition (c) implies no simultaneity between price and quantity within the

---

[50] Dean, "Changes in Supply Response and Elasticity for Hogs", pp. 845-860.

[51] Shepherd, Agricultural Price Analysis, p. 40.

> marketing period, i.e. quantity is assumed to be predetermined.[52]

In addition to the observations of Dean and Heady, Shepherd reported that:

> Evidence in recent years, however, indicates that the four-year hog production and price cycles are inherent in the internal conditions of the hog industry and do not require shocks from outside to keep them going. After 1952, the stabilization operations of the CCC were conducted on so large a scale that they almost completely damped down year to year variations in corn prices. Yet hog production and prices continue their four-year cyclic movement much the same as before.[53]

Larson[54] and Talpaz[55] both attempted to quantify the hog cycle. Larson utilized trigonometric functions to approximate the hog-corn price ratio, pork productions, and sow farrowing. Talpaz combined the work of many researchers and "statistically tested and accepted the existence of the combined series of cycles operating

---

[52] Dean, "Changes in Supply Response and Elasticity for Hogs", p. 846.

[53] Shepherd, Agricultural Price Analysis, p. 40.

[54] Larson, Arnold B., "The Hog Cycle As Harmonic Motion", Journal of Farm Economics, (1964), Vol. 46.

[55] Talpaz, Hovav, "Simulation, Decomposition, and Control of a Multi-Frequency Dynamic System: The United States Hog Production Cycle", (unpublished Ph.D. Dissertation, Michigan State University, 1973).

simultaneously".[56] He found that not only did a four-year sow farrowing cycle exist, but that five smaller cycles also existed which were 2, 1.25, 1, .5, and .3-year cycles. Talpaz predicted the sow farrowing via regression analysis with 94 percent of the variation in the dependent variable being explained.

Based on the past research and particularly Talpaz's work, there appears to be little doubt that a hog cycle does exist and that it can be quantified. Other economic factors do play a role on the impact of producer decisions and consequently one could hypothesize that the cycle could be disturbed or changed by any one of these factors. The combined time span of these past cyclical studies, however, encompasses 1947 through 1971 and the hog cycle has continued to exist.

The method employed by Talpaz was used to estimate the future monthly supply of U.S. slaughter hogs. A Fourier Series of the form:

$$X(t) = \sum_{n=0}^{T} A_n \text{Cos}(nut) + b_n \text{Sin}(nut) + e)$$

where

$X(t)$ = monthly hog slaughter in month t

T = the number of terms in the series

---

[56] Ibid., p. 64.

$U = 2\pi/48$; radian frequency for a 48 period cycle

t = time period, 0-48

e = error term

n = selected integer values between 1.0 and 18.

was appropriate for the Talpaz sow farrowing estimation and was also used in this research to estimate the monthly hog slaughter. Utilizing the same Step-wise Delete Routine[57] as Talpaz, the coefficients on the cosine and sine variables with an F-test, significance level of five percent was estimated. The resulting estimated equation was:

$$\begin{aligned} Q_t &= \underset{(120.0)}{6{,}900} + \underset{(130.8)}{592.2X_1} - \underset{(89.7)}{239.2X_2} - \underset{(165.7)}{144.7X_3} \\ &\quad + \underset{(131.4)}{71.6X_4} + \underset{(57.7)}{195.7X_5} + \underset{(167.3)}{484.7X_6} - \underset{(157.4)}{249X_7} \end{aligned}$$

$R^2 = .64$

D.W. = 2.08

(xx) = standard error of coefficients

---

[57] Ruble, W. L., "Improving the Computation of Simultaneous Stockastic Linear Equations Estimates", Agricultural Economics Report No. 116 and Econometrics Special Report No. 1, Department of Agricultural Economics, Michigan State University, E. Lansing, MI, October 1968.

where

Q_t = quantity of commercially slaughtered hogs (in thousands) in month t

X_1 = Cos ($\pi t/6$)

X_2 = Cos ($\pi t/3$)

X_3 = Sin ($\pi t/24$)

X_4 = Sin ($\pi t/6$)

X_5 = Sin ($2\pi t/3$)

X_6 = Cos ($\pi t/24$)

X_7 = Cos ($\pi t/12$)

The explanatory power of the hog slaughter equation is much lower than Talpaz's equation of sow farrowing. A reduction in explanatory capabilities was expected since producers have the ability to adjust hog marketings and slaughter via production practices.

These estimates of hog slaughter and live hog prices were made in order to estimate the wholesale value of hog products. Margin revenue for the plant was determined by a set of linear regression equations which estimated monthly hog slaughter and monthly per capita income to predicted live hog prices which, in turn, was used to estimate wholesale hog values. The margin revenue was defined as the price difference in liveweight value and wholesale value per hundredweight of live hog times the quantity of live hogs (hundredweight) slaughtered by the firm.

Cost Estimation

The cost associated with processing hogs depend upon the production level and the price of slaughter hogs. The particular production costs of a firm are generally regarded as confidential and released only after certain safeguards have been met.

Two potential sources of production cost data were investigated. These were the "Hog Cut-Out Values and Margins" published by Madigan-Abraham Associates, Inc.[58] and a "Cost Components" study conducted for the Economic Research Service, U.S.D.A. by Food Management, Inc.[59] Both sources provided labor and overhead costs, but neither related cost changes to output level fluctuations.

The cooperating firm was approached to provide the necessary information which related output level changes to cost changes. Understandably, the firm did not want the actual costs of production made public. An acceptable

---

[58] Madigan-Abraham Associates, Inc., <u>Hog Cut-Out Values and Margins</u>, 1627 Whitfield Avenue, Sarasota, Florida 33580.

[59] Food Management, Inc., <u>Cost Components-Cattle and Hog Slaughter Plants</u>, ERS, USDA Contract No. 12-17-02-5-943 October 1974.

compromise which combined the "Cost Components" data and the plant's production cost resulted.

The "Cost Components" report contained a survey of midwestern hog slaughtering plants which had an hourly-rated slaughter capacity between 390 and 480 head. The cost data for these four plants were combined by using a simple average of the average cost per head for the various cost components. These cost components are shown in Table 2 for a plant with a 400 hog, hourly-rated capacity, and a nine-hour production work day.

The average processing cost per hog for the four firms was 4.77¢ per pound of live hog processed. The associated output level with an average production capacity of 445 hogs per hour is approximately 18 million pounds of liveweight per month.

The case study plant provided twelve months of data which reflected the average cost of production over the production range of 11 to 22 million pounds per month. The data were plotted and visually inspected to ascertain an appropriate functional form. The data showed no evidence of a curvilinear relationship and linear regression was selected as an appropriate estimation method.

The resulting equation of the form

$$Y^* = K_0 - \alpha M \text{ lbs.}$$

explained 58 percent of the variation in Y* where

TABLE 2. DAILY HOG PROCESSING COSTS - SLAUGHTER, CUT, RENDER, AND CLEAN-UP - 1974

Variable			
	Direct Labor	$ 6,540	
	Supplies	4,032	
	Utilities	1,332	
	Sanitation Labor	1,172	
	Repair Labor	972	
	Other (transport buy, sell, etc.)	13,536	
			$30,584
Fixed			
	Administration	3,100	
	Meat Inspection	72	
	Other	4,908	
	Depreciation	1,556	
	Interest	1,007	
			$10,643
	TOTAL DAILY COST		$41,227

Average Cost Per Hog	$11.45
Average Processing Cost Per Hog	$ 9.91

(Average Cost Less Depreciation and Interest ($0.0477/lb. Liveweight)

M lbs. = million pounds of hogs slaughtered

K_0, α = constants

Serial correlation was not present.

The firm's average cost curve over the given production range was shifted vertically by adding an amount δ to the constant K_0 where δ was allowed to be positive or negative. This adjustment of the intercept forced the average processing cost curve of the firm through the coordinates of the average processing cost of the surveyed midwestern hog processing plant. The resulting equation which depicts the average cost of processing hogs over the given production range is:

$$\begin{array}{cccc} Y = & .0837 & - & .002\text{M lbs.} \\ & (.0076) & & (.0005) \end{array}$$

where

Y = average cost per pound of liveweight slaughtered in dollars

M lbs. = million pounds of hogs slaughtered per month

(xx) = standard error of coefficient

D.W. = 1.87

Adjustments in specific cost components were made to account for changes in resource use and expected price increases. This adjustment procedure required monitoring the use level of specific inputs in the production process. When price changes occurred, the new price was multiplied by the quantity of input used and added to the production cost equation while the old price multiplied by the quantity of input used was removed from the cost equation. Labor usage, fuel oil, and natural gas were three inputs which were specifically monitored.

The quantity of labor, fuel oil, and natural gas were allowed to adjust with production level changes. Monthly labor costs were adjusted according to inflationary expectations of the firm and production hours worked. The labor union contract called for a guaranteed minimum weekly pay for 36 hours and time and a half for overtime. If the firm paid for more hours than were actually worked in a given month, due to the minimum wage provision, the firm could utilize those hours in the following month without any additional cost. These provisions of the labor union contract were utilized to adjust labor costs when necessary.

Energy costs were adjusted according to production fluctuations and expectations of the firm regarding price increases and energy constraints. A five percent annual increase in energy prices were also considered to obtain a measure of the simulation model's sensitivity to energy prices. These expectations are shown in Chapter VI, in the section entitled Expectation Component of The Simulation Model.

Margin revenue for the firm was estimated by predicting the price difference between wholesale value and liveweight value and multiplying by the units of production. Production costs for the firm were estimated from firm data and adjusted to cost data provided from hog processing plants with similar characteristics to protect the confidentially of the firm's data. Net earnings to the firm are the difference between margin revenue and production costs which include processing costs plus fixed costs.

