The total capital spending is $1279M in current dollars, up from $1100M. This creates the initial rate base of $1349M, compared with the constant dollar rate base of $1182M. In the fifth year, the rate base of $1268M is made up of $868M of debt and $400M of equity. The interest charge is .09 x 868 = $78M. The return on equity is 400 x .15 = $61M. (The $61M is higher than 400 x .15 because of return on working capital.) The income taxes required are $66M. Depreciation is $60M per year. The final component of the cost of service is the by-product credit of $31M. In summary:

	Current $, M
O&M	264
Interest on debt	78
Return on equity	61
Taxes on income	66
Depreciation	60
By-product credits	(31)
	$499

This produces a gas price of 499 ÷ 82.125 = 6.08/Mcf. A similar exercise produces a trajectory of gas prices in current dollars listed in Table 4.23, and plotted in Figure 4.13. Notice that gas price increases slightly, reflecting the fact that inflation is causing O&M cost to grow faster than capital-related charges decrease.

Discounting this cost of service back to 1975, 499 ÷ $(1.05)^9$ = $322M in 1975 dollars. Dividing by the gas production yields a 1975 dollar gas price of $3.92/Mcf. This is contrasted with a $4.93/Mcf for the base case neglecting inflation. The lower price is due to the fact that the capital cost components of the cost of service have not inflated to as high a level as the rest of the prices in the economy. To illustrate this point, the current dollar costs above are discounted to 1975 dollars, and compared with the base case numbers:

GAS PRICE
IN CURRENT DOLLARS

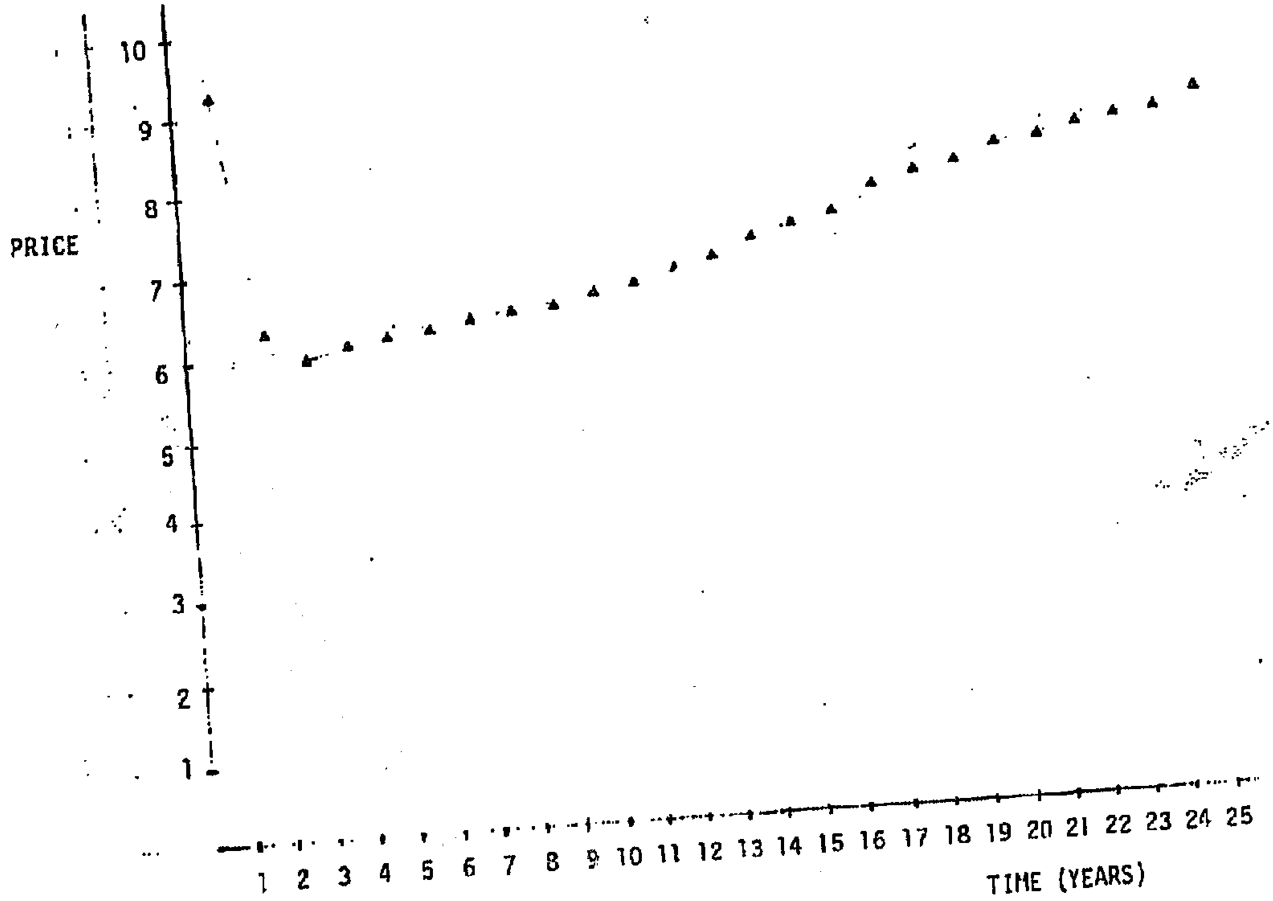
YEAR	PRICE
1	9.33
2	6.35
3	5.95
4	6.01
5	6.08
6	6.16
7	6.24
8	6.33
9	6.43
10	6.54
11	6.66
12	6.79
13	6.92
14	7.07
15	7.22
16	7.39
17	7.57
18	7.76
19	7.97
20	8.08
21	8.15
22	8.23
23	8.33
24	8.45
25	8.58

AVERAGE PRICE - 7.19

Table 4.23

Figure 4.13

GAS PRICES IN CURRENT DOLLARS



Fifth Year Cost of Service

Category	Base Case 1975 $M		Inflation Considered	
O&M	170		170	
Interest on debt	69	230	50	171
Return on equity	53		39	
Taxes on income	56		43	
Depreciation	52		39	
By-product credits	(20)		(20)	
Total	380		322	

The O&M costs are equal, but the items related to the rate base are significantly lower ($230M versus $171M for interest on debt, return on equity, and taxes on income).

The model applies the above procedure to calculate the inflation-corrected gas price trajectory. Table 4.24 lists the price track from the altered base case. Figure 4.14 plots the prices, and compares them with the base case prices. The inflation-corrected prices are lower, representing the gain due to the lower inflation on the rate base-related cost categories.

It is also possible to look at the cash flows to equity, set out in Table 4.25. This should be compared with the base case figures contained in Table 4.7. The entries in Table 4.25 are in current, or inflated, dollars. These would be the actual cash flows that would occur over time. The equity flows are larger, reflecting the investment of a larger number of dollars and the increased payback required. This increases the rate base, and causes the profit figures to be higher ($61M versus $53M). Since inflation increases the O&M cost every year, and working capital is one eighth of the O&M account, there is a continual small investment in working capital. The profit earned on the ever increasing working capital causes the slight upward trend in profit. However, except for this slight trend, the profit is flat over the middle years of plant operations, after the investment is completed, but before depreciation starts to repay the equity

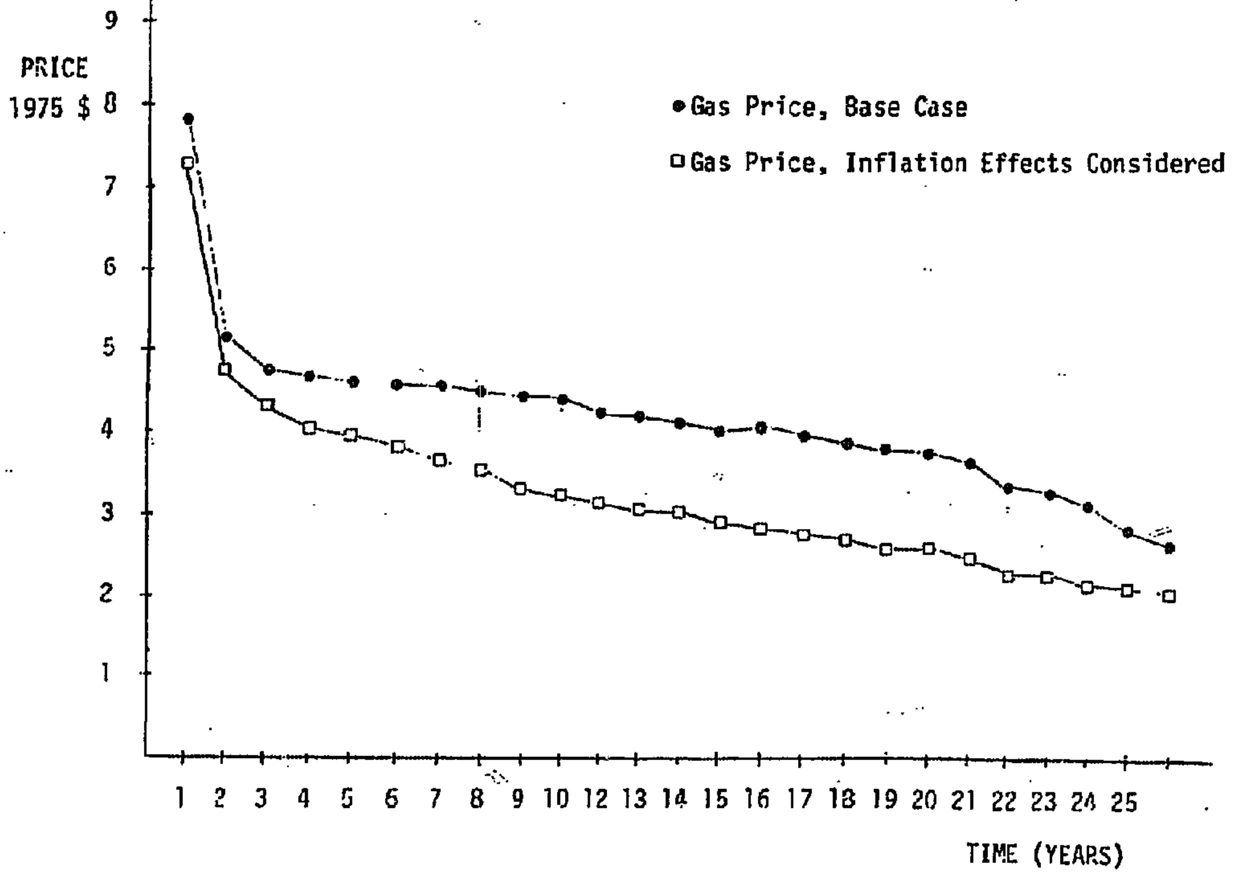
GAS PRICE
INFLATION EFFECTS INCLUDED

YEAR	PRICE
1	7.31
2	7.74
3	4.23
4	4.07
5	3.92
6	3.78
7	3.65
8	3.53
9	3.41
10	3.30
11	3.20
12	3.11
13	3.02
14	2.94
15	2.86
16	2.79
17	2.72
18	2.65
19	2.59
20	2.51
21	2.41
22	2.32
23	2.23
24	2.16
25	2.08

AVERAGE PRICE - 3.18

Table 4.24

Figure 4.14: Effect of Inflation on Gas Price



BASE CASE
INFLATION EFFECTS CONSIDERED

YEAR	EQUITY INVEST	WORKING CAPITAL	PROFIT	ITC	CASH FLOW TO EQUITY	CUMULATIVE CASH FLOW
-4	-28.9	0	0	0	-28.9	-28.9
-3	-60.6	0	0	0	-60.6	-89.5
-2	-127.3	0	0	0	-127.3	-216.9
-1	-66.9	-5.6	0	0	-72.5	-289.3
1	-18.8	-1.2	55.1	0	35.1	-254.2
2	-19.8	-0.7	58.1	0	37.7	-216.5
3	0	-0.4	61.2	0	60.8	-155.7
4	0	-0.4	61.2	0	60.8	-94.8
5	0	-0.4	61.3	0	60.9	-34.0
6	0	-0.4	61.3	0	60.9	27.0
7	0	-0.5	61.4	0	61.0	87.9
8	0	-0.5	61.5	0	61.0	148.9
9	0	-0.5	61.6	0	61.1	210.0
10	0	-0.5	61.6	0	61.1	271.1
11	0	-0.5	61.7	0	61.2	332.2
12	0	-0.6	61.8	0	61.2	393.5
13	0	-0.6	61.9	0	61.3	454.7
14	0	-0.6	62.0	0	61.3	516.1
15	0	-0.7	62.1	0	61.4	577.5
16	0	-0.7	62.2	0	61.5	638.9
17	0	-0.7	62.3	0	61.5	700.4
18	0	-0.8	62.4	0	61.6	762.0
19	38.1	-0.8	62.5	0	99.7	861.8
20	60.4	-0.9	56.9	0	116.4	978.2
21	60.4	-0.9	48.0	0	107.5	1085.7
22	60.4	-0.9	39.0	0	98.5	1184.2
23	60.4	-1.0	30.1	0	89.5	1273.7
24	60.4	-1.0	21.2	0	80.6	1354.3
25	60.4	21.7	12.3	0	94.4	1148.7

ROE = 15.9%

Table 4.25

investment. The ITC column is all zeros, reflecting the fact that no investment tax credit effects have been considered. The return to equity is 15.9%.

The gas prices can be calculated for combinations of ITC passthrough to the customers and a surcharge during construction. Figure 4.26 summarizes the results by listing the average gas price for each possibility. The average gas prices have the same relationships between them as in the non-inflation case, with all of the prices lower. The returns to equity were also calculated. However, the results were almost identical with the numbers from the previous analysis in Table 4.20, and are not reproduced.