CHAPTER VI

SIMULATION MODEL

The simulation model was designed to investigate the decision strategies of a hog processing plant over a six-year time horizon. The decision strategies available for consideration were limited by energy supply constraints which were to be implemented during specific time intervals. Consequently, decision strategies were also time related. Annual decisions were made in regards to changes in the firm's production functions and shifts in the function were allowed as the level of capital embodied in technology was adjusted. Monthly decisions determined the level of production for the plant.

The objective of this research was to determine the effect of plant earnings and energy flows as various strategies were considered. Three basic strategies were considered: (1) change production levels, (2) adopt energy reducing technology, and (3) change output composition. Monthly production could be reduced to meet energy constraints kept at the normal level or adjusted to maximize profit. Energy reductions due to technology changes occurred as alternatives with positive net present value were adopted. Energy consumption, earnings technology adjustments, and total production were reported monthly over the six-year time horizon.

The effect of the natural gas constraint and the energy conservation goal on earnings was measured by comparing three modifications of the simulation model. These models differed in two respects, either the decision criteria was modified or the energy constraints were considered jointly and separately.

Variation of the constraints and decision rules were separated into three groups, called Models A, B, or C. Model A simulated the energy and financial changes due to rising energy prices and standard plant management strategies. Model B differed from Model A by the addition of two energy constraints. A 12 percent energy conservation goal for 1982 and natural gas supply reductions for the period of 1976 to 1980 were imposed. Model B was considered the most likely estimate of the hog processing plant situation. Model C eliminates the firm's strategy used in Model B and replaced it with a profit maximizing strategy. Model A was designed to show the impact of rising energy prices. Model B was designed to approximate the situation and reaction of the hog processing plant. Model C was designed to provide a comparison of theoretically prescribed behavior with the behavior of the firm. Table 3 illustrates the difference between these models.

TABLE 3. COMPARISON OF HOG PROCESSING PLANT SIMULATION MODELS

	MODEL A	MODEL B	MODEL C
<u>CONTRAINTS</u>	1. Monthly production $\geq$ 42,000 hogs	1. Same as A	
	2. Monthly production $\leq$ 90,000 hogs	2. Same as A	1. Monthly production limited to 45,000 * work days
		3. 12% energy reduction goal by 1982	2. 12% energy reduction goal by 1982
		4. Interruptible gas shut-off by 1980	3. Interruptible gas shut-off by 1980
<u>EXPECTATIONS</u>	1. Energy price increases	1. Same as A	1. Same as A
	2. Labor price increases 5% per annum	2. Same as A	2. Same as A
	3. Cyclical hog supplies	3. Same as A	3. Same as A
<u>DECISION CRITERIA</u>	1. Firm's status quo-market share and labor contract determine output level	1. Same as A	1. Maximum difference of total revenue and total cost
		2. Select production alternatives with a positive net present value	2. Same as B

Description of Simulation Model

Each of the simulation models have similar components:

1. Production component
2. Energy demand component
3. Expectation component
4. Decision strategies component
5. Production alternative component.

The production component was based upon the cooperating firm's production records. The total quantity of each product produced by the firm was converted to a simple percentage of the quantity of live hogs slaughtered and the pounds of hog carcasses which were dismembered. The quantity of hogs slaughtered and cut were the only required inputs to estimate the quantities of the various products produced. The production component reported: (a) pounds of prime steam lard, (b) pounds of animal feed, (c) pounds of dried blood, (d) pounds of white grease, (e) pounds of fresh pork (loins, hams, butts, picnics, bellies, ribs), and (f) pounds of miscellaneous pork products. The production component equations were included in Appendix A.

The energy demand component was derived from the production component and the overall level of production. Total energy demand for the plant was estimated by the regression equation developed by Johns-Mansville engineers for a hog processing plant.[60] This total energy demand was estimated by:

$$Y = 10{,}419 + .6975X$$

where

Y = million B.T.U. per month

X = 1,000 pounds of production per month.

Energy demand for the slaughter, cut, rendering, and refrigeration processes were derived from engineering estimates and experiments by the firm's personnel. Energy estimates were related to production levels for the following activities.

1. Blood drying
2. Hog scalding
3. Hog dehairing
4. Edible rendering
5. Inedible rendering
6. Plant clean-up
7. Hog chill cooler
8. Hog cutting floor
9. Loin cooler
10. Fresh meat cooler
11. Offal freesing

---

[60] Johns-Mansville, Inc., National Provisioner, January 31, 1976, p. 30.

12. Cooling the shipping area.

The energy demand equations for these production activities are shown in Appendix B. The energy demand estimates for activities one through five utilize boiler steam as the main energy source. A five percent energy loss for steam transportation and a 20 percent boiler loss was assumed for all of the first five activities. Twenty percent boiler loss was assumed for the clean-up activity since steam was not transmitted through the plant for this activity.

Refrigeration and cooling energy demands are highly dependent upon the cooling requirements due to location (relative to heat areas), insulation, entering and exiting activity. Consequently, cooling energy demands are quite plant specific. In addition, energy sources used are also plant specific. For the case study plant, about 45 percent of the cooling energy demand was provided by interruptible natural gas. The remaining refrigeration needs were supplied by electricity.

The energy demand for each cooling area was estimated from engineering studies by the firm. The primary determinates of refrigeration demands for a given plant were temperature, operating procedures, and quantity of product. In all cooling areas, the operating procedure differs for daily production activity and for zero production activity such as a weekend. Refrigeration energy demands are lower when production ceases, although these demands never approach zero. When fresh pork or carcasses have been cooled, less energy is needed to maintain the lower temperature. Consequently, on weekends or zero production days, many cooling units can be shut off. Conversely, in some areas, cooling is essential to prohibit bacterial growth and the cooling units are kept operating 24 hours a day, seven days a week. Monthly refrigeration energy demands are shown in Appendix B.

The decision component of this simulation model was subdivided into short-run and long-run decisions. The short-run decision component selected the best monthly production level; while the long-run decision component selected production alternatives and adjusted production energy demands. The decision activities differed between simulation models. Each model has either a different decision criteria or different constraints. Models A and B had the same decision rules. Model A, however, does not have an energy reduction goal. Model A is concerned only with rising energy prices and the firm's decision criteria. Model C has the same energy constraints as Model B but doesn't use the same decision criteria. Model C uses the decision rules suggested by economic theory - profit maximization.

Expectation Component of The Simulation Model

The management of the hog processing plant has decided that two proposed energy constraints will occur according to proposed governmental time schedules. These energy constraints are:

1. The firm's interruptible natural gas supply will be progressively reduced to the zero level by 1980.
2. A 1982 energy conservation goal of 12 percent will be imposed upon meat packing plants.

The firm's expected supply of interruptible natural gas (I.N.G.) is shown in Table 4.

TABLE 4. EXPECTED REDUCTION SCHEDULE FOR INTERRUPTIBLE NATURAL GAS SUPPLIES

YEAR:	PERCENT OF PREVIOUS YEARS SUPPLY OF I.N.G. AVAILABLE
1976	100
1977	100
1978	50
1979	50
1980	50
1981+	0

As natural gas supplies are decreased, the firm expects the prices of energy sources to increase. Energy price expectations were based upon several factors, which were subjective and objective in nature. The firm's management expected energy prices to rise over the next six years. Fuel oil prices were expected to increase four cents a gallon each year until 1980, after which increases would range from zero to two cents per gallon until 1983. The price of interruptible natural gas was expected to increase as much as 35 percent a year until 1978 when the price per B.T.U. for interruptible natural gas and fuel oil would be identical for the remaining four years of the time horizon under consideration. The firm's energy price expectations are shown in Table 5.

TABLE 5. EXPECTED FUEL OIL AND INTERRUPTIBLE NATURAL GAS PRICES

YEAR	Price of Fuel Oil Per Gallon	Price of I.N.G. Per 1,000 C.F.
1976	$0.24	$0.87
1977	0.28	1.19
1978	0.32	2.39
1979	0.36	2.69
1980	0.38	2.83
1981	0.40	--
1982	0.40	--

Energy prices beyond 1982 were expected to increase at five percent per annum.

The proposed energy conservation goal of 12 percent was expected to be enforced. If the hog processing plant did not meet this goal, it was expected that the firm would not receive an agricultural priority rating and would thus not be guaranteed sufficient energy supplies to profitably operate the plant. This expectation precipitated the decision to meet the 12 percent energy conservation goal.

Decision Component of The Simulation Model

Decision making is only one of the six functions of management.[61] The other functions of management, however, are inextricably interwoven into the decision process. Before making a decision, a manager must be aware of the cost or reward of a particular decision. As the cost or risk of a particular decision increases, the other functions of management are used more extensively. Managers generally need to obtain data, form expectations, and perform some analysis prior to making a decision. Information is a key commodity in the decision process.

One of the most important aspects of management is problem identification. The way a manager defines the problem will certainly influence the type of information obtained and the perceived risks associated with a particular decision.

The firm has identified its problem as an energy

---

[61] Johnson, Glenn L., et.al., Managerial Process of Mid-Western Farmers, Iowa State University Press, Ames, IA, 1961, p. 172.

conservation goal requiring a 12 percent reduction in energy use, rising energy prices, and a decrease in natural gas supplies.

In conjunction with the problem identification, the firm has formed expectations of prices and energy supplies. These expectations have been quantified in the previous section and were used in the decision making process.

The prices of most concern to the firm are those of labor, energy, hog and hog products. Labor price expectations were based upon an annual trend projection of five percent. Hog price expectations were based upon hog supply estimation, the associated cost of production, and industry market price. Estimates of these factors were shown in Chapter V, Revenue and Cost Estimation.

Two sets of decision criteria were considered. The decision criteria of the firm and the decision criteria of profit maximization were considered for short-run production decisions. The selection criteria for long-runs adjustments in production technology was based upon net present values and the need to meet the 12 percent energy conservation goal.

The short-run decision strategy utilized by the firm to determine the best output level was based wholly upon information about the desired market share and production costs as affected by labor costs. Based upon their knowledge and experience, management had established an upper and lower constraint on production. Between these constraints, the plant utilizes its decision strategy to select the best level of output.

The decision strategy of the firm was weighted such that about 65 percent of the decision depended upon market share and about 35 percent upon labor hours available at zero cost. These "free" labor hours existed because of the labor union contract and "over-payment" for hours worked in the previous month. The firm perferred a status quo strategy and did not wish to start a price war for their basis input - hogs.

The firm's status quo strategy was contrasted with the profit maximizing strategy suggested by economic theory. Differences in production levels were ascertained by comparing Model B with Model C.

The long-run decision strategy for the firm not only selected but determined the time period of adopting energy saving technology. Energy technology was adopted by the plant when a positive net present value occurred. A discount rate of 15 percent was set by the management and two levels of energy prices were considered. Technology was adopted on a priority basis. All technology which had a positive net present value was adopted and the largest net present value was adopted first. In addition, if the 12 percent reduction goal had not been achieved by 1982, production alternatives would be selected according to the highest net present value.

Production Alternative Component of The Simulation Model

Six energy reduction technologies were considered for the hog processing plant. About half of the technologies utilized waste heat and about half reduced energy demands by engineered adjustments. The technologies considered were:

1. Continuous cooker heat reclamation (cchr)
2. Heat exchange for the hog singer (he-hs)
3. Shell and tube ammonia condenser (stac)
4. Low temperature rendering system (ltr)
5. Centrifuge blood drying (cbr)
6. Change rendering pipeline system (crp).

The energy savings derived from these technologies depend upon the annual production level of the firm. The production level for future time periods reflected the status quo strategy of the firm and production was determined by calculating the firm's market share based upon the predicted U.S. commercial hog supply, which was derived in Chapter V, Revenue and Cost Estimation. The energy savings for the technology considered are shown in Table 6.

A flow diagram of the simulation model is presented on page 92 and the step-by-step operating procedure is in Appendix E.

TABLE 6. ENERGY REDUCING PRODUCTION ALTERNATIVES CONSIDERED IN THE HOG PROCESSING SIMULATION MODEL

Production Alternative	Investment	Annual Cost	Therms of Energy Saved Per Hour of Operation	Life
Continuous Cooker Heat Reclamation	$ 26,000	$ 700	40.34	10
Heat Exchanger Hog Singer	10,000	-0-	18.75	15
Shell and Tube Ammonia Condenser	30,185	-0-	35.0	10
Low Temperature Rendering	371,600	15,000 + E[62]	40.82	10
Centrifuge Blood Drying	143,635	-0-	49.05	15
Change Rendering Pipeline	1,000	-0-	6.10	15
Selling Whole Blood	4,000	9,750	23.66	15

---

[62] E is the added electrical cost for using this system where E = 4.4 therms * hours of production * price of electricity per therm

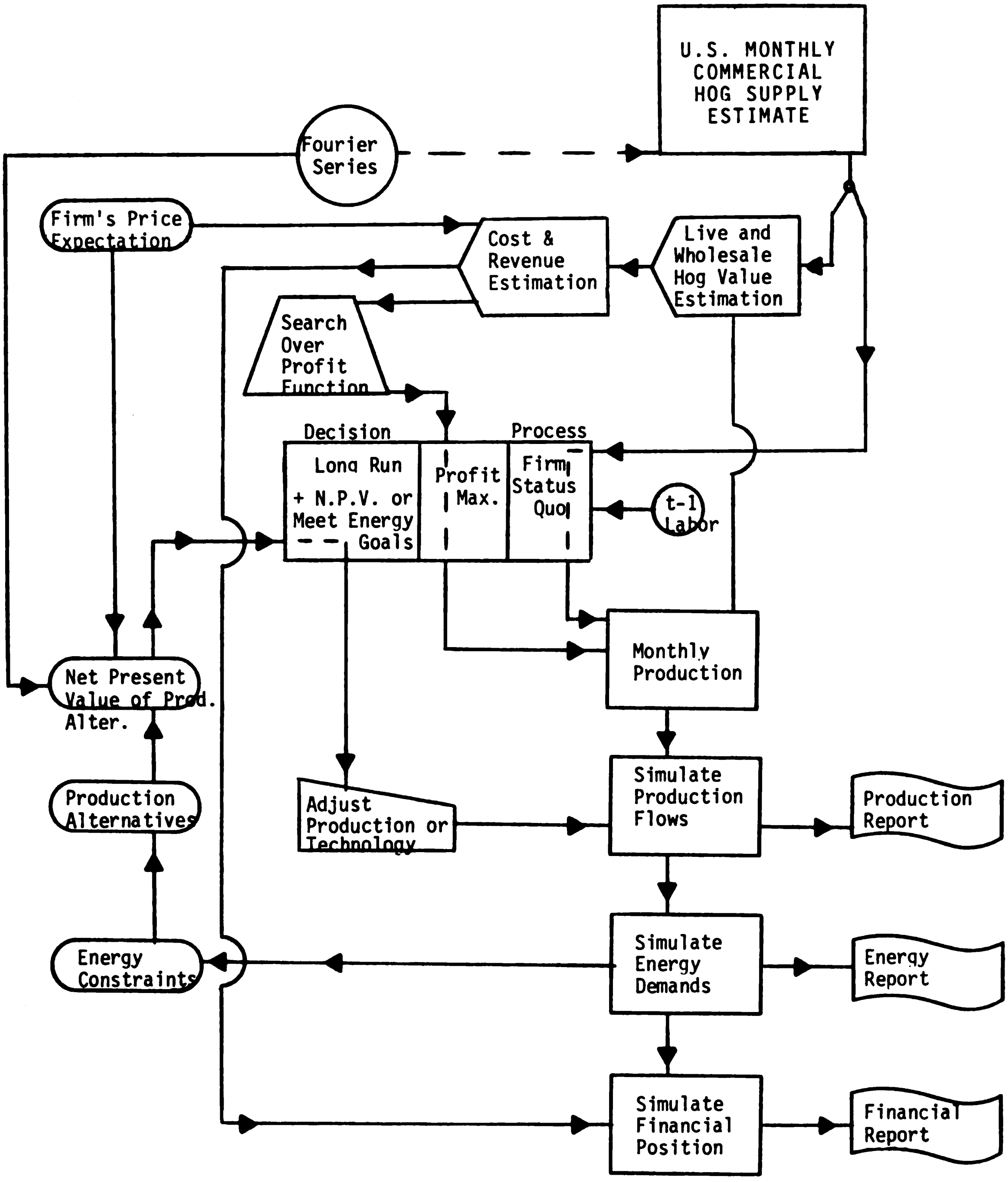


FIGURE 8. FLOW DIAGRAM OF SIMULATION MODEL

Description of Energy Reducing Technology

Continuous cooking heat reclamation system was designed to utilize escaping steam from a dry rendering system. Typically, exhaust vapors which are primarily steam were released directly to the atmosphere. Since steam is at 212°F, the opportunity existed to preheat water with this steam. The preheated water could reduce boiler steam demands or it could be used to heat the buildings during the winter months by piping the water through a device similar to a radiator and forcing air through it.

The dry rendering system operates during the day; this allowed full use of exhaust vapors to heat water when the hot water demand was highest. Based upon an eight-hour work day and assuming 80% boiler efficiency, $8390 * 10^9$ B.T.U. per year could be saved. On an hourly basis, 40.34 Therms can be saved for each hour of production time.

This heat reclamation system would require an investment of $26,000 and has an annual operating cost of $700. The expected life of this system was ten years.

Heat exchange equipment has been designed to capture wasted heat. The hog singeing process utilized natural gas to burn fine hair particles off of the hog carcass. The heat from this singeing process was commonly ignored as a heat source and was released within the building.

A device similar to a car radiator can be placed over the hog singeing area. As the heat rises, it warms water passing through the heat exchanger and preheats it for future use within the production processes.

The initial investment can be installed for $10,000. Approximately 18.75 therms can be saved per hour of operation since the hog singer operates when hot water is demanded throughout the plant. Expected service life was approximately 15 years.

Shell and tube ammonia condensers were utilized to heat air and water. Cold water flows into a container and is dispersed among several tubes within the container. Ammonia gas also enters the container and is allowed to flow around the tubes and is condensed to a liquid. The heat removed from the gas consists of the latent heat of condensation although there was a minor amount of heat loss which would reduce the gas temperature from the superheated stage to the condensing temperature as it left the compressor. The water temperature was increased approximately 20 to 30°F by this system as it passed through the tubes.

These condensers could be placed in many locations throughout the plant. The case study plant had five potential locations for shell and tube condensers. Each condenser had an expected service life of ten years and would require an initial investment of $40,185. The annual operating cost was minimal. Approximately 35 therms of energy can be saved each hour of the work day for each condenser installed.

The <u>low temperature rendering system</u> could be used to replace the wet rendering method. The wet rendering method injected steam directly into the cyclindrical rendering vat for about four hours. Prime lard, an emulsion, and a residual liquid were the three products from the wet rendering system. The emulsion was recooked and the residual liquid was completely evaporated leaving a residue used for stock feed.

The low temperature rendering system used indirect heat from steam and the condensate was recovered and did not have to be evaporated, thus reducing the energy required to produce prime lard. The total savings was 47.35 therms per 12,000 pounds of raw fat. Electrical energy demands were increased 158 KWH per 12,000 pounds of raw fat.

The initial investment for the low temperature rendering system was $271,620 plus installation costs of $100,000. Annual maintenance costs would be approximately $15,000 for each year of the ten-year life expectancy.

The <u>centrifuge blood drying system</u> would eliminate part of the blood drying energy demands by pre-heating the raw blood and pumping it into a centrifuge through a network of piping and a steam coagulator. The centrifuge separated the coagulated blood into solids and liquids. The moisture content of the centrifugal solids was about 50 percent of the moisture content of whole blood. The solids are then dried to produce dried blood. In contrast, the common method used by meat packers who dry blood requires the collection and evaporation of raw whole blood.