SUMMARY OF BASE CASE RESULTS

The financial model, used to analyze the base case defined in Table 4.2, provides the following major results:

1. The trajectory of gas prices, shown in Figure 4.11, averages $4.13/Mcf. The sensitivity of this average price to changes in base case assumptions is shown in Table 4.6. Some effects can be appreciable. For example, if maintenance cost is 8% of capital, the average price increases to $4.96/Mcf.
2. Return on equity is sensitive to the ITC treatment. Table 4.15 shows that the return can be in excess of 20%. Special cases may be possible that provide returns in the range of 30 to 50%.
3. A surcharge during construction provides consumers with an opportunity to vary the magnitude and timing of payments for the gas.
4. Inflation has the effect of reducing the constant dollar average price from $4.13/Mcf to $3.18/Mcf. The detailed relationship is shown in Figure 4.14.

GAS PRICES
INFLATION EFFECTS CONSIDERED

CASE		
ITC PASSTHROUGH	SURCHARGE	AVERAGE GAS PRICE, 1975 $/McF
No	No	3.18
No	Yes	2.97
Yes	No	3.13
Yes	Yes	2.92

Table 4.26

FINANCIAL MODEL OUTCOMES

The financial model outputs the following variables, all corrected for inflation:

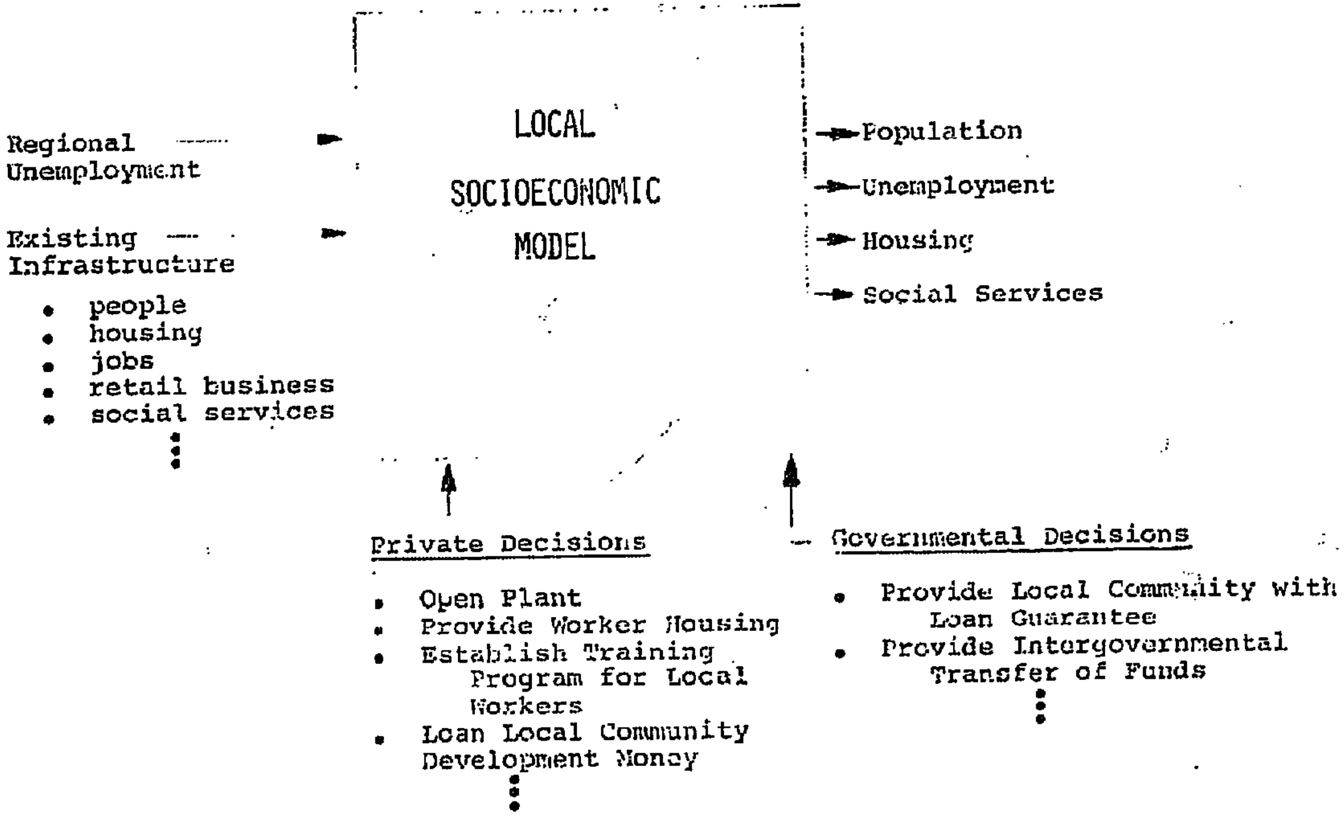
1. The trajectory of gas prices at the plant gate,
2. The surcharge paid by customers during construction, and
3. The actual returns to equity under a wide range of assumptions about investment tax credits.

Strictly speaking, none of these variables are outcomes in that they are not fed directly into the social value model. However, the price trajectories are important inputs to the SRI National Energy Model, which is used to ca culate the economic impact of the gasification plants.

4.1.3 LOCAL SOCIOECONOMIC MODEL

Construction and operation of gasification plants have significant potential social and economic impacts on the local area in which the plants are built. By "local" we mean an area within roughly 50 to 100 miles of a plant. All of the potential plants would be located in relatively sparsely populated areas in the West -- nearby towns have populations in the range of several hundred to a few tens of thousands. Building even single plants that require 3000 construction workers and 1000 to 1500 operating workers poses both far-reaching problems and opportunities for such areas. The influx of workers and their dependents implies demands for housing and public services that such areas may be hard pressed to meet. On the other hand, particularly in the longer range, the employment and potential economic stability offered by the plant provides opportunities for development that many would deem worthwhile. In any case, the lifestyles of many of the "natives" of the area will be permanently altered.

The purpose of the socioeconomic model is to relate the impact of private and governmental decisions to local socioeconomic outcomes of interest to national decision makers. This process is outlined in Figure 4.15. Besides the actual establishment of the plant, typical private decisions that directly affect the local area are whether or not to provide



THE ROLE OF THE SOCIOECONOMIC MODEL

Figure 4.15

worker housing; whether to train local workers or to import skilled workers; whether to provide loans or grants for public facilities; and so on. Similarly, the federal government might provide loan guarantees or outright grants to the communities to develop social services, or state governments might provide for transfer of tax revenues to local jurisdictions. These decisions interact with the existing conditions in the town and region in which it is located to yield the local socioeconomic outcomes listed to the right in Figure 4.15 -- population, unemployment, housing, and social services. We will define these outcomes much more precisely later in the section; for the moment, they represent the general categories of impacts that we are considering.

CHARACTERISTICS AND STRUCTURE OF THE SOCIOECONOMIC MODEL

In any town there are a variety of social, political, and economic processes going on. The socioeconomic model does not attempt to represent all of these processes in detail -- it focuses on those that are most important in describing the evolution of the town. There is a housing market in which certain numbers of living units of varying quality are available for a variety of prices. Because of its importance, the model contains an explicit housing submodel. Some people in town may have particular advantages in furthering their own interests because they are cousins of the mayor. The model does not attempt to address these sorts of interactions. In general terms, the key attributes of the model are that it focuses on:

1. Interactions -- the interactions and reciprocal relationships between the important local socioeconomic variables are represented rather than just looking at each one in isolation.
2. Dynamics -- many of the potential problems in local areas are ones of timing; for example, needs for service precede revenues to provide services. The model represents the impacts on the socioeconomic outcomes over time.
3. Aggregation -- the interactions in the model are at a relatively aggregate level. For example, in modeling economic phenomena, detailed market price behavior is not represented, but rather a description of the results of this process is offered.

Finally, the model has been designed to provide a large degree of flexibility in performing sensitivity analyses and testing alternative decisions.

The principal interactions represented in the socioeconomic model can be outlined as shown in Figure 4.16. The model can be thought of in terms of five submodels:

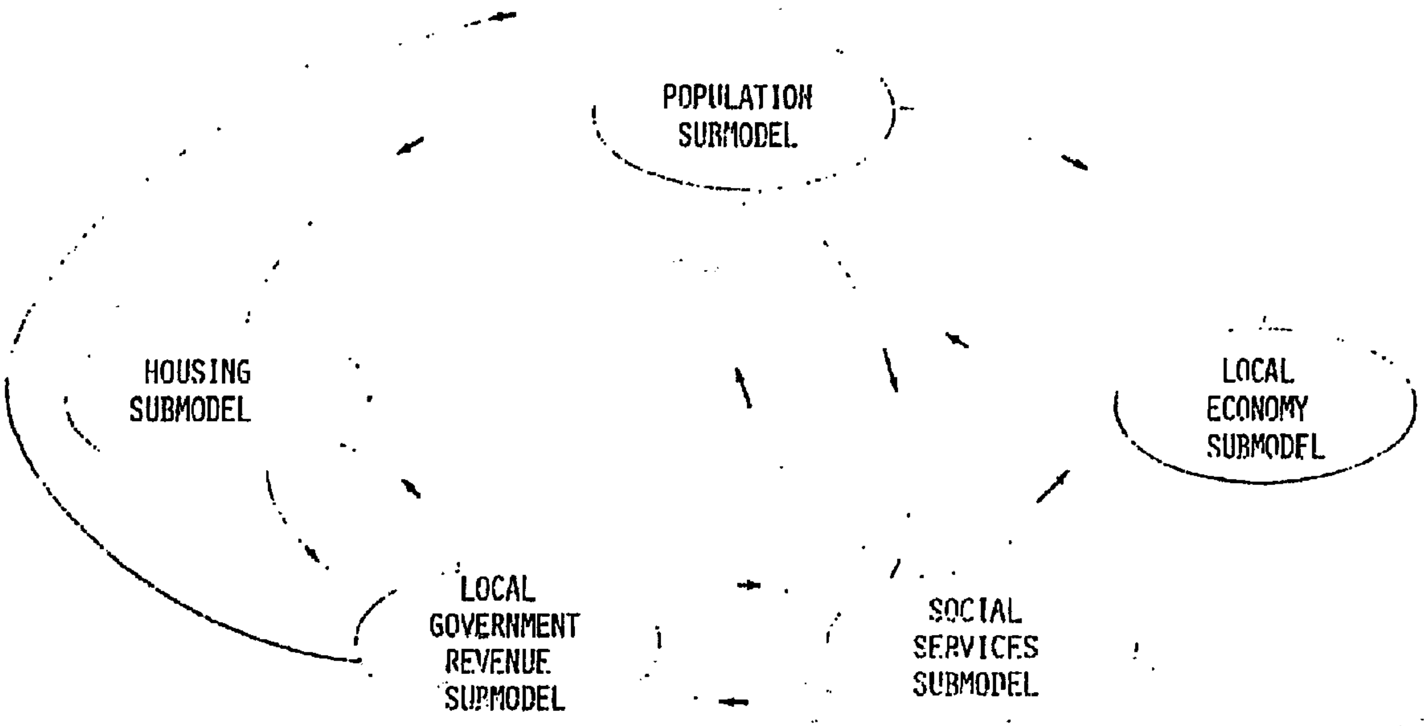
1. Population
2. Local economy
3. Housing
4. Social services
5. Local government revenue

The population model represents the population dynamics of the town. We assume that workers come to the town in response to job availability and leave if jobs become scarce. Initially, most new jobs are a direct consequence of the plant; however, other jobs are generated in retail business and in the provision of social services. In addition to leaving the area because of job scarcity, workers will also leave if public services are inadequate over too long a period.

The local economy submodel takes account of the plant on the local economy, focusing particularly on the impact on unemployment and retail business.

The relationship between existing housing units and the demand is represented in the housing submodel. It is a description of the overall interactions that take place -- not a detailed supply/demand model based on market price. For property tax purposes, a measure of property value is calculated by relating existing housing to demand.

The social services submodel calculates the social services that would be desirable as a function of population and determines what can be provided with existing revenue sources. A distinction is made between investment in social infrastructure — schools, roads, and so on — and the maintenance of existing facilities. Jobs generated in providing social services are input to the local economy submodel.



OUTLINE OF MAIN INTERACTIONS IN SOCIOECONOMIC MODEL

FIGURE 4.16

Sources of funds available to the local government -- property tax, retail sales tax, municipal bonds, transfers from other governmental bodies, and money provided by the gasification companies -- are represented in the local government revenue submodel. The property tax rate is sensitive to the level of services provided compared to the required or desirable level.

A gasification plant would directly impact each of these submodels in a variety of ways. The most important potential impacts are:

1. Population -- Plant affects immigration directly through number of workers that must be imported, and indirectly through adding more jobs to the general pool. The fraction of workers that must be imported from outside the area is an important parameter under at least partial control of the gasification company.
2. Local economy -- Plant adds jobs and indirectly generates retail business.
3. Housing -- The gasification company could affect the housing market by providing either permanent or temporary housing for workers. From the socioeconomic point of view, this is an important decision variable.
4. Social services -- The company could provide some social services directly, although provision of funds is more likely.
5. Local government revenue -- Revenue for government services could be provided either on a grant or loan basis, either by the gasification company, or by the federal government as part of the commercialization program.

By setting initial conditions and parameter values appropriately, the model outlined in Figure 2 can be used to represent the impact of a gasification plant on any small Western town. It can also be used to test the sensitivity to both alternative sets of assumptions and to different governmental policies, such as grants and municipal loan guarantees.

DETAILED INTERACTIONS

In the last section we outlined in general terms the interactions in the socioeconomic model. In this section we will discuss our assumptions in more detail.* Figure 4.17 represents the detailed interactions represented in the socioeconomic model. Most of the variables represented in the model are shown, along with the variables with which they interact directly. The figure is drawn as a causal interaction diagram. An arrow between two variables indicates that two variables interact directly. The direction of the arrow indicates which variable affects the other and the sign on the arrow shows the sense of the interaction. Thus the interaction between population and retail business

$$\text{Population} \xrightarrow{+} \text{Retail Business}$$

indicates that population directly affects retail business and that an increase (decrease) in population causes an increase (decrease) in retail business, if all other variables are held constant. Similarly, the minus sign on the interaction between unemployment and immigration indicates that an increase (decrease) in unemployment decreases (increases) immigration.