The centrifuge blood drying system reduced steam energy demands nearly 75 percent. The particular system investigated can process 5,000 pounds of raw blood per hour and requires 3,000 pounds of steam at 150 PSI. The initial investment was $123,633 plus a $20,000 installation charge. Its expected service life was 15 years. There is no estimate of maintenance costs which are presumed to be minimal.

Based upon plant estimations, the conventional blood drying system required 19,345 B.T.U./hog while the centrifuge system requires 5,417 B.T.U./hog if the system was fully utilized. The case study plant could provide only 72 percent of the optimum flow. Consequently, the realized energy savings would be:

$$(19{,}345 - [(\frac{1}{.72})\ 5{,}417]) = 11{,}820 \text{ B.T.U./hog}$$

Selling whole blood was an alternative to processing and marketing dried blood. The current practice required drying whole blood by evaporation. As a dried product, it may be used as a high protein stock feed, an organic fertilizer, and, in some situations, by pharmaceutical manufacturers. The expected energy savings of selling whole blood instead of dried blood would be approximately .06 therms per hog or 200 therms for a daily hog slaughter rate of 3,500 hogs. This alternative required an investment of $4,000 and annual costs of refrigeration of the whole blood would be $9,750 based on current (1975) energy prices. For comparable units, the firm can currently sell whole blood for a higher price than dried blood. The price difference was considered a temporary market adjustment problem and was not considered in the present value computations.

The current pipeline structure was designed to direct raw fat from the kill area to one of two available cooking units and raw fat from the cutting area to one of three available cooking units. Fat from both areas was cooked under identical procedures and the resulting prime steam lard was mixed together as the rail tank cars were filled.

On many days, raw fat from the kill and cut floor was not sufficient to fill some cooking vats. Consequently, two-part loads, one from the kill area and one from the cut area, were cooked as though they were full loads.

<u>Changing the rendering pipelines</u> could reduce the energy demand for rendering prime lard as much as 20 percent. The advantage of combining kill and cut fat into one cooking unit would eliminate the need for one of the five cooking units.

Exact estimates of financial changes were uncertain at this time. The initial investment would be approximately $1,000 and no pipeline maintenance cost was expected over the 15-year life of the pipeline. Expected energy savings were computed for various production levels but they should average about 55 therms daily.

Validation of Simulation Model

The quantity of commercial hogs slaughtered was quite important to the results of this model. This estimate affected production levels and energy use within the plant and hog prices. The U.S. commercial hog slaughter estimation procedure utilized linear regression which explained 64 percent of the monthly variation in the U.S. commercial hog slaughter. Two-thirds of the monthly estimate were within nine percent of the observed value and, over a 12-year period, the average monthly error was only two percent.

Although the monthly estimate of the U.S commercial hog supply was not as accurate as desired, it should be noted that the comparison of results between simulation Model's A, B, and C would not be greatly affected by this estimation error, since all models used the same hog supply estimations.

Twelve months of data were utilized to varify the price spread estimates (between live and wholesale value) and the production level of the plant for fiscal year 1975. This year was not the best year to varify estimates since hog slaughter was lower than previously recorded lows and hog prices were consequently higher than previous low years.

Margin revenue estimations were approximately eight percent higher than reported live and wholesale price difference in 1975. The error for any particular month in the time period ranged as high as $4.00 per hundredweight. A very low level of confidence should be attached to monthly revenue estimates, but annual financial results appear to be within ten percent of the actual situation.

The critical factor regarding energy demand was the hours of production occurring at the plant. Production time depends heavily upon the number of hogs slaughtered. Both the estimations of the firm's status quo decision strategy and the U.S. commercial hog supply affected the flow of hogs into the plant. Although 1975 was considered somewhat atypical of the meat packing industry, the estimates of hogs slaughtered at the plant were quite accurate. The maximum error for any given month was less than 15 percent. The estimate of hogs slaughtered for the year was only one-half of one percent in error.

Since energy utilization and the financial situation of the firm depended heavily on the actual flow of hogs into the plant, additional data was obtained from the plant for 1974. For 1974 and 1975, the annual estimate of hogs slaughtered at the plant was within one-half of one percent. Although statistical estimates of confidence levels were not obtained, the energy demand estimates and the feasibility of production alternatives were considered quite reliable.

The basic structure of this simulation model could be readily adapted by other meat processors. The energy consumption and energy reduction estimates were determined according to the production levels and the production processes within the plant. Plants which utilized the same equipment as the hog processing plant would need to adjust only the production flow coefficients if different coefficients were deemed necessary. Additional equipment could be added by an additional energy demand equation. The refrigeration energy demands were highly plant specific, however, and those equations would normally need modifications for use in other plants.

CHAPTER VII

RESULTS

A six-year planning horizon was simulated for a hog processing plant. Energy supply constraints, energy prices, and production goals were imposed upon the operating plant exogenously. The simulation models were designed to investigate the effects of production strategies and the economic feasibility of selected production alternatives as energy prices and hog supplies changed over the time horizon.

The plant was initially constrained to meet natural gas supply restrictions, a 12 percent energy reduction goal, and to produce at the normal level of production. The combined effect of these constraints was found to not adversely affect the annual earnings of the plant. Sufficient energy reducing technology and production adjustments were available to meet the energy reduction requirements. An investment of nearly $200,000 was required to make the adjustments in production technologies and procedures. Energy consumption decreased about 20 percent for the assumed price and production situation and earnings before taxes increased only one percent.

The production goal imposed by the firm on the plant was eliminated as a constraint and alternative options were investigated. It was found that the least preferred strategy to follow was attempting to reduce production as the only means of reducing energy consumption. Annual losses in excess of $2,000,000 would result. The most preferred strategy by the plant would be a profit maximizing strategy. The plant would adopt the same energy reduction methods as when its production was constrained but production would increase nearly 20 percent and earnings before taxes would increase 15 percent. The overall energy reduction would be about five percent lower than the production constrained situation but energy use would fall sufficiently to meet the imposed energy constraints.

Figure 9 shows the various production strategies considered in the simulation model. The dotted arrows indicate the most likely strategy the firm would adapt.

All of the energy reducing methods which were adopted, were adopted in the first time period. The energy technology which was adopted had a positive net present value at the start of the simulation procedure. The sensitivity of the model to energy prices was explored by decreasing energy price expectations to only five percent annual increases. The same technology was adopted with these lower energy prices in the same time period. The net present values of the adopted energy technology under both energy price expectations is shown in table 7.

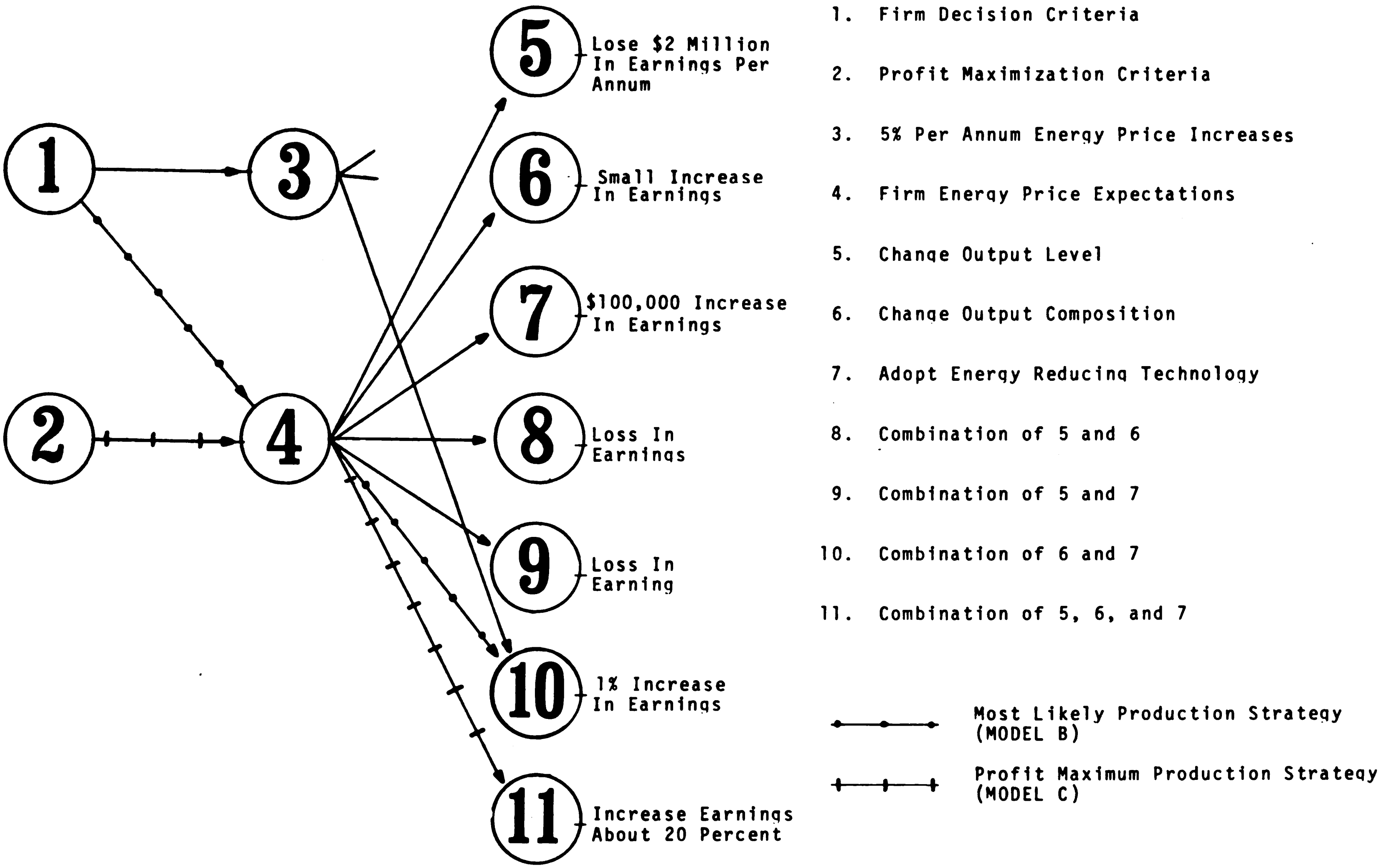


FIGURE 9. PRODUCTION STRATEGIES FOR A HOG PROCESSING PLANT

TABLE 7. NET PRESENT VALUE OF ENERGY REDUCING TECHNOLOGY -- 1976

Alternative Considered	Net Present Value Based On	
	Firm's Energy Price Expectation	Assuming A Five Percent Annual Increase in Energy Price
Shell and Tube Condenser	$ 55,392	$ 6,750
Continuous Cooker Heat Reclamation	956,826	396,190
Heat Exchanger -- Hog Singer	49,035	14,660
Low Temperature Rendering System	-379,058	-435,789
* Centrifuge Blood Drying	10,800	- 79,122
Change Rendering Pipeline	18,206	7,023
* Sell Whole Blood	85,101	17,587

* These Two Alternatives Are Mutually Exclusive and Would Not Be Adopted Simultaneously

Three simulation models were used to examine the effect of energy reducing technology and to compare alternate production strategies. Model A assumed energy price increases identical to the firm's expectations. The plant's production, energy, and financial situations were simulated after assuming that no energy supply constraints or energy reducing technology were available. Model B used the same decision criteria as Model A, but energy supply constraints were imposed and energy technology was considered. Models A and B were compared to determine the effect of energy supply constraints. Model C differed from Model B only in the choice of production strategy. A profit maximizing strategy was used in Model C and all energy constraints and alternatives were considered. Models B and C were compared to determine the effect of changing production strategies. Table 8 summarizes Models A, B, and C for comparison purposes. Figure 10 depicts the effect on earnings and energy for the three simulation models.

Energy consumption decreased about 20 percent when energy reducing technology was adopted by the plant. The criteria used to select production alternatives required the technology to be adopted in the first time period that a positive net present value occurred. All of the energy reducing technology was utilized in the first year except for the low temperature rendering system and the centrifuge blood drying technology. This rendering system did not have a positive net present value in

TABLE 8. RESULTS OF HOG PROCESSING PLANT SIMULATION MODEL

	MODEL A (no energy constraints)	MODEL B (most likely outcome)	MODEL C (profit maximizing)
Therms Of Energy Consumed			
YEAR - 1976	2,561,672	1,915,812	2,049,653
77	2,484,210	1,876,488	1,986,995
78	2,516,928	1,893,126	2,010,503
79	2,584,351	1,927,207	2,071,317
80	2,560,916	1,914,996	2,055,234
81	2,483,645	1,876,263	1,987,538
Average Energy Reduction	-	25%	20%
Annual Hog Slaughter			
YEAR - 1976	856,605	856,605	1,028,934
77	806,024	806,024	948,226
78	827,350	827,350	978,811
79	871,571	871,571	1,057,194
80	856,685	856,685	1,036,926
81	805,572	805,572	948,788
Average Increase in Hog Slaughter	-	-	19%
Earnings Before Taxes			
YEAR - 1976	8,807,681	8,826,997	10,028,081
77	4,734,907	4,733,777	5,341,211
78	7,656,880	7,761,418	8,921,116
79	13,936,003	14,065,797	16,166,926
80	13,665,629	13,803,486	15,999,259
81	6,579,893	6,718,734	7,908,640
Average Increase in Earnings	-	1%	16%

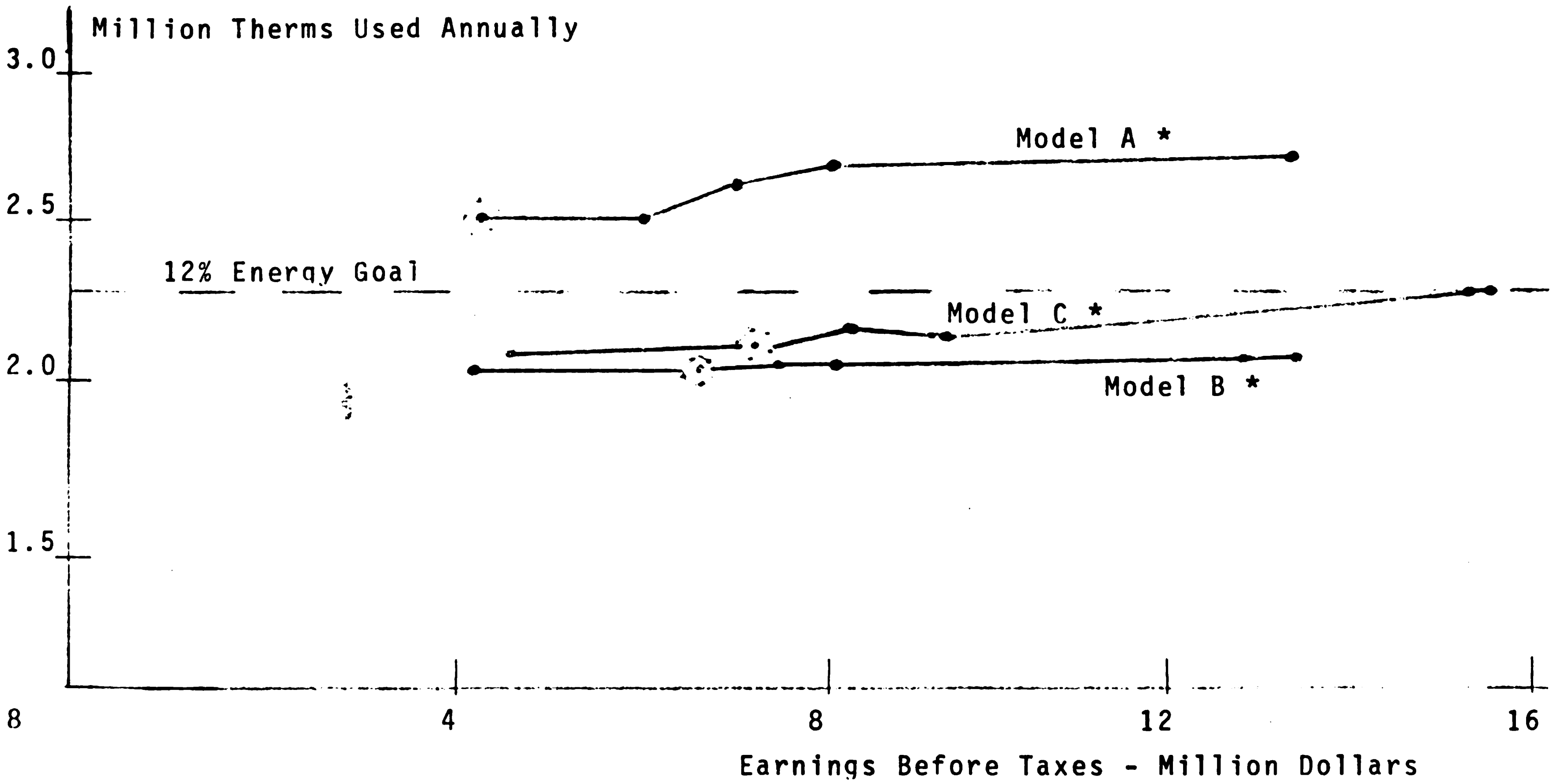


FIGURE 10. EFFECT OF ALTERNATIVE PRODUCTION STRATEGIES ON THE PLANT'S EARNINGS AND ENERGY CONSUMPTION

* The time dimension was not incorporated into Figure 10; consequently, annual earnings are not sequentially arranged along the energy use lines of Models A, B, and C. Movements along an energy use line are due to changes in production levels caused by the decision criteria of the model.

any of the six time periods considered. The centrifuge blood dryer had a positive net present value but the mutually exclusive alternative of selling whole blood was a more attractive option. The first energy reducing technology to be adopted was the continuous cooker heat reclamation.

Two levels of expected energy prices were considered. The case study plant expected a 300 percent increase in the price of interruptible natural gas and a 100 percent increase in the price of fuel oil. An alternative set of energy price expectations per annum for both energy sources was also considered. The energy reducing technologies which would be adopted under both sets of price expectations were identical in regards to technologies selected and time periods adopted. Table 9 reports the investment and energy savings of the adopted energy reducing technologies.

Changes in energy consumption occurred when the interruptible natural gas supply constraints and the energy conservation goals were imposed. Rising interruptible natural gas prices, alone, did not cause a shift to fuel oil. The case study plant relied upon natural gas to provide nearly 60 percent of its energy requirements over the six year time period when energy constraints were applied, natural gas consumption decreased to only 15 percent of the plant's energy demand and fuel oil consumption rose from 30 percent to 75 percent of the plant's

TABLE 9. SIMULATED ENERGY SAVINGS FROM TECHNOLOGY AVAILABLE TO A HOG PROCESSING PLANT

Adjustments and Technology Considered	Investment Dollars	1976	1977	1978	1979	1980	1981
		(1,000 Therms of Energy)					
Sell Whole Blood	$ 4,000	5.4	49.1	51.1	55.4	54.0	49.1
Centrifuge Blood Drying	$143,635	111.9	101.8	106.0	114.8	111.9	101.8
Reclamation From Inedible Rendering	$ 26,000	92.1	83.7	87.1	94.4	92.1	83.7
Shell and Tube Condensor	$ 30,185	79.9	72.6	75.6	81.9	79.9	72.6
Heat Exchanger For Hog Singer	$ 10,000	42.8	38.9	40.5	43.9	42.8	38.9
Change Rendering Pipeline	$ 1,000	13.9	12.7	13.2	14.3	13.9	12.7

total energy demands.