Notice that by carefully representing all of the direct interactions between variables in the model, many complex indirect interactions are evantually represented. For example, suppose population is increased. One of the effects of this is to increase retail business, which generates more jobs so that total jobs are increased. This in turn decreases the unemployment rates which causes immigration to increase and finally causes population to increase. Thus there is a positive, or deviation simplifying, feedback loop. However, it interacts with many other loops. The same

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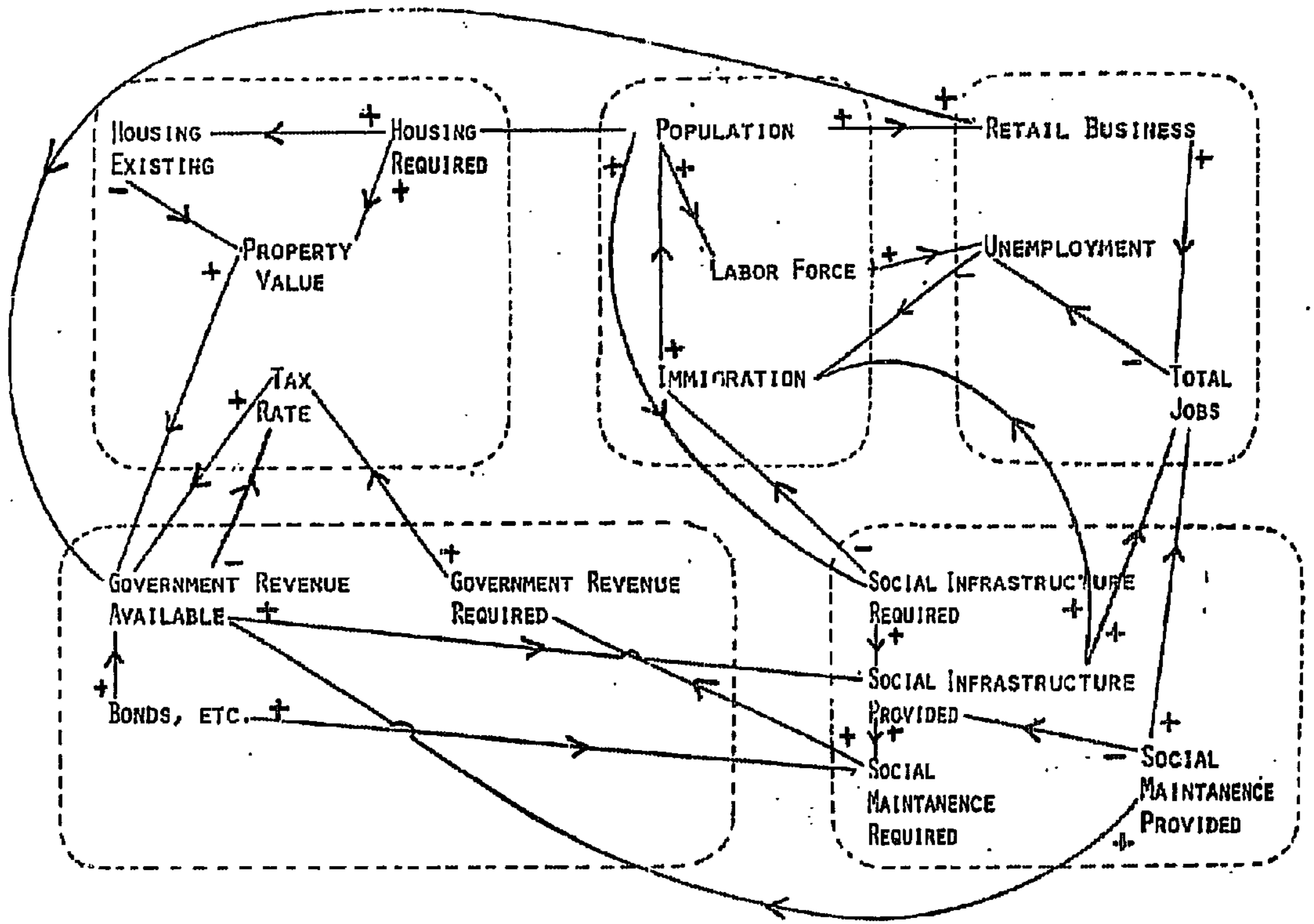
* Readers not interested in the detail can skip to the next section.



DETAILED INTERACTIONS IN SOCIOECONOMIC MODEL

Figure 4.17

original increase in population leads to an increase in the labor force which causes increase in unemployment. This decreases immigration and hence population. This is a negative, or deviation decreasing, feedback loop. To understand the potential interactions represented in the model, we will outline the assumptions made in each submodel.

POPULATION SUBMODEL*

Population grows at a fixed rate plus immigration. Immigration is a function of both the fraction of construction and operating labor that must be imported from outside the area and the unemployment rate and level of government services. If the local unemployment rate is small relative to the larger region in which the area is located, more people will tend to immigrate. If the level of government services provided is below the level that would be desirable for a particular population, people will eventually tend to emigrate.

LOCAL ECONOMY SUBMODEL

The total number of jobs available at any given time is the sum of plant jobs, retail jobs, government jobs, and other jobs. The other jobs represent ranching and farming jobs, other industrial jobs, financial jobs, and other jobs not explicitly modeled. They are assumed to grow at a fixed rate. Plant jobs are input as either construction or operating jobs. Government jobs are determined by dividing the level of government services by the average number of dollars spent per worker. There are two categories of government wrokers — those involved in building capital facilities and those involved in maintaining existing facilities. Retail business is found by multiplying the total population by the average spending per person. Retail jobs can then be determined by dividing the total retail business by an average amount of retail sales generated by an employee. The labor force is calculated by multiplying population by the fraction of the people that work. Finally, the unemployment rate is just equal to the labor force minus the total jobs available divided by the total jobs available.

HOUSING SUBMODEL

A measure of the housing required is calculated by dividing the total population by the average number of people per living unit. The dynamics

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* The equations for each submodel are included in Appendix A.

of the housing market are then modeled descriptively as follows: If the housing required is greater than the amount of housing available, new housing is constructed at a rate proportional to the difference with a specified average construction delay. Until adequate housing is available, people are assumed to double up and to live in substandard units. If the amount of existing housing is greater than that required, then the housing stock depreciates at a rate proportional to the difference with a specified average depreciation time. Housing can also be supplied exogenously independent of the operation of the market as might be done by a gasification company. The overall property value of the housing stock is found by evaluating the stock at a nominal value per unit and then taking account of inflation caused by any imbalance between required and existing housing. The property tax rate is a function of the ratio of government revenue required to provide a desirable level of social services to the actual government revenue available. Account is taken of the time delays inherent in the social and political processes that accompany changes in tax rates.

SOCIAL SERVICES SUBMODEL

Two different types of activities are distinguished in the social services submodel. They are investment in social infrastructure such as schools, courthouses, roads, and so on, and maintenance and operation of existing facilities. For each of these categories a "required" figure and a "provided" figure is calculated. The "required" figure reflects levels that would be desirable and the "provided" figure reflects what can actually be accomplished.

The social services submodel is based on the assumption that there is a level of investment in social infrastructure that is necessary to provide a set of adequate and desirable services such as schools, police, roads, and so on, in a community. This figure is commonly thought to be in the range of $5,000 to $7,000 per person. Thus, a level of required social infrastructure can be found by multiplying the population times the required social infrastructure per person. The amount of social maintenance required to operate and maintain existing social infrastructure is some fraction of the social infrastructure actually in place plus repayments of loans and bonds as necessary.

In actuality, the amounts of infrastructure and maintenance provided may be different than the required amounts depending on the amount of revenue available. In spending available funds we assume that maintenance is provided for first. If there is adequate money available to also cover investment in new infrastructure, the money is spent at a rate proportional to the difference between what is required and what is provided, with an average time delay to account for the lags in implementing and completing capital projects. When possible, new investment covers not only new facilities, but also depreciation of old facilities. If there is not adequate revenue to cover required maintenance, then only partial maintenance is provided and no investment, causing the social infrastructure to begin to depreciate.

LOCAL GOVERNMENT REVENUE SUBMODEL

Local government revenue is collected from four sources: property tax, including the plant property tax, bond revenue, intergovernmental transfers, and money from other sources (principally loans or grants from gasification companies).

LOCAL SOCIOECONOMIC MODEL RESULTS

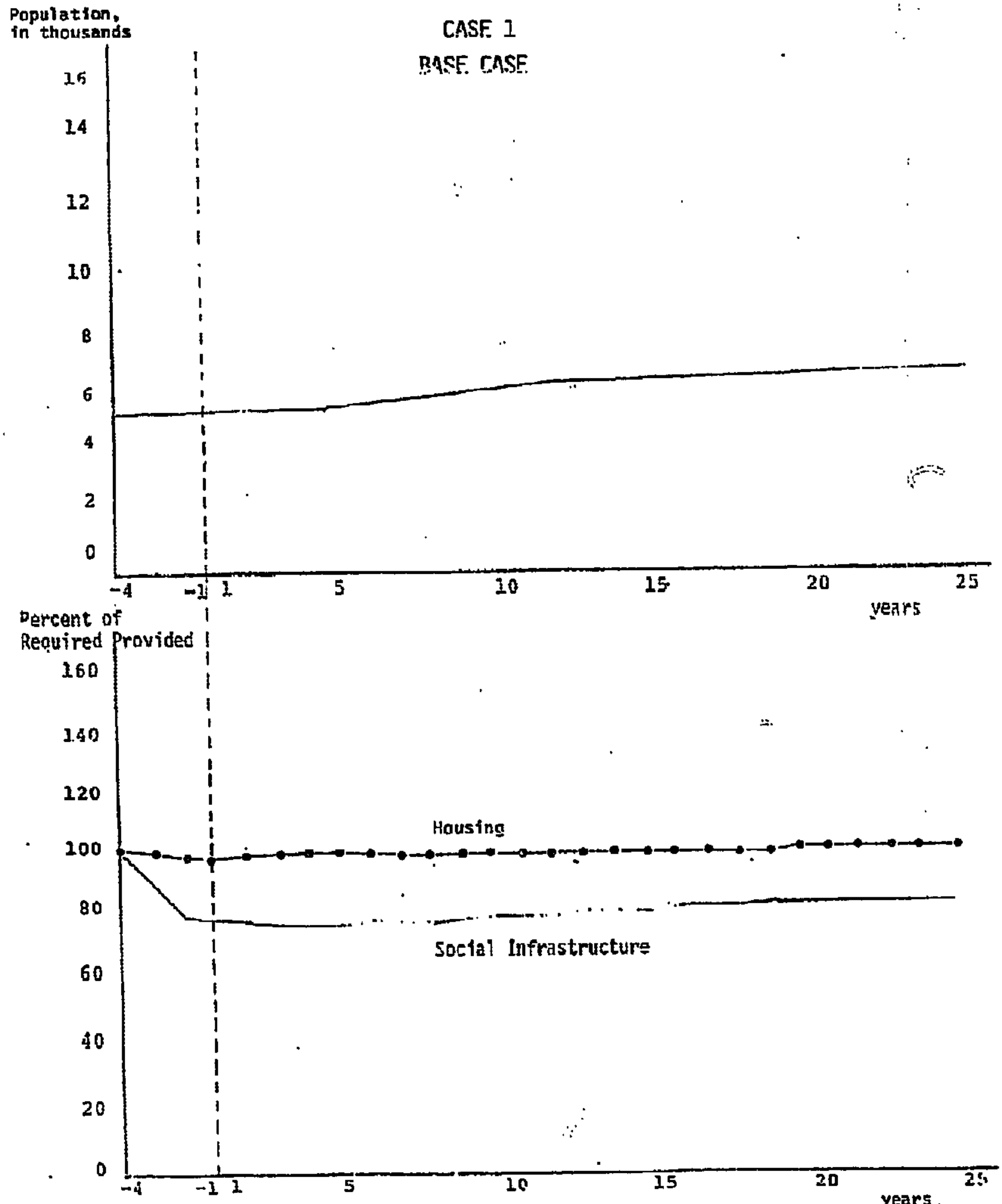
The local socioeconomic model has been run to demonstrate the interactions captured in the model, to make a preliminary assessment of the implications of introducing a plant into a remote environment, and to explore possible means of mitigating the resulting impacts. A base case has been constructed representing a hypothetical Western town where a gasification facility might be built. Table 4.27 is a detailed listing of the assumptions for this case. The town starts with 5,000 citizens. There are enough jobs to produce an unemployment rate of slightly less than 5%. The housing stock and existing social infrastructure are sufficient to support the existing population. The state government provides $1M of outside support per year.

Three important variables are plotted over time in Figure 4.18. The bottom axis represents time. The negative numbers are plant construction years, of which there are four. (This has no meaning for the base case.)

Table 4.27

BASE CASE TOWN ASSUMPTIONS

Population Submodel	
Initial Population	5,000
Population Growth Rate	1%
Population Percent in Labor Force	35%
Regional Unemployment Rate	5%
Service Adjustment Time	5 years
Local Economy Submodel	
Initial Other Jobs	1280
Other Job Growth Rate	1%
Average Maintenance Per Government Employee	$10,000
Average Investment Per Government Employee	$100,000
Initial Retail Sales	$10M
Average Sales Per Retail Employee	$50,000
Housing Submodel	
Initial Housing Units	1818
Value of a House	$25,000
House Building Delay	2 years
House Destruction Delay	20 years
Average People Per House	2.75
Initial Property Tax Rate	2%
Tax Adjustment Time	4 years
Initial Property Value Inflation	1%
Property Value Adjustment Time	2 years
Social Services Submodel	
Desired Social Infrastructure Per Capita	$5,500
Social Investment Delay	3 years
Initial Social Infrastructure	$27.5M
Social Maintenance Fraction	10%
Nominal Depreciation Rate	5%
Local Government Revenue Submodel	
Inter Governmental Revenue Transfers	$1M/year
Sales Tax Rate	1%
Initial Town Tresury	$0


CASE 1

BASE CASE

Figure 4.18

The years labeled 1 to 25 are the life of a gasification plant. The top graph shows the town's population. It grows slowly over time, responding to the slow growth of the economic base of the community. The bottom graph has two percentage plots. One shows the percent of the required housing that is provided. It is essentially 100%, being slightly less to reflect the lag in the housing market. The second line traces out the percent of required social infrastructure provided. It initially drops, and settles at about 80%. The town is slightly short of tax base, and cannot raise enough tax revenue to provide and support the required social infrastructure.