Total energy consumption decreased 21 percent after the energy reducing technology was adopted. Average energy consumption per pound of live hog processed was decreased from 1,263 B.T.U. to 995 B.T.U. To achieve these energy savings, an investment of $192,000 was required. The effect of reducing energy consumption, however, was not apparent in the before tax earnings of the plant.

A profit maximizing strategy increased production in the hog processing plant approximately 20 percent. Although the firm paid a higher price for hogs and labor, the financial returns (earnings before taxes) were 16 percent higher when the profit maximizing strategy was used instead of the firm's production strategy. Energy consumption with the profit maximizing strategy was about five percent higher than the firm's strategy, but the 12 percent energy conservation goal was not a constraint on production.

Energy consumption in total and by energy source is summarized in Table 10 and the respective costs are reported in Table 11.

The firm utilized market information on hog supplies and prepaid labor from the previous month to determine the production level in the current time period. The economic information regarding average costs and average revenue appeared to receive little weight in the decision process. The simulation model provided an indication of

TABLE 10. SIMULATED NATURAL GAS AND FUEL OIL CONSUMPTION FOR A CASE STUDY HOG PROCESSING PLANT, 1976-1981

THERMS OF ENERGY :	MODEL A (no energy constraints)	MODEL B (most likely outcome)	MODEL C (profit maximizing)
Natural Gas Consumption			
YEAR - 1976	1,517,720	938,970	938,970
77	1,498,275	524,700	524,700
78	1,485,260	219,750	219,750
79	1,485,260	46,430	46,430
80	1,485,260	5,160	5,160
81	1,484,900	0	0
TOTAL - 6 YEAR	8,956,675	1,735,010	1,735,010
Fuel Oil Consumption			
YEAR - 1976	762,170	856,210	993,460
77	712,670	1,230,190	1,343,500
78	754,805	1,552,165	1,672,560
79	814,810	1,760,465	1,908,250
80	793,955	1,789,305	1,933,080
81	725,545	1,754,615	1,868,715
TOTAL - 6 YEAR	4,563,955	8,942,950	9,719,565

TABLE 11. SIMULATED ENERGY COST FOR A HOG PROCESS PLANT

	Total Energy Cost	Fuel Oil Cost	Interruptible Natural Gas Cost
MODEL A			
Year			
1976	$415,515	$132,460	$128,075
1977	475,930	144,500	172,935
1978	687,965	174,910	344,170
1979	781,545	212,415	387,195
1980	815,920	218,475	408,705
1981	831,510	210,160	430,110
MODEL B			
1976	350,070	148,805	79,235
1977	435,790	249,435	60,560
1978	544,190	359,675	50,920
1979	613,970	458,935	12,105
1980	642,385	492,368	0
1981	660,040	508,235	0
MODEL C			
1976	383,250	172,655	79,235
1977	466,885	272,410	60,560
1978	581,160	387,575	50,920
1979	664,185	497,460	12,105
1980	693,855	531,930	0
1981	702,960	541,285	0

the firm's choice of decision strategies. The average cost curve was U-shaped as predicted by economic theory; but the average cost curve was quite flat over the normal production ranges. The typical situation which resulted was that the firm could operate between 120 and 200 hours a month (20 days) and the average cost of production would hardly vary. Since the plant manager only had one observation along the average cost curve for any given time period, he would not know exactly where average costs would begin to increase as production expanded. Also, any error in judgment would not be highly visible since average costs were almost identical over the normal production range.

It appeared as though the plant manager would use market share to establish an initial production goal. This goal would then be adjusted according to labor costs, such as over-paying when less than 36 hours were worked per week or under-paying, when pre-paid labor was available from the previous month. Given the data available to the plant manager, he bounded production by minimum and maximum constraints which were set at the extremes of the horizontal portion of the average cost curve. Within those bounds, production would increase above market share when labor was pre-paid or when labor would be paid for unworked time.

This analysis revealed that rising energy prices, alone, would not cause the hog processing plant to reduce its relatively high use of natural gas as compared to fuel oil consumption, as long as gas prices per heat unit were equal to or less than prices for comparable units of fuel oil. Total energy consumption was reduced above the energy conservation goal when energy reducing technology was considered. This energy reduction, however, did not significantly affect the net earnings of the hog processing plant. Since nearly $200,000 would need to be invested in the energy reducing technology, the technology would probably not be adopted as rapidly if the net present value method were not used in the analysis.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

Summary

The meat packing industry was anticipating energy supply constraints and rising energy prices. Considerable concern was expressed about the nature and the magnitude of the proposed energy supply constraints. The Federal Power Commission had begun to implement a user priority system which would reduce natural gas supplies to the industry about 40 percent. Natural gas used by steam boilers was to be incrementally reduced between 1976 and 1980. By 1980, natural gas was not to be used in any steam boilers. In addition, the Federal Energy Administration was granted the authority by Congress to establish energy conservation goals and to allocate energy supplies during periods of short supplies. A 12 percent energy goal was proposed for the meat packing industry. The industry was thus faced with a problem which required finding substitute energy sources for natural gas and reducing overall energy consumption.

The meat packing industry ranked as one of the most important among the food processors. It employed a high proportion of the food industries labor and produced a high value product. It also was a large energy user, over 100 trillion B.T.U. were used annually by the meat packing industry. Meat packing plants have been located in almost every geographic region in the United States. As time elapsed, the plants have been modified to reflect the changes in population, transportation, and technology. Consequently, the meat packing industry did not regard any plant nor group of plants as being representative of their industry.

A single plant analysis was chosen as the best means to consider the effects of energy constraints and rising prices on the meat packing industry. It was determined that the analysis of one plant would provide specific information about adjustments to energy constraints while the analysis of a group of non-representative plants would provide information of questionable value.

A midwestern hog processing plant was selected for this research. The plant was large enough (over 75 head per hour) to be included in the classification of plants which slaughter the major portion of meat animals. In addition, a sufficient quantity of production processes were performed at the plant. These were slaughtering, processing, boning, and rendering edible and inedible fats.

This research was primarily concerned with identifying and evaluating the production technologies available to the hog processing plant. The nature of the constraints imposed upon the plant, however, were important in the identification of possible strategies. The imposed energy constraints were scheduled to be implemented during the next six years. By using this implementation procedure, the constraints imposed a time dimension on the decision strategies available to the hog processing plant. In addition, the hog processing plant had a production constraint imposed upon it by the parent firm. Consequently, the decision strategies available to the plant were constrained by time, the parent firm, and energy supplies.

An important distinction must be made concerning the analysis of this hog processing plant and the analysis of a firm or an industry. In many respects, the hog processing plant could be mistakenly considered as a firm. The plant does not fit the neo-classical definition of a firm and it does not attempt to maximize profits. The plant is not autonomous in the sense that its production goals and output prices are established by the plant's parent firm.

Similarly, the plant does not represent the industry nor any major segment of the industry. The plant is assumed to operate in a market situation where its actions will not affect the prices or behavior of other plants, firms, or the industry. Although the energy constraints imposed on the plant are also being imposed on most other plants, the effect of industry adjustments are not included in this study nor are any such adjustments allowed to affect the hog processing plant's behavior. The only industry and national adjustment that affect the plant is the plant's own energy price expectation which subjectively accounts for energy use adjustments. The hog cycle was expected to continue and hog prices were assumed to follow historical movement.

It is true, however, that many meat packing plants will be subjected to both the F.E.A. and F.P.C. energy constraints. Since this study concentrated on hog processing activities, it is applicable to other plants which use similar rendering and by-products processing methods.

The purpose of this research was to evaluate the potential effects of pending energy regulations and expected rising energy prices on a hog processing plant. Five specific objectives were set forth:

1. To describe the hog production processes
2. To delineate mass-energy flows for production processes which utilize natural gas and fuel oil
3. To identify and evaluate production adjustments and technologies which might reduce energy flows
4. To estimate the effect of alternative production strategies on the financial contribution of the plant to the firm
5. To evaluate the financial impact of a 1982-12 percent energy conservation goal.

The plant's normal production strategy for determining output levels was ascertained and compared with a profit maximizing strategy. Revenues were estimated from predicted hog supplies and hog prices and production costs were estimated from data provided by the hog processing plant. Labor union contracts and hog price adjustments for the particular market area of the plant were included in the accounting procedure. Two levels of energy price expectations were utilized. The lower level of price increases assumed a five percent per annum increase. The expected energy price increases of the plant were a 300 percent increase in natural gas prices and nearly a 100 percent increase in fuel oil prices in the next six years.

Linear regression was utilized to quantify many important relationships and to estimate the value of variables in future time periods. The U.S. commercial hog supply was estimated by a linear regression model which utilized a harmonic sine and cosine function over the time horizon. Hog prices were estimated by adapting the Hayenga-Hacklander price prediction model. Linear regression also was utilized to estimate the relationship between hog prices and the wholesale value of hog carcasses. The revenue estimation procedure relied upon these linear regression equations.

The cost estimation procedure utilized data supplied by the firm. Production costs were provided over a wide production range and the cost-quantity relationship was quantified by linear regression. Secondary data from a survey of hog processing plants was used to shift the firm's cost curve vertically to protect the confidentially of their data.

Derived energy demands from the firm's production processes were obtained from plant engineers. Production processes were metered by engineers and standard engineering methods and procedures were used to determine energy demands.

Production alternatives were identified and assessed for economic feasibility. About half of the energy reducing technologies utilized waste heat to preheat water or to warm buildings and half reduced energy demands by engineered adjustments. The technologies considered were:

1. Heat recovery from the inedible rendering process
2. Heat recovery from the hog singeing process
3. Heat recovery by shell and tube ammonia condensers
4. Low temperature rendering equipment
5. Centrifuge blood drying equipment
6. Changing the rendering pipeline system
7. Changing the output composition by selling whole blood instead of dried blood.

A simulation model was constructed with the following components:

1. Production component
2. An energy demand component
3. An expectation component
4. A decision strategies component, and
5. A production alternative component.

A simulation model was utilized to estimate the financial and energy situation of the plant over a six-year (76-82) time horizon. Energy constraints, price expectations, and decision strategies were analyzed in three variations of the simulation model. Model A considered expected price increases only. Energy reducing technology was assumed unavailable. Model B was designed to provide the most likely estimate of the firm's actual situation. Energy supply constraints and energy reducing technology were considered. The firm's price expectations, decision criteria, and all production technology were considered. Model C used a profit maximizing decision criteria, but maintained the price expectations and production alternatives of Model B.

This study revealed that the hog processing plant had three basic options available to meet the combined energy supply constraints:

1. Reduce production
2. Adopt energy reducing technology
3. Change output composition to eliminate energy intensive products.

These options were considered individually and in combination. Given the production and energy constraints imposed upon the hog processing plant, the best strategy available to the plant was to combine options two and three. This strategy was found to be the best combination of options even under alternative energy price expectations.

The simulation model showed that no adverse effects would result from the imposition of natural gas and total energy supply constraints. Both constraints could be met by the hog processing plant within the six-year time horizon. An investment of nearly $200,000 could be utilized to decrease total energy consumption eight percent lower than the Federal Energy Administration's 12 percent conservation goal. Before tax earnings for the plant would remain almost constant for comparable production levels as reduced energy requirements offset rising energy prices.

All production alternatives were evaluated by utilizing the net present value method with a 15 percent discount factor. The plant expected energy price increases well over 100 percent in the six-year time period. Alternative energy price expectations were also considered to determine the result's sensitivity to energy prices. No difference occurred in the selection of production alternatives as a five percent per annum energy price increases were compared with the plant's price expectations.

Alternative production goals were also investigated. The firm normally establishes production goals for the plant by a status quo market share criteria. This criteria could be maintained and the addition of energy constraints would not force the plant into any dilemna. If the firm would reduce the plant's production goal as the only means of decreasing energy consumption, the plant would suffer nearly a two million dollar loss per annum. If production goals were established by a profit maximizing criteria, the plant's annual production would be raised above the status quo production levels. Before tax earnings would increase about 15 percent as a result of increased production even though higher energy and labor cost (overtime) and higher hog purchase costs (above predicted industry price) would result. Energy reductions would be lower under the profit maximizing criteria but the 12 percent energy conservation goal and the natural gas supply constraint would be met.

It was generally found that the plant could achieve higher energy reductions by adopting processing technology, but the waste heat recovery technology should be adopted first under a net present value adoption criteria. The technology that received the highest priority of adoption was heat reclamation from the inedible fats rendering process. The low temperature rendering system had substantial energy savings but would not be adopted under either set of energy price assumptions.

Implications

Two federal agencies are concerned with energy utilization by various industries. The Federal Energy Administration is concerned with total energy utilization; while the Federal Power Commission is concerned with the industry's use of natural gas. Each agency is approaching the energy supply problem differently, but they have a simultaneous impact on the industries.

The Federal Power Commission has proposed a schedule to administratively reduce the supply of interruptible natural gas to the various industries. The impact of this constraint was two fold. First, the case study plant had a perfect substitute, fuel oil, available for interruptible natural gas supplies. Consequently, when the plant activities were simulated using current natural gas supplies and compared with restricted supplies, the change in earnings before taxes was less than one percent. Secondly, the constraint was significant in adjusting the quantity of natural gas used by the plant.

The combined impact of the F.E.A. and the F.P.C. constraint has considerable implications for the meat packing industry. The major change in before tax earnings occurred when production was decreased below normal levels. Substantial losses in earnings resulted from this strategy. From the analysis of this one plant, it would appear that the industry could adopt energy reducing technology and that a shortage of pork products would not result due to the implementation of these energy regulations.

Since the energy reducing technology can offset rising energy prices by decreased energy consumption, it would appear that such technology would be adopted quite rapidly. This seems particularly true if the industry is assured adequate energy supplies by the F.E.A., if the

firms meet the proposed energy conservation goals.

There appears, however, considerable hesitation to adopt new technology. Several reasons are relevant, first rapid adoption of energy technology could cause the firm to forego further energy reduction as new technology is developed. Thus, rapid adoption of technology could increase investments over a slow adoption strategy. Second, the industry appears extremely concerned about cost control and may not have adequate information for evaluating technology. Generally, the life expectancy of technology, salvage value, and discount factors are not used in the analysis of alternatives. Thirdly, the industry is not fully utilizing its engineering resources in the energy reduction area. Engineers are generally utilized full time to keep plants operating according to schedule. Only when other work is not pressing would the energy area receive attention. Finally, the allocation of capital among competitive uses appears to be very important. It appears that the basic choices for the firm is to build new plants or modify the existing ones. Apparently, new construction generally receives a higher priority.

Suggestions for Further Research

This research considered only one hog processing plant which utilized many of the production processes used in the meat packing area. Energy use in the production processes was studied in regards to production levels and available technology. Management of the production processes, per se, was considered a fixed factor of production.

Investigations in the future should expand energy research in three areas. Initially, further work is needed in identifying the energy demands from production processes which were not studied in this research. Aggregation of such industry energy data would be useful to federal agencies and regulators. Evaluation and development of alternative production adjustments is perhaps the most important aspect that future research should concentrate upon.

As noted earlier, considerable variation in energy consumption between industry plants has been observed. The causes of this variation have not been accurately assessed nor quantified. Quantification of these energy demands and variations would provide information which could lead to substantial adjustments in the meat processing industry. Many meat products are canned, smoked, processed into luncheon meats, weiners, and speciality products. The processing energy costs of many products have not been assessed. Little effort has been expended to ascertain energy demands as affected by the technical production processes and the managerial aspects. These two sources of energy variation have not been investigated.

Engineers need to ask questions about every phase of the production process. As an example, several questions come to mind:

1. Why scald a hog?
2. Why scrap, singe, and shave a hog?
3. Why should water injected via steam in one production stage be evaporated out in the next stage?
4. Are all production processes needed?
5. Must a certain energy source be used for a certain product?

Many seemingly simple changes could be very important. Reducing the size of a hog scald tank could reduce scalding energy demands as much as 30 percent. Connecting two pipelines by ten feet of pipe could reduce edible fat rendering energy demands as much as 20 percent.

The management aspects of energy savings should not be overlooked. Several trade-offs are being made continually without any apparent regard or analysis of the effects on energy consumption. Energy consumption is affected by the efficiency of the production equipment. Management determines the priority of equipment maintenance for its engineers and foremen. Operating schedules and procedures are also important. As an example, it is common for meat processors to refrigerate the meat working areas during weekends or down periods, even though no meat is stored in these areas. The management would prefer to expend cooling energy to retard bacterial growth instead of re-cleaning the work area before the start of the next production period. Several management decisions are made without any apparent analysis of the trade-offs between energy use and other resources.

Federal regulations need to be reviewed for their appropriateness for today's situation. As an example, hot water requirements for cleaning could be traded for warm water containing chemical cleaning and sterilizing agents.

The causes of energy consumption have not been clearly separated, identified, nor evaluated for the meat processing industry. New technology has not kept pace with our energy situation. Considerable work lies ahead for engineers, economists, federal agencies, and business firms if the energy situation is to be improved in a prudent and equitable manner.

BIBLIOGRAPHY

BIBLIOGRAPHY

American Gas Association. Gas Rate Fundamentals. Washington, D.C., 1969.

American Meat Institute. By-Products of the Meat Packing Industry. Institute of Meat Packing, University of Chicago, 1953.

________. Pork Operations. Institute of Meat Packing, University of Chicago, 1954.

Baker, Allen J. Personal Correspondence. Economic Research Service, U.S. Department of Agriculture, November 11, 1975.

Brandow, G. E. Interrelations Among Demands for Farm Products and Implications for Control of Market Supply. Pennsylvania State University, Agricultural Experiment Station Bulletin 680, 1961.

Cross, Howard. Personal Correspondence. Michigan Department of Commerce, Office of Energy Evaluation, September 1975.

Dean, Gerald E., and Earl O. Heady. "Changes in Supply-Response and Elasticity for Hogs." Journal of Farm Economics, Volume 40, 1958.

DeGolyer and MacNaughton. Twentieth Century Petroleum Statistics. September 1, 1973.

Development Planning and Research Association, Inc. Industrial Energy Study of Selected Food Industries. Federal Energy Administration Contract No. 14-01-0001-1652, 1974.

Federal Energy Administration. The Natural Gas Shortage: A Preliminary Report. August 1975.

Food Management, Inc. Cost Components - Cattle and Hog Slaughter Plants. Economic Research Service, U.S.D.A. Contract No. 12-17-03-5-943, October 1974.

Foster D. Snell, Inc. *Energy Conservation in the Meat Packing Industry*. Federal Energy Administration Contract No. C-04-50090-00, January 1975.

Halter, A. A. "Use of Simulation in Evaluating Management Policies Under Uncertainty: Application to A Large Scale Ranch." *Journal of Farm Economics*, Volume 47, No. 3, August 1975.

Hayenga, Marvin. *An Evaluation of Hog Pricing and Grading Methods*. Agricultural Economics Report 192, Department of Agricultural Economics, Michigan State University, May 1971.

________, and Duane Hacklander. "Monthly Supply-Demand Relationships for Federal Cattle and Hogs." *American Journal of Agricultural Economics*, Vol. 52, No. 4, November 1970.

Heady, Earl O. *Economics of Agricultural Production and Resource Use*. Prentice-Hall, January 1964.

Henderson, James M., and Richard E. Quant. *Microeconomic Theory*. McGraw-Hill Book Company, 1958.