In interpreting the plots of required housing and infrastructure provided, it is important to keep clearly in mind the sense in which the world "required" is used in the model. The required level of housing is the number of living units that would be necessary to house the total population at any time if an average of 2.75 people lived in every house. When the amount of housing provided is less than the required level, we assume that people double up and live in substandard units. The required figure is a number used for comparison. Similarly, the required social infrastructure is the amount of infrastructure that would be required if $5,500 worth were provided for every person in the population.

SENSITIVITY ANALYSIS

Seven sensitivity runs were made. All introduce a coal gasification facility into the local area, and trace the socioeconomic impacts. Various mitigating measures have been attempted. The assumptions for the base case are retained, except for those changed as listed in Table 4.28.

Case 2 introduces the plant into the area without any attempt to reduce the adverse effects. The local labor force is increased by the construction and operating associated with the gasification venture. The tax base is increased by $100M when plant start-up occurs. The full plant value is $1,100M. The fact that only part of the plant value is included in the local tax base represents an attempt to model the amount of tax revenue that will flow to the town from a large facility located

Table 4.28

Changes in Assumptions

Case 2

Plant Labor

Year	-4	-3	-2	-1	1	2	3 to 25
Construction	200	1200	2800	2800	1000	500	0
Operation	100	200	600	900	1300	1400	1400

Assessed Value of Plant

Year	-4 to -1	1 to 25
Assessment, $M	0	100

Case 3

Same as Case 2 except:

Exogenous Housing Provided, New Units per Year

Year	-4	-3	-2	-1	1 to 25
Units	50	450	1500	500	0

Case 4

Same as Case 3 except:

Outfront Money

Year	-4 to -1	1 to 25
Amount per year, $M	10	0

Outfront Money Repayment

Year	-4 to -1	1 to 25
Amount per year, $M	0	1.5

Case 5

Same as Case 4 except:

Plant Assessed Value

Year	-4 to -1	1 to 25
Assessment, $M	0	1,100

Case 6

Same as Case 3 except:

Government Transfers

Year	-4 to 2	3 to 25
Transferred Funds, $M	10	6

Case 7

Same as Case 1 except:

Plant Labor

Year	-4	-3	-2	-1	1	2	3	4	5 to 25
Construction	200	1000	1600	1500	1500	1600	1000	250	0
Operating	100	200	500	800	1000	1100	1300	1400	1400

Case 8

Same as Case 7 except:
Same Exogenous Housing as Case 3
Same Outfront Money and Repayment as in Case 3

just outside its legal boundaries. The results of introducing the plant are shown in Figure 4.19. The top graph shows that population increases rapidly during construction, and settles down after plant start-up to a figure of about 12,000. The housing market is initially unable to provide the desired housing. There is a building boom, which overreacts in the early plant operation years. The market eventually does reach an equilibrium of about 100%. Social infrastructure is not adequate to support the population during influx. Over the long run, the greatly increased population cannot be supported by the increased tax base. However, almost 90% of the required infrastructure is provided, compared to the 80% achieved by the town alone in the base case.

Case 3 is shown in Figure 4.20. The same plant is introduced into the area. However, exogenous housing of 2500 units is provided by some outside entity. The population growth is slightly higher than in Case 2. The additional housing stock generates a broader tax base, providing more revenue for government services. The higher level of government services induces more citizens to remain in the town after completion of the plant. The housing shortage during construction is much less marked. The social infrastructure is slightly improved from Case 2, reflecting the higher tax base caused by the additional houses.

Case 4 adds out-front money from an outside agent. In other words, a series of $10M grants are made to the town during construction, with repayment of $1.5M during plant operation. Figure 4.21 shows the results. Population is similar to other plant runs, with slightly higher growth due to the more acceptable level of social services. Again, the exogenous housing input has reduced shortages. The social infrastructure shortfall has not been eliminated -- it would be almost impossible to provide infrastructure for such rapid growth -- but is has been significantly reduced.

Case 5 makes on addition to Case 4. The exogenous housing and out-front money is still provided, but the full plant value of $1,100M is included in the local tax base. Housing and population are essentially unchanged from Case 4. There is, again, a slight increase in the population

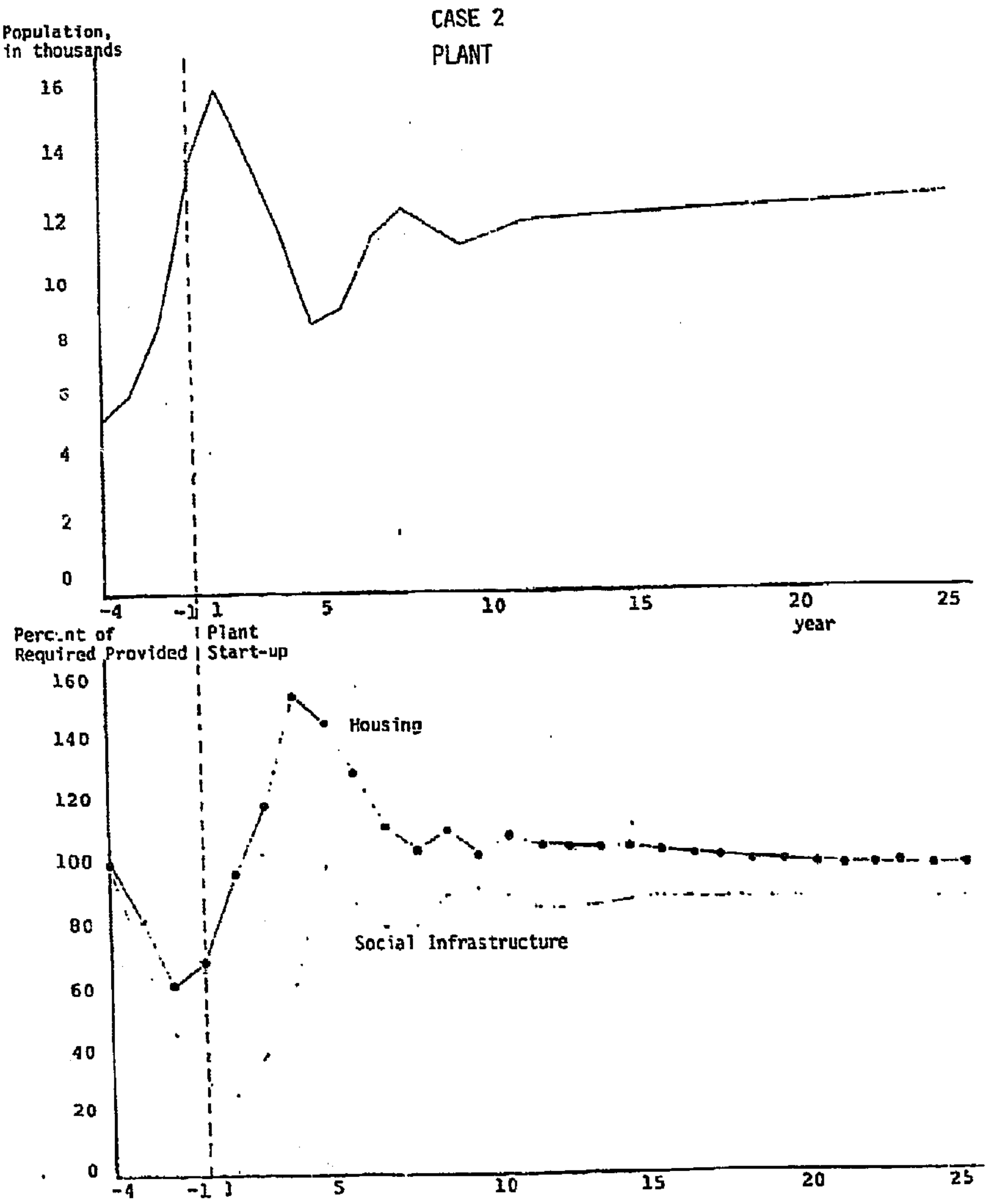
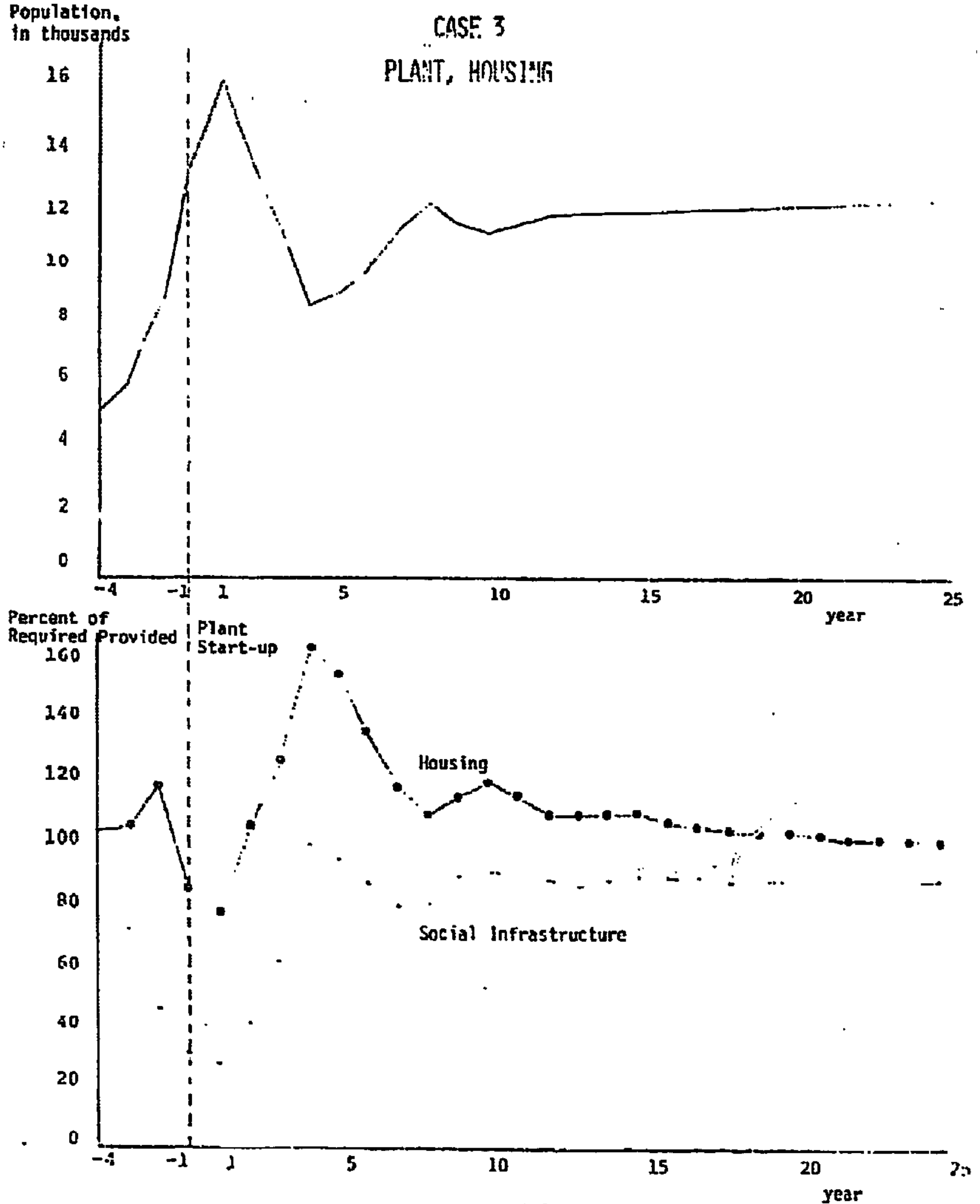

CASE 2
PLANT
Population,
in thousands
16
14
12
10
8
6
4
2
0
-4
-1
1
5
10
15
20
25
year
Percent of
Required Provided
Plant
Start-up
160
140
120
100
80
60
40
20
0
Housing
Social Infrastructure
-4
-1
1
5
10
15
20
25
year

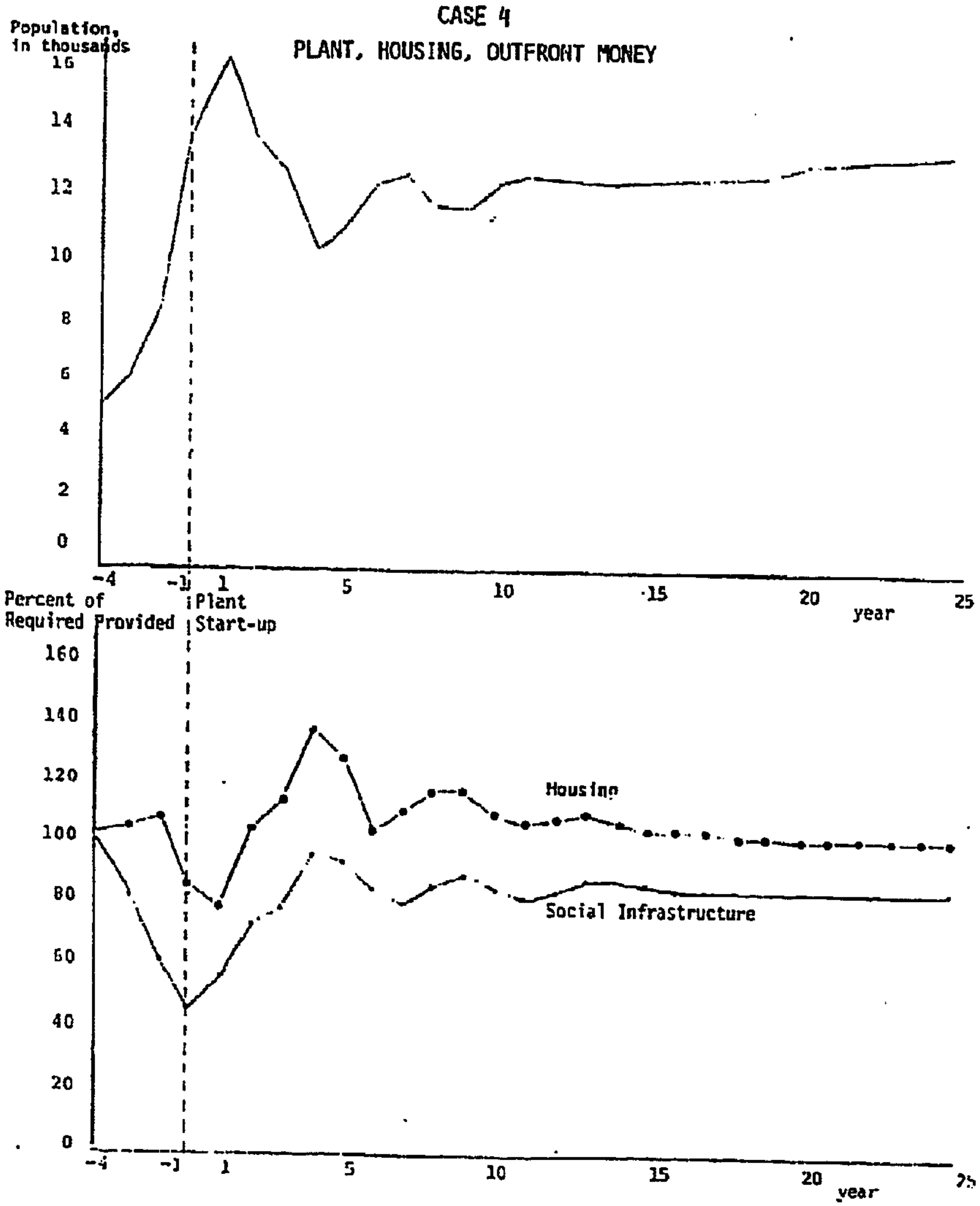
Figure 4.19



CASE 3

PLANT, HOUSING

Figure 4.20



CASE 4

PLANT, HOUSING, OUTFRONT MONEY

Figure 4.21

due to the increased level of social amenities. The increased tax base does not start until plant operation, so that the initial shortage of social infrastructure is not reduced during construction. However, the town now has sufficient funds to provide the desired infrastructure in the long run. Figure 4.22 illustrates this case.

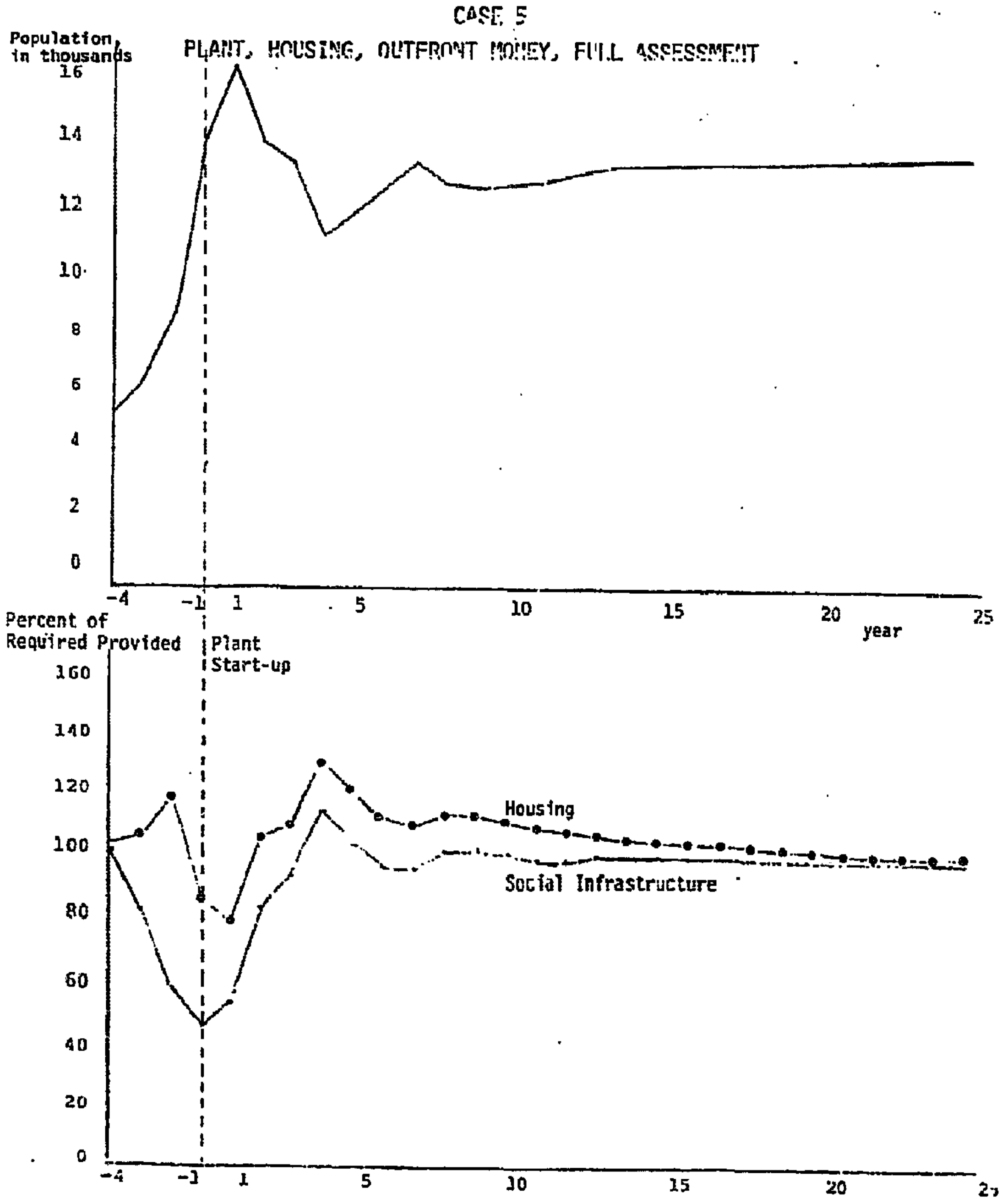
Case 6 drops the out-front, repayable money and full assessment assumptions. Instead, the intergovernmental transfers of funds to the town are increased, greatly at first to build infrastructure, and at a reduced rate later to maintain the existing base. Figure 4.23 provides the graphics. The plot is almost identical to the previous figure. The early government funds duplicate the effects of out-front money, while the revenue transfers during plant operation provide results similar to the increased tax base of the previous case.

Case 7 introduces a new plant construction schedule, "phased" construction. While the final capacity is the same as in former cases, it is built in two stages, requiring eight years of construction instead of six. No outside money or housing is provided, so this case should be compared to Case 2. Intuition would indicate that phased construction, with its lower peaks in construction labor, would cause less chaos. However, the result is contrary, as demonstrated in Figure 4.24. The shortfalls in housing and social services are almost as great at any period of time, and persist for a longer duration. The socioeconomic impacts of phased construction actually seem more severe.

Case 8 attempts to mitigate the impacts of phased construction. The same amount of exogenous housing and out-front money is provided as in Case 4. As Figure 4.25 demonstrates, progress is made. However, paralleling the results of the previous case, a mitigated phased construction schedule impacts the local community in a less desirable manner than a mitigated regular construction time table.

DETAILED MODEL RUNS

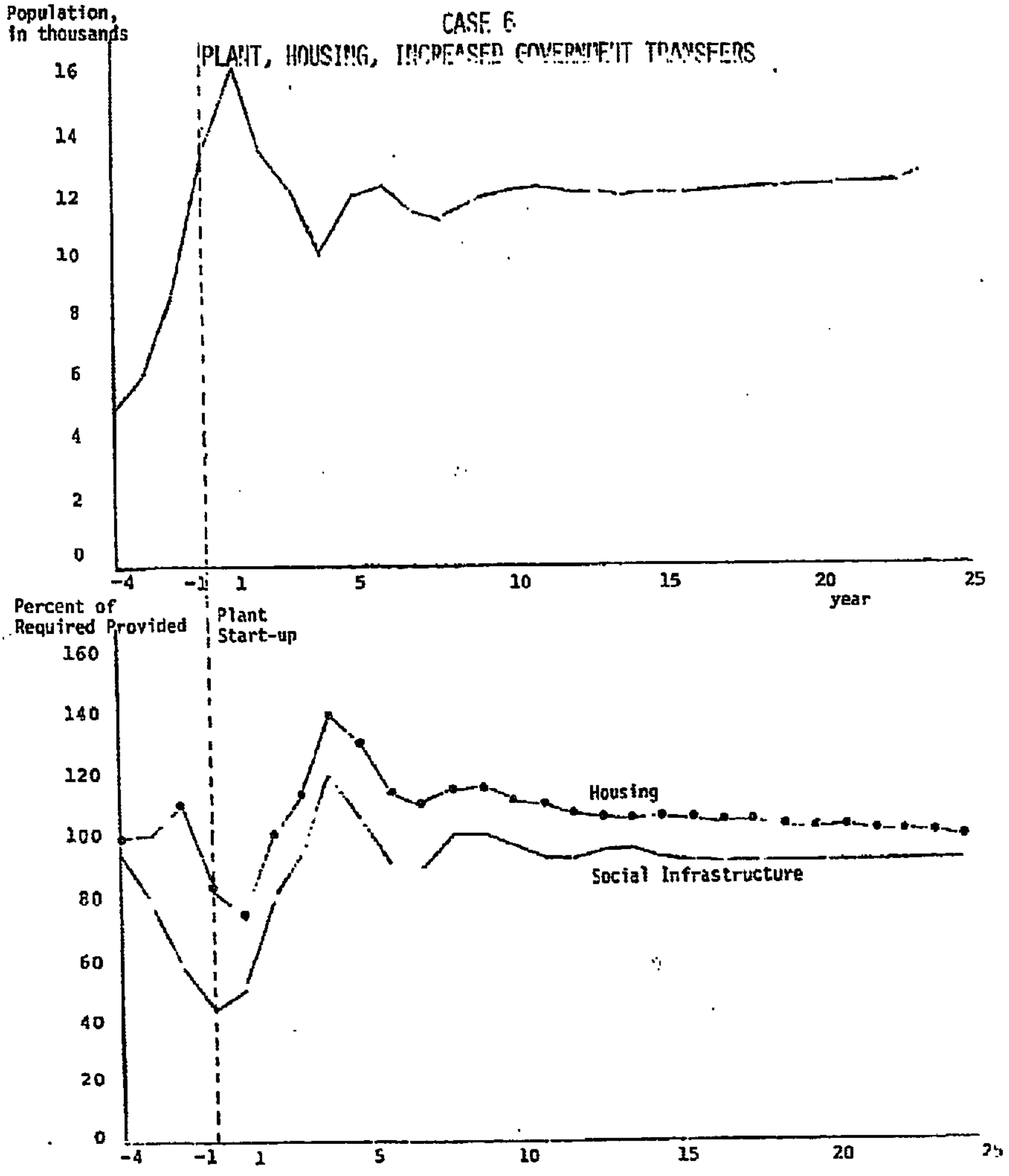
The local socioeconomic model is very complex, capturing numerous interactions of the social system. For the reader interested in building a more complete understanding of the model, the detailed outputs of Cases



CASE 5

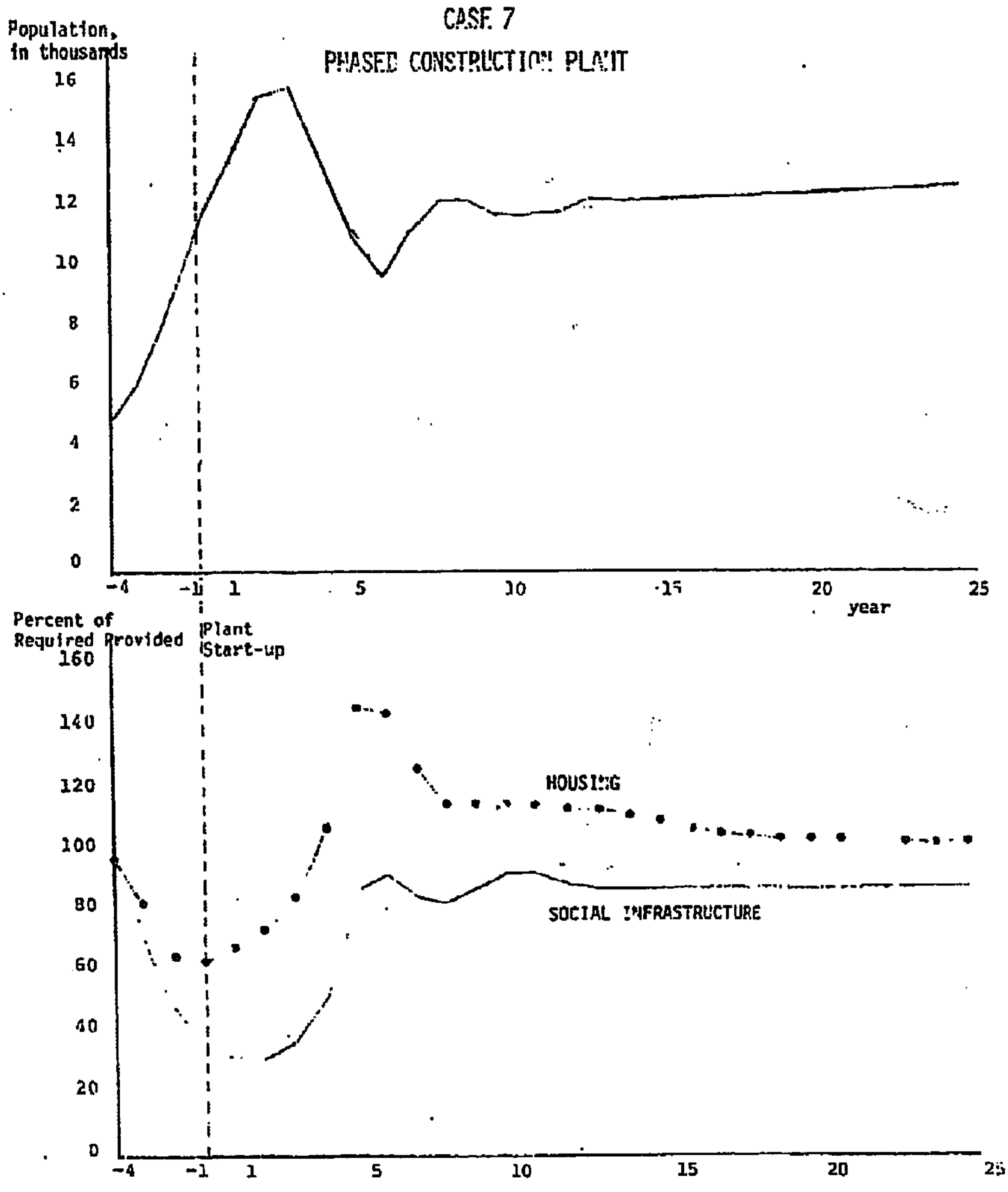
PLANT, HOUSING, OUTFRONT MONEY, FULL ASSESSMENT

Figure 4.22



CASE 6
PLANT, HOUSING, INCREASED GOVERNMENT TRANSFERS
Population, in thousands
16
14
12
10
8
6
4
2
0
-4
-1
1
5
10
15
20
25
year
Percent of Required Provided
Plant Start-up
160
140
120
100
80
60
40
20
0
Housing
Social Infrastructure
-4
-1
1
5
10
15
20
25
year