Johns-Mansville, Inc. "How Pork Plants Rated On Energy." *National Provisioner*. January 31, 1976.

Kmenta, Jan. *Elements of Econometrics*. MacMillan Company, New York, 1971.

Larson, Arnold B. "The Hog Cycle as Harmonic Motion." *Journal of Farm Economics*, Volume 46, 1964.

Learn, Elmer W. "Estimating Demand for Livestock Products At The Farm Level." *Journal of Farm Economics*, Volume 58, 1956.

Madigan-Abraham Associates, Inc. *Hog Cut-Out Values and Margins*. 1627 Whitfield Avenue, Sarasota, Florida 33580

Marks, Lionel S., and Harvey N. Davis. *Tables and Diagrams of The Thermal Properties of Saturated and Superheated Steam*. Longmans, Green, and Co., Fourth Avenue and 30th Street, New York, 1920.

Ruble, W. L. *Improving The Computations of Stockaster Linear Equations Estimates*. Agricultural Economic Report No. 116 and Econometrics Special Report No. 1, Department of Agricultural Economics, Michigan State University, East Lansing, Michigan, October 1968.

Sheperd, Geoffrey S. Agricultural Price Analysis. 5th Ed., Iowa State University, Ames, Iowa, 1964.

Talpaz, Havau. "Simulation, Decomposition, and Control of A Multi-Frequency Dynamic System: The United States Hog Production Cycle." Unpublished Ph.D. dissertation, Michigan State University, 1973.

U.S. Congress, House. Energy Conservation and Conservation Act of 1975. H.R. 6860, 93rd Congress, 2nd Session, 1975.

Department of Agriculture. Livestock and Meat Statistics. Statistical Bulletin No. 522, ERS, SRS, AMS, July 1973.

Department of Commerce. Survey of Current Business. 1969-1973.

________, Government. Federal Register. Volume 39, No. 62, March 29, 1974.

APPENDICES

APPENDIX A

PRODUCTION COMPONENT EQUATIONS OF SIMULATION MODEL

$A_1 = 0.036X_1$

$A_2 = 0.175A_1$

$A_3 = 0.7245X_1$

$A_4 = 0.0322X_1 + 0.1007A_3$

$A_5 = 0.64A_3$

$A_6 = 0.1028X_1 + 0.0271A_3 + 0.018X_2$

$A_7 = 0.567A_6$

$A_8 = 0.433A_6$

$A_9 = 0.1863A_3$

$A_{10} = 0.2225A_3$

$A_{11} = 0.0649A_3$

$A_{12} = 0.1086A_3$

$A_{13} = 0.1522A_3$

$A_{14} = 0.0372A_3$

$A_{15} = 0.0952A_3$

$A_{16} = 0.43X_2$

where variables are defined as shown below:

A_1 = pounds of raw blood

A_2 = pounds of dried blood

A_3 = pounds of hog carcass to cut

A_4 = pounds of matter available for the edible rendering process

A_5 = pounds of prime steam lard

A_6 = pounds of matter available for the inedible rendering process

A_7 = pounds of animal feed derived from the inedible rendering process

A_8 = pounds of white grease derived from the inedible rendering process

A_9 = pounds of loins produced

A_{10} = pounds of hams produced

A_{11} = pounds of butts produced

A_{12} = pounds of picnic hams produced

A_{13} = pounds of pork bellies produced

A_{14} = pounds of pork ribs produced

A_{15} = pounds of other pork products produced

A_{16} = pounds of house grease produced

X_1 = pounds of live hog slaughtered in time period t

X_2 = number of hogs slaughtered in time period t

APPENDIX B

ENERGY DEMAND COMPONENT OF THE SIMULATION MODEL

$TS = 113.919 + 15.1317X_2$

$TD = 71.875X_2$

$TB = .00080606X_5$

$TE = 129.217X_3$

$TI = 0.0129375X_4$

$TG = 30X_2$

$TC = 605.8X_6$

$TH = 21.27X_6$

$TR = 1450 + 0.4632X_7 + 147.75X_8X_6 + 14.39\ (X_6 + 4) + X_9$

$TT = 104{,}190 + 0.6975X_1$

where

TS = therms of energy required to scald hog carcasses in time period t

TD = therms of energy required by the dehairing activity

TB = therms of energy required to dry whole blood

TE = therms of energy required for the edible rendering activity

TI = therms of energy required for the inedible rendering activity

TG = therms of energy required to singe hogs

TC = therms of energy required to clean up plant in time period t

TH = therms of energy required to process house grease in time period t

TR = therms of energy required for refrigeration in time period t

TT = total therms of energy demanded by the plant

X_1 = 100 pounds of products sold by the plant

X_2 = hours of production time in time period considered

X_3 = number of edible cooking vats required

X_4 = pounds of matter processed = A_6 in Appendix A

X_5 = pounds of whole blood processed

X_6 = number of days plant is operated in time period t

X_7 = number of hogs slaughtered in time period t

X_8 = hours of cooling time required which is the hours of production plus four hours

X_9 = $437 + 2.1X_2$ if time period is 1, 2, 3 (January, February, March)

= $688.8 + 7.9X_2$ if time period is 7, 8, 9 (July, August, September)

= $546 + 5.0X_2$ if time period is 4, 5, 6, 10, 11, 12

APPENDIX C

PREDICTED U.S. COMMERCIAL HOG SLAUGHTER, 1976-1982

MONTH	1976	1977	1978	1979	1980	1981	1982
January	7,724	7,537	6,801	7,950	7,724	7,537	6,801
February	7,419	7,154	6,557	7,685	7,419	7,154	6,557
March	7,418	7,059	6,633	7,697	7,418	7,059	6.633
April	7,173	6,707	6,479	7,443	7,173	6,707	6,479
May	6,370	5,793	5,777	6,613	6,370	5,793	5,777
June	6,318	5,633	5,837	6,523	6,318	5,633	5,837
July	6,650	5,869	6,290	6,814	6,650	5,869	6,290
August	6,729	5,871	6,495	6,855	6,729	5,871	6,495
September	7,286	6,379	7,183	7,386	7,286	6,379	7,183
October	7,620	6,697	7,649	7,709	7,620	6,697	7,649
November	7,253	6,353	7,413	7,351	7,253	6,353	7,413
December	7,366	6,528	7,676	7,498	7,366	6,528	7,656
TOTAL U.S.	87,326	77,580	80,770	87,524	85,326	77,580	80,770

APPENDIX D

PREDICTED U.S. COMMERCIAL HOG PRICE, 1976-1979

(VALUE PER HUNDREDWEIGHT OF LIVE HOG)

MONTH	1976	1977	1978	1979	1980	1981
January	26.17	29.45	40.41	39.09	44.91	49.05
February	22.84	29.16	38.01	33.78	42.69	46.44
March	31.09	37.74	44.82	40.82	44.82	53.06
April	28.42	34.55	38.38	38.45	45.70	53.18
May	31.84	41.47	47.57	46.36	51.08	57.56
June	33.02	41.98	44.92	42.26	48.39	59.26
July	29.36	37.21	38.52	40.51	47.90	57.40
August	32.54	44.30	44.57	46.55	48.47	57.85
September	30.77	41.37	38.65	39.04	48.05	58.65
October	27.65	38.70	37.75	46.13	48.90	58.13
November	33.88	44.43	41.41	46.15	47.22	59.69
December	32.75	41.39	35.67	41.12	50.03	59.90

APPENDIX E

OPERATING PROCEDURE OF SIMULATION MODEL

I. Exogenous Inputs

1. U.S. Commercial Hog Supply - 72 Months

2. Price Expectations
    - a. Labor
    - b. Fuel Oil
    - c. Natural Gas

3. Energy Supply Expectations
    - a. Fuel Oil Supply
    - b. Natural Gas Supply
    - c. 12% Energy Reduction Goal by 1982

II. Simulation Model

1. Select Energy Reduction Alternatives Prior to Start of Production Year
    - a. Estimate Production for the next 15 Years - Market Share of U.S. Hogs
    - b. Compute N.P.V. of Alternatives Given Production Level and Expected Energy Prices
    - c. Long-Run Decision - Adopt Technology if N.P.V. > 0
    - d. Estimate Energy Demand for First Year
    - e. Check Energy Supply with Expected Energy Demands; if S > D, Continue; if S < D, Adopt Next Best Technology

2. Set Production Level for Month I, I = 1 12
    - a. Firm Decision Criteria
        1. Production in Month I is a Function of Market Share and Prepaid Labor
        2. Estimate Live and Wholesale Hog Value for U.S. Hog Supply
        3. Adjust Live Hog Values if Production is Not Equal to Market Price
        4. Compute Monthly Costs and Revenues for Production Level I
        5. Compute Monthly Products Processed Within Plant

   6. Compute Monthly Energy Demands for Product Processed and Reduce Demands if Production Alternatives were Adopted
   7. Compute Monthly Financial Position
   8. Write Reports--Production, Financial, Energy
   9. Change Month I = I + 1 and Repeat Steps (2a1-2a8) until I = 13; if I = 13, return to 1

  b. Profit Maximizing Decision Criteria
   1. Production in Month I is Determined by the Level of Profits
   2. Estimate Live and Wholesale Hog Values for U.S. Hog Supply
   3. Adjust Live Hog Values for Possible Production Range
   4. Compute Monthly Costs and Revenues Over Production Range
   5. Search Over Profit Function to Select Maximum Profit
   6. Production in Month I Determined by Profit Maximization
   7. Compute All Costs and Revenues for Monthly Production Level
   8. Compute Monthly Products Processed
   9. Compute Monthly Energy Demands for Products Processed and Reduce Demands if Production Alternatives were Adopted
   10. Compute Monthly Financial Report
   11. Write Reports--Production, Financial, Energy
   12. Change Month I = I + 1 and Repeat Steps (2b1-2b11) Until I = 13; If I = 13, Return to 1

3. Write Annual Reports When I = 72