Figure 4.23



CASE 7
PHASED CONSTRUCTION PLANT

Figure 4.24

CASE 8

PHASED PLANT, HOUSING, OUTFRONT MONEY

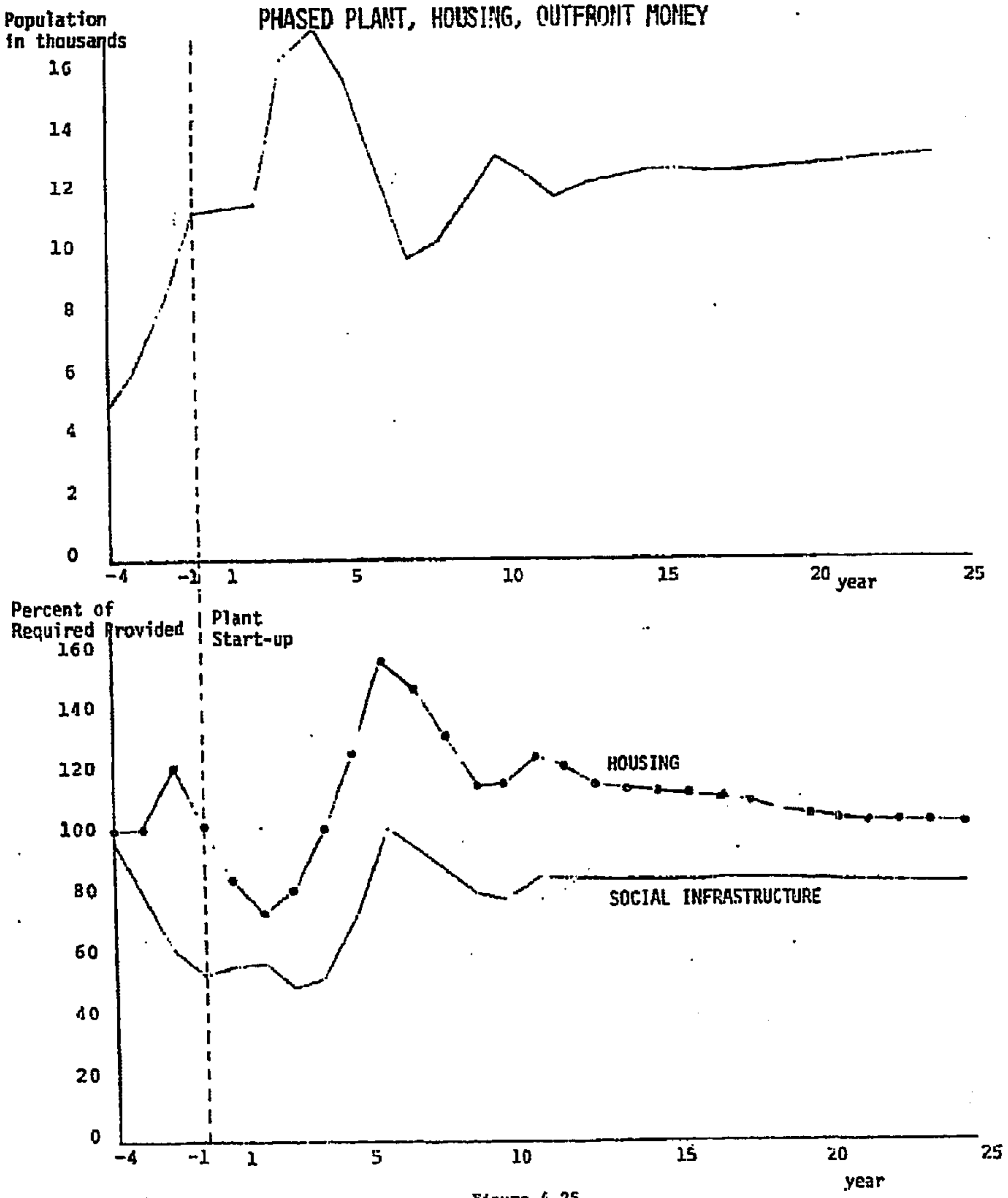


Figure 4.25

1, 2, and 4 are listed in Table 4.29. These results, and the equations listed in Appendix A, can be studied at the desired level of detail.

SUMMARY OF LOCAL SOCIOECONOMIC RESULTS

The analysis of the impact of the gasification facility on the base case town provides the following results:

1. The local community will be strongly impacted by the introduction of a coal gasification plant.
2. Various combinations of measures can help reduce the impacts on the town.
3. The labor force build-up associated with a plant is so rapid that total elimination of adverse impacts appears very difficult, if not impossible, to achieve.
4. Long run help, in the form of increased government transfers, or inclusion of the plant in the local tax base, is required to support the increased population in the town.
5. A phased construction schedule appears undesirable.

SOCIOECONOMIC OUTCOMES

The outcomes from the socioeconomic model, defined in general terms in Figure 1, can now be defined more precisely:

1. Population increase over base case measured in number of people
2. Housing available minus housing required measured in number of units
3. Social infrastructure provided minus social maintenance required measured in dollars
4. Social maintenance provided minus social maintenance required measured in dollars

All of the variables are calculated yearly throughout construction and the life of the plant.

Table 4.29A

CASE 1

BASE CASE

YEAR	POPULATION	IMMIGRATION RATE, %	TOTAL JOBS	UNEMPLOYMENT RATE, %	HOUSING REQUIRED	HOUSING PROVIDED	INFRASTRUCTURE REQUIRED $M	INFRASTRUCTURE PROVIDED $M
-4	5040	0.2	1683	4.7	1836	1818	27.8	27.5
-3	5111	1.4	1722	3.7	1858	1827	28.1	24.3
-2	5232	1.0	1745	4.7	1902	1843	28.8	22.6
-1	5333	-0.4	1759	5.8	1939	1873	29.3	21.9
1	5368	-0.8	1774	5.6	1952	1906	29.5	21.6
2	5375	-0.4	1790	4.8	1955	1929	29.6	21.7
3	5406	0.2	1809	4.4	1966	1942	29.7	21.9
4	5472	0.4	1829	4.5	1990	1954	30.1	22.3
5	5551	0.3	1851	4.7	2018	1972	30.5	22.7
6	5622	0.1	1873	4.8	2044	1995	30.9	23.2
7	5684	0.1	1894	4.8	2067	2020	31.3	23.6
8	5743	0	1916	4.7	2089	2043	31.6	24.1
9	5808	0.2	1938	4.7	2112	2066	31.9	24.6
10	5876	0.2	1960	4.7	2137	2089	32.3	25.1
11	5945	0.1	1982	4.7	2152	2113	32.7	25.6
12	6011	0.1	2004	4.8	2185	2137	33.1	26.0
13	6076	0.1	2026	4.8	2210	2162	33.4	26.4
14	6141	0.1	2047	4.8	2233	2186	33.8	26.8
15	6207	0.1	2069	4.8	2257	2209	34.1	27.2
16	6273	0.1	2091	4.8	2281	2233	34.5	27.6
17	6339	0	2112	4.8	2305	2257	34.9	28.0
18	6405	0	2134	4.8	2329	2281	35.2	28.3
19	6470	0	2156	4.8	2353	2305	35.6	28.6
20	6536	0	2178	4.8	2377	2329	36.0	29.0
21	6602	0	2200	4.8	2401	2353	36.3	29.3
22	6669	0	2222	4.8	2425	2377	36.7	29.6
23	6735	0	2244	4.8	2440	2401	37.0	29.9
24	6802	0	2266	4.8	2484	2425	37.4	30.2
25	6870	0	2288	4.8	2498	2449	37.8	30.4

Table 4.29B

CASE 2

PLANT

YEAR	POPULATION	IMMIGRATION RATE, %	TOTAL JOBS	UNEMPLOYMENT RATE, %	HOUSING REQUIRED	HOUSING PROVIDED	INFRASTRUCTURE REQUIRED $M	INFRASTRUCTURE PROVIDED $M
-4	5,050	10.0	1903	-12.2	1836	1818	27.8	27.5
-3	6161	15.0	3164	-46.8	2240	1827	33.9	24.3
-2	8,980	17.5	6297	-68.5	3265	2034	49.4	22.6
-1	13,830	18.8	5810	-20.1	5028	2650	76.1	22.1
1	16,250	-0.6	4593	19.2	5909	3839	89.4	22.7
2	13,090	-10.3	4207	13.4	5049	4874	76.4	30.0
3	11,650	-15.2	3919	8.8	4236	4962	64.1	39.2
4	8,761	2.4	3624	-18.2	3106	4925	48.2	47.5
5	9,130	11.2	3661	-14.6	3320	4838	50.2	47.7
6	10,200	15.6	3743	-4.8	3710	4762	56.1	48.5
7	11,730	6.1	3864	5.9	4266	4710	64.5	51.1
8	12,470	6.9	3937	9.8	4536	4688	68.6	55.5
9	11,790	3.9	3921	4.9	4286	4680	64.8	58.2
10	11,420	1.9	3921	1.9	4152	4660	62.8	57.8
11	11,760	1.6	3946	4.1	4275	4635	64.7	57.0
12	12,050	-0.4	3973	5.8	4382	4717	66.3	57.5
13	12,130	-1.3	3999	5.8	4410	4605	66.7	57.6
14	12,090	-0.9	4021	5.0	4396	4595	66.5	58.3
15	12,100	-0.2	4044	4.5	4401	4585	66.6	59.2
16	12,200	0	4067	4.8	4437	4576	67.1	59.9
17	12,320	-0.3	4090	5.1	4480	4569	67.8	60.3
18	12,405	-0.6	4111	5.3	4509	4565	68.2	60.5
19	12,460	-0.6	4132	5.2	4527	4562	60.5	60.8
20	12,490	-0.5	4152	5.0	4543	4560	68.7	61.0
21	12,560	-0.4	4174	5.0	4566	4559	69.1	61.3
22	12,630	-0.4	4195	5.1	4592	4563	69.5	61.6
23	12,700	-0.5	4218	5.1	4619	4577	69.9	61.8
24	12,770	-0.5	4240	5.1	4643	4598	70.2	62.1
25	12,830	-0.5	4263	5.1	4667	4621	70.6	62.5

Table 4.29C

CASE 4

PLANT, HOUSING, OUTFRONT MONEY

YEAR	POPULATION	IMMIGRATION RATE, %	TOTAL JOBS	UNEMPLOYMENT RATE, %	HOUSING REQUIRED	HOUSING PROVIDED	INFRASTRUCTURE REQUIRED $M	INFRASTRUCTURE PROVIDED $M
-4	5,050	10.0	2072	-17.2	1836	1858	27.8	27.5
-3	5,161	15.0	3250	-50.7	2240	2317	33.9	27.6
-2	8,980	17.5	5442	-73.2	3265	3813	49.4	29.7
-1	13,830	18.8	6035	-25.7	5028	4285	76.1	36.3
1	16,250	-0.6	5010	11.9	5909	4657	89.4	49.5
2	13,890	-3.1	4523	6.9	5049	5283	76.4	55.3
3	12,830	-11.5	4005	10.8	4664	5271	70.6	54.5
4	10,450	4.2	3930	-9.4	3801	5241	57.5	55.6
5	11,100	12.1	3970	-2.4	4037	5169	61.1	56.2
6	12,480	1.9	4034	7.6	4538	5112	68.6	57.0
7	12,820	-8.6	4065	9.4	4660	5034	70.5	55.7
8	11,870	-1.8	4055	2.4	4315	5062	65.3	56.0
9	11,760	5.9	4073	1.0	4276	5025	64.7	57.4
10	12,570	1.3	4120	6.4	4571	4938	69.1	58.1
11	12,850	-3.3	4152	7.7	4673	4957	70.7	58.1
12	12,560	-2.1	4166	5.2	4568	4952	69.1	58.7
13	12,460	0	4183	3.7	4516	4933	68.3	59.8
14	12,440	0.6	4205	4.3	4563	4912	69.0	60.5
15	12,740	-0.1	4227	5.3	4636	4895	70.1	60.6
16	12,860	-0.9	4240	5.6	4677	4892	70.7	60.6
17	12,880	-0.9	4267	5.3	4683	4871	70.8	60.7
18	12,890	-0.6	4286	5.0	4686	4852	70.9	60.9
19	12,940	-0.3	4306	4.9	4705	4853	71.2	61.3
20	13,020	-0.4	4328	5.0	4736	4846	71.6	61.5
21	13,110	-0.5	4350	5.2	4766	4840	72.1	61.7
22	13,170	-0.6	4372	5.2	4790	4836	72.5	62.0
23	13,230	-0.5	4394	5.1	4810	4834	72.8	62.3
24	13,290	-0.5	4416	5.1	4833	4833	73.1	62.6
25	13,360	-0.5	4439	5.1	4858	4833	73.5	62.9

4.1.4 COAL MINE MODEL

The coal mine model keeps track of the coal that must be provided for the plant, the number of lives lost mining the coal, and the disruption of the land resulting from mining and plant operation. The amount of coal mined is calculated directly based on the thermal efficiency and stream factor of the plant. The coal mining deaths are proportional to the tons of coal mined.

The land utilized by the plant and mine falls into two categories: First, permanent facilities are erected on land; that is, land is utilized throughout the project life by plant and mine permanent facilities. The second contributing factor to land disruption is the mine. Two years before the plant start-up, pre-stripping operations begin in the mine. Coal is mined throughout the life of the plant. It takes three years, after mining, to restore the land to approximately its original state. Thus, at any time during the plant operation, four years worth of mining acreage is disrupted. The model accounts for land disrupted by mining over time, including start-up of mining and the reclaiming that takes place after the plant shuts down. The model also keeps track of the amount of land that has been reclaimed at any time.

MINE OUTCOMES

The outcomes from the mine model are the number of deaths related to coal mining and the amount of land disrupted each year after initiation of plant construction. The air and water pollutants associated with the mine are included in the plant emissions.

4.1.5 WATER SUPPLY MODEL

Under some conditions, extensive gasification facilities might utilize a significant fraction of the water available in a given region. This would have undesirable impacts both in terms of withdrawing the water from other potential uses and in causing an undesirable aesthetic impact. At present, rather than developing a detailed model of the water supply, we have a simple accounting relationship that keeps track of the total amount of water used by the gasification plant and mine. If the magnitude of water usage appears to be of critical significance, the model can be elaborated at a later date.

WATER SUPPLY OUTCOMES

The outcome from the water supply model is the yearly amount of water utilized by the plant and mine. Water pollution is accounted for in the plant model.

4.1.6 GOVERNMENT COST MODEL

Although, as we discussed in Section 2.0, the cost to the government can be misleading if it is considered in isolation, it is still an outcome of interest. The government cost model accumulates six categories of cost:

1. Subsidies
2. Construction grants
3. Administrative
4. Transfer payments
5. Lost taxes
6. Defaults

In calculating government costs, we will use the same base case assumptions given in earlier subsections, plus the following three: First, assume that full cost of service pricing is used. Second, assume that the government administration costs are one-half million per year. Third, assume that a Northern Great Plains location is used.

SUBSIDIES

Subsidies are payments from the government to the energy producers to provide financial incentives for development. These payments are currently not anticipated in the coal gasification program, and are not considered further.

CONSTRUCTION GRANTS

Construction grants are monies that the government contributes to the erection of energy producing facilities. This form of incentive is not anticipated in the coal gasification program, and is not considered further.

ADMINISTRATIVE

The administrative cost is \$2.0 million per year during construction, and \$.5 million per year for the 25 operating years of a gasification plant.

TRANSFER PAYMENTS

A coal gasification facility will employ workers in new jobs. These workers can be considered to be drawn from two categories: the unemployed and the employed. Each job in a gasification plant will create approximately one other job in the support services sector. Every job that utilizes a previously unemployed person reduces government transfer payments, such as welfare and unemployment benefits.

The transfer payment area must be approached with caution on two points. First, the jobs will not all reduce unemployment. The economy as a whole will change, as people realign themselves with the economic activity that exists after the coal gasification plant is in operation. Many of the plant jobs will be filled by workers that were previously employed in other jobs, implying that one hundred jobs created at a gasification facility would reduce unemployment by significantly less than one hundred. Second, transfer payments represent money flows from one part of society to another. There is no net benefit associated with an increase or decrease in transfer payments.

What is the maximum magnitude of savings? Assume that a facility employs 1,000 people, creating a total of 2,000 jobs. Assume that all 2,000 jobs are filled by unemployed persons. For the transfer payment savings, use an unemployment payment of about \$75/week. The yearly savings is

$$2{,}000 \text{ people} \times \$75/\text{person-week} \times 52 \text{ weeks/year} = \$7.8\text{M}$$

The discounted present value is

$$\int_{4}^{29} 7.8e^{-rt}dt = \frac{7.8}{r}\, e^{-rt}\Big|_{29}^{4}.$$

At r = .1, the result is \$48M.

For analyzing the difference between bids, it is important to calculate differences between bids in transfer payment savings, and the government bodies that receive the benefits. That is, it is important to understand differences in national benefits, and the regions that receive the benefits.

First consider the differences between bids. Northern Great Plains plant location would be very similar in the absolute value of transfer payments saved, because they will tap approximately the same labor markets. The Four Corners plant locations will likewise have approximately equal savings. However, since unemployment on the Navajo Reservation is high, it is possible that the Four Corners plants may generate more savings than a Northern Great Plains location. Assume that non-native American workers are split: 80% employed, 20% unemployed. Assume that a Northern Great Plains plant employs 10% native Americans, while a Four Corners plant employs 60% native Americans. The number of unemployed workers hired is

Four Corners:

$$.4 \times .2 + .6 \times .6 = 44\%$$

Northern Great Plains:

$$.9 \times .2 + .1 \times .6 = 24\%$$

The difference in benefits saved would be

$$(.44 - .24) \times \$48M = \$9.6M$$

in favor of a Four Corners location. (This assumes that a Navajo receives the same transfer payment as a non-native American.)

There is also a possible regional difference in the distribution of the savings. Assume that all non-native American transfer payments are made by state and local governments, while native Americans are paid by the federal government. The breakdown by source of savings for transfer payments is

	Federal Payments	State Payments
Four Corners	$17.3M	$3.8M
Northern Great Plains	$ 2.9M	$8.6M

LOST TAXES AND DEFAULTS

The last two categories of government costs are lost taxes and default costs. Under deterministic conditions with full cost of service pricing as we have assumed for coal gasification, there are no lost taxes or default costs. The reason there are no default costs is obvious; however, the rationale for the statement that there are no lost taxes requires a little more explanation.

Suppose the capital market is robust enough so that it is essentially what economists call a linear market with respect to the capital investments being made in gasification. This means that the coal gasification venture financing would not affect the cost of capital for the economy. Since the gasification plant would cost approximately $1.1B, spread over a four-year period, and total capital expenditures by private industry fall in the range of $100B per year, the linear market assumption is reasonable. If the rate of return guaranteed to the gasification companies by the regulatory agencies approximates the return in the capital markets, then the investment in gasification plants will have no incremental effects on capital expenditures or returns and hence there will be no lost taxes. Of course, neither of these assumptions will ever hold exactly in practice; however, they appear to be reasonable approximations in the present context.

Notice that this discussion says nothing about the fact that the resources used in a gasification venture may not be optimally utilized. That is, they may produce a higher social product in another application. This effect is reflected in the cost benefit portion of the analysis, and does not change the government tax revenues.

We will assume that there are no lost taxes or default costs under certainty. These costs only occur when we consider uncertainty explicitly; if, for example, the plant fails. Figure 4.26 outlines in general terms the situations under which there might be lost taxes or default costs. To get an idea of the size of potential costs that we might find in the probabilistic analysis, let's discuss each case.

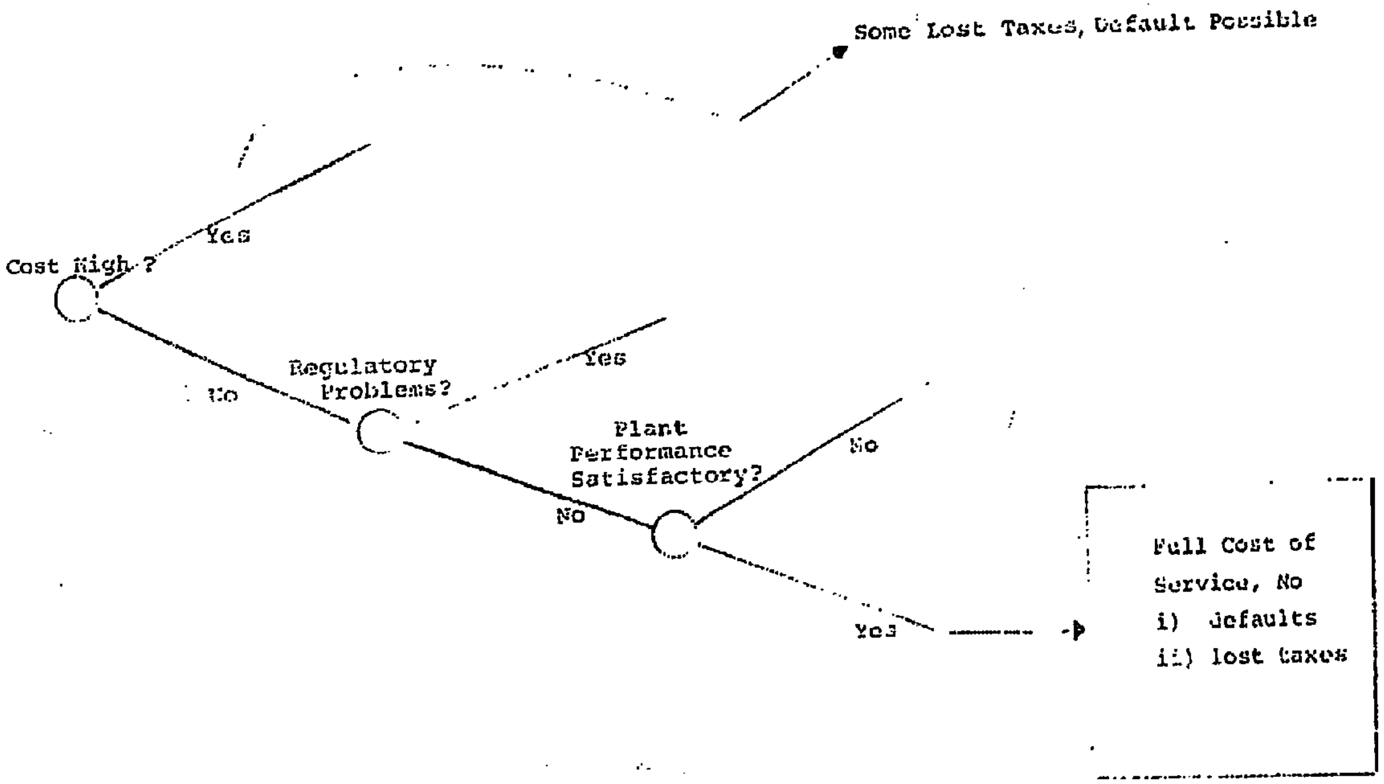

Some Lost Taxes, Default Possible
Cost High ?
Yes
No
Regulatory Problems?
Yes
Plant Performance Satisfactory?
No
No
Yes
Full Cost of Service, No
i) defaults
ii) lost taxes

Figure 4.26

LOST TAXES

If, for some reason, the cost of service method is not used to determine price, a reduced return to debt or equity would result in lower tax revenues. If the after-tax profits decrease, there are less taxes paid by the company. Also, the reduced profit of the company would reduce the stock dividends. These dividends are paid to individuals, who pay tax on them. Thus, the government would find reduced taxes from two sources, the utility and individuals.

Consider the following example. The cost of service is reduced, so that the utility earns 10% on equity instead of 15%. The interest on debt is maintained. The company has a 52% total tax rate. 40% of the after-tax profits are paid out in dividends, to people with an average tax rate of 35%. Table 4.30 shows how the lost taxes are calculated. The profit levels correspond to the profits earned in the base case of the gasification plant. If the substantial reduction of company profits occurs, then government taxes are reduced significantly. If interest is not paid, it is multiplied by the average tax rate of its recipients to calculate the amount of lost tax.

DEFAULT

The loan part of the plant financing is guaranteed by the government; if the venture is a failure, the private sector participants may default on the loans, and the government would have to repay them. Any government cost would be offset by proceeds from operating or selling the facility that it took title to at default. If full cost of service is allowed, then there is no possibility of default, for the consumers are paying all costs of operation of the facility.

If, for some reason, price is not determined by the cost of service, it is necessary to determine if the cash flows would induce the private company to continue plant operation. The company has two options:

i) Default. The remaining equity investment is taken as a loss, and written off against pre-tax income. This reduces taxes, by an amount equal to the equity written off times the company tax rate. Since this figure could be a large amount of money,

CALCULATION OF LOST TAXES

$M

YEAR	FULL PROFIT	LOST PROFIT	LOST COMPANY TAXES	LOST DIVIDENDS	LOST PERSONAL TAXES	TOTAL LOST TAXES
1	48.2	16.1	17.4	6.4	2.2	19.6
2	50.6	16.9	18.2	6.8	2.4	20.6
3-19	52.8	17.6	19.1	7.0	2.5	21.6
20	47.6	15.9	17.3	6.4	2.2	19.5
21	39.9	13.3	14.4	5.3	1.9	16.3
22	32.1	10.7	11.6	4.3	1.5	13.1
23	24.3	8.1	8.8	3.2	1.1	9.9
24	16.4	5.5	5.9	2.2	.8	6.7
25	8.6	2.9	5.1	1.2	.4	5.5

Table 4.30

it is possible that there would not be enough pre-tax income in the year of default to use all of the write-off. Then the tax savings are discounted at the company's cost of capital to arrive at a present value.

ii) Operate. The plant is producing an operating margin. This is the sales revenue, including by-product credits, minus O&M cost and interest on debt. The tax cash flow is the tax rate times the operating margin minus the tax rate times the depreciation. If the depreciation exceeds the operating margin, then the plant is making a tax loss. This would result in a negative tax, indicating a positive cash flow. The third component of yearly cash flow is an outflow to repay the debt on the facility. The yearly cash flow can be computed for all remaining years of the plant life, and discounted to a present value using the company's cost of capital.

The company compares the present values associated with each option, and selects the decision with the highest value. (This assumes that the company does not place a value on the public relations aspects of defaulting on a government loan.) If the default option is chosen, then the government must pay off the outstanding debt.

The government cost would be reduced by the remaining value of the asset that it has taken ownership of. The plant is producing a stream of cash flows equal to the sales revenue minus the O&M cost. (Notice that interest and debt repayment are not considered at this stage of the analysis.) The government could operate the facility, and receive these cash flows. Or, the plant could be sold to private industry. The price would be computed as the discounted value of the cash flow stream to the company. The cash flow stream is made up of the variable cash flow discussed at the beginning of the paragraph, corrected by the tax payments. The private company purchase price would establish an asset on their books, which would be depreciated across the remaining life of the project. The tax would be the variable cash flow times the tax rate minus the depreciation times the tax rate.

RESULTS OF THE BASE CASE

Subsidies and construction grants are not in force for the coal gasification commercialization program. Because the price is determined by the full cost of service, the government will lose no tax revenues, nor have to pay back bond holders on default. The administrative cost is $2M per year during construction, and $.5M during operation of the gasification plant.

The Northern Great Plains location determines the transfer payment savings caused by a coal gasification facility construction and operation. The total labor assumed for a plant in the socioeconomic model is used. For every 1,000 workers, the federal government saves

$$.06 \times 7.8 = \$.47M$$

in transfers to Indians. This figure is multiplied by the workers per year to produce the transfer payment savings by year. Except for the construction years, the federal government has positive flows -- or negative costs -- for every year of a gasification project. However, the magnitude is very small. Table 4.31 contains the yearly costs, where the parentheses represent a negative cost.

4.2.0 LONG RUN EFFECTS

The long run effects of commercializing a Lurgi plant now versus not commercializing now are analyzed on a regional basis over a fifty-year time horizon using the SRI National Energy Model. This section describes how that model is used to answer the following question: If a Lurgi plant is commercialized today, what would be the regional and national economic, environmental, and socioeconomic changes in the energy system over time? A detailed description of the model itself is not available at this time; however, an overview is included in Appendix B. This discussion will first address what capabilities are required of the energy model and then how to use them.

COST TO GOVERNMENT

YEAR	LABOR	TRANSFER PAYMENT COST, $M	ADMINISTRATIVE COST, $M	TOTAL COST $M
-4	300	(.14)	.50	.36
-3	1400	(.66)	.50	(.16)
-2	3400	(1.60)	.50	(1.10)
-1	3700	(1.74)	.50	(1.24)
1	2300	(1.08)	.50	(.58)
2	1900	(.89)	.50	(.39)
3 To 25	1400	(.66)	.50	(.16)

Table 4.31

4.2.1 ENERGY SYSTEM MODEL CAPABILITIES

Consider a single bid, that is, a single proposed Lurgi plant at a given location and time. There are two options available:

1) Accept that particular bid;
2) Reject that particular bid.

We will now develop three potentially important categories of consequences of accepting or rejecting that particular bid — economic, environmental, and socioeconomic. It should be kept in mind that the energy system model we are describing is deterministic; uncertainty will be discussed later.

ECONOMIC EFFECTS

The economic effects of accepting or rejecting a particular bid are manifested in terms of changes in gas prices and hence in terms of changes in usable energy prices.* If the bid is accepted, the gas from the plant will be sold, usually at a high price, in a particular region which we will call the "commercial plant demand region." All other regions, where no gas from the first plant will be sold, will be called the "non-commercial plant demand regions." Suppose we plot the price of gas in the commercial plant demand region over time assuming (a) that the bid is accepted, and (b) that the bid is not accepted. The top plot in Figure 4.27 illustrates what such a plot might look like. If the bid is accepted, that region might expect to pay higher gas prices, particularly in the near term, than if the bid is rejected. However, economic benefits of building the first commercial Lurgi plant are realized in terms of lower gas prices from future Lurgi plants and perhaps future second generation gas plants. If indeed the first plant is built to give experience, the case could be made that the first plant will "slide" the learning curve for synthetic gas forward in time, perhaps even decrease the curve for all time. Figure 4.28 illustrates such a learning curve, which is the same type as those discussed in Section 4.1.1. This curve assumes that the first Lurgi plant simply slides the curve forward in time. Figure 4.28 describes only the capital cost per Mcf of output; similar learning curves msut be considered for many other aspects of the plant as well. The learning curve in Figure 4.28 would imply declining gas

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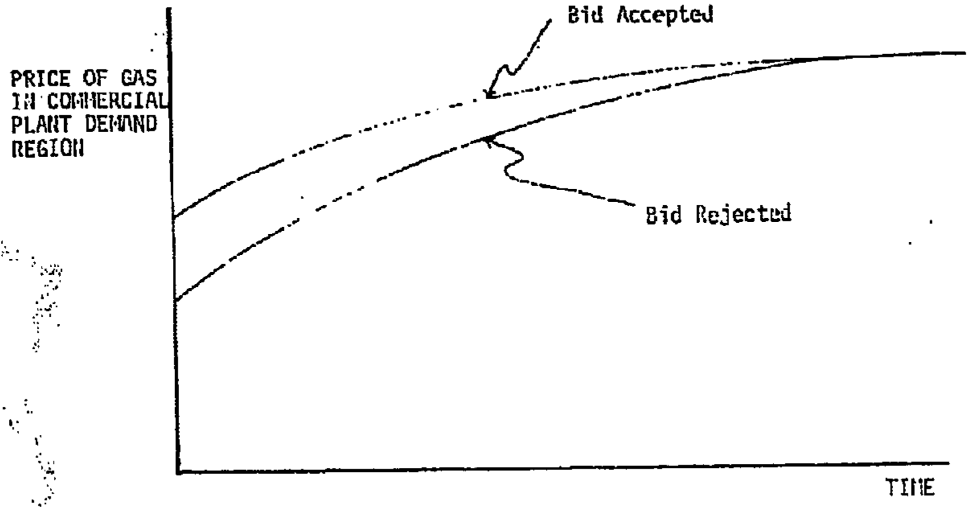
* For the present, we will assume de-regulation of natural gas at the wellhead. Appendix C outlines conceptually how regulation could be incorporated into the SRI National Energy Model if it should be necessary.



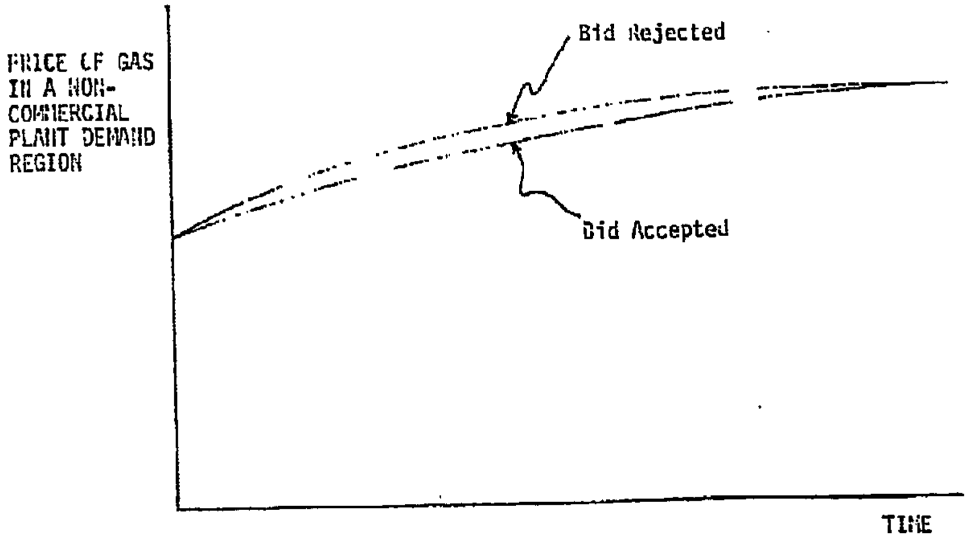
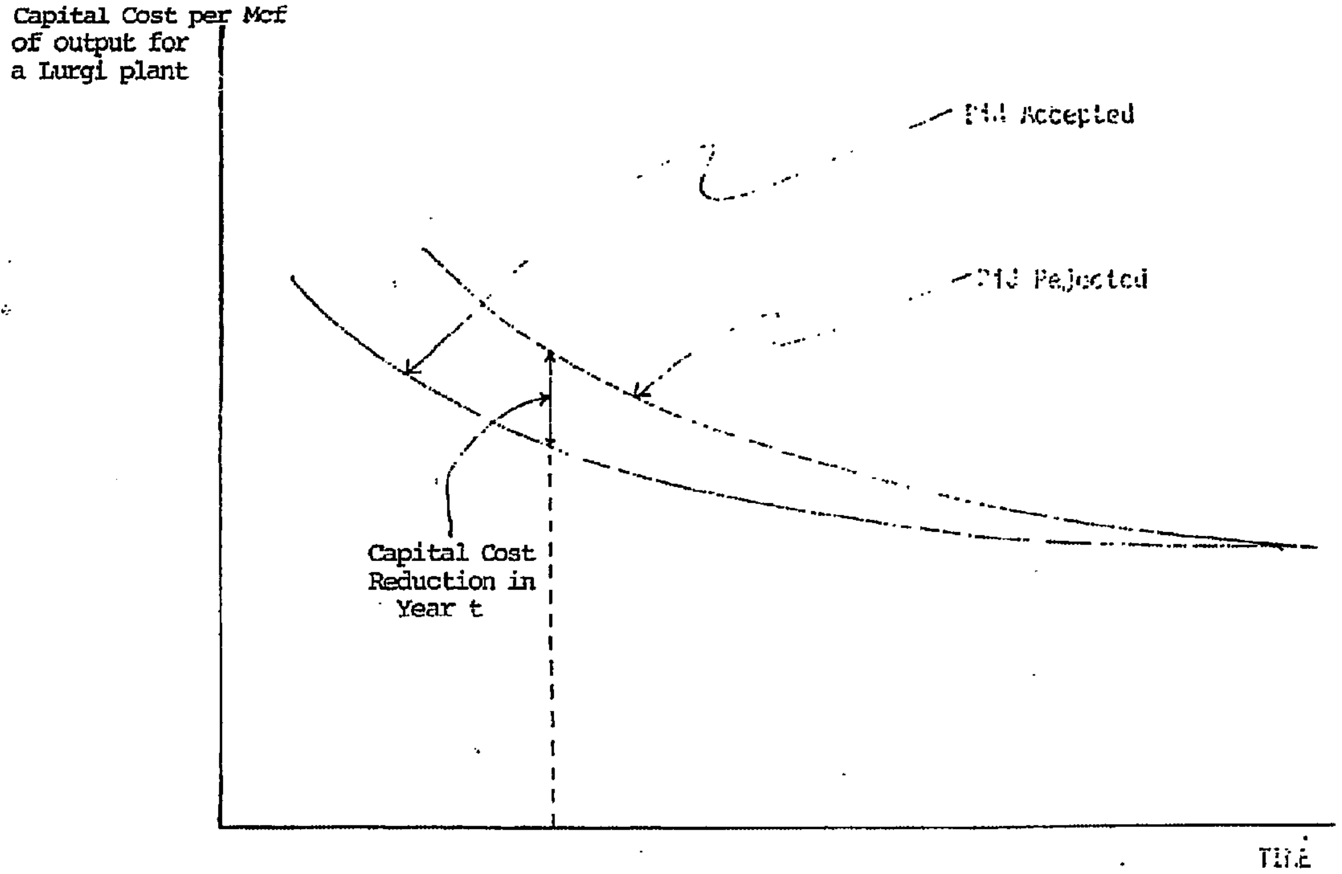


Figure 4.27 Gas Prices



LURGI GAS CAPITAL COST LEARNING CURVE

Figure 4.28

prices from synthetic gas plants over time due to reduced capital cost per Mcf of output. Note that the capital cost reduction in Figure 4.28 ultimately declines to zero if we assume that the first plant simply slides the learning curve forward in time; as the synthetic gas industry becomes mature, the way it was first commercialized becomes less important. Hence, in the commercial plant demand region, the high cost of gas from the first Lurgi plant is borne throughout its life. But the benefits from building subsequent gas plants at lower cost using what was learned from the first plant will begin to accrue in the longer run.

In both the bid acceptance and rejection cases, the actual price of gas in the commercial plant demand region is a complicated function of many factors besides the capital cost pictured in Figure 4.28. Other factors include the natural gas supply, LNG supply, Canadian gas imports, Alaskan gas supply, and gas supply from both Lurgi and second generation synthetic gas plants built outside this loan guarantee program. The price is not only a function of other supply sources, but is also a function of ongoing gas R&D programs. Thus our energy system model must be capable of computing regional gas price information over time in a very complex environment.

Gas price information, however, is not sufficient, for if gas prices increase customers may switch to other energy froms, depending on the economics of those other energy forms relative to gas. The economics of these switchovers must be incorporated. Hence, we must look at the price of <u>usable</u> energy over time in the commercial plant demand region, taking into account the relative prices and conversion costs of <u>all</u> fuels in the region. That is, we must construct the top plot in Figure 4.29 as well as the top plot in Figure 4.27. Because gas is only one of the fuels competing to satisfy the demand for usable energy, the economics of all competing fuels and the economics of switchover to each of the competing fuels must be considered in computing usable energy prices. This means that the synthetic gas commercialization decision interacts with <u>all</u> R&D and commercialization decisions -- nuclear, liquid fuels, enhanced recovery, conservation, and so forth. Hence an extremely detailed national and regional interfuel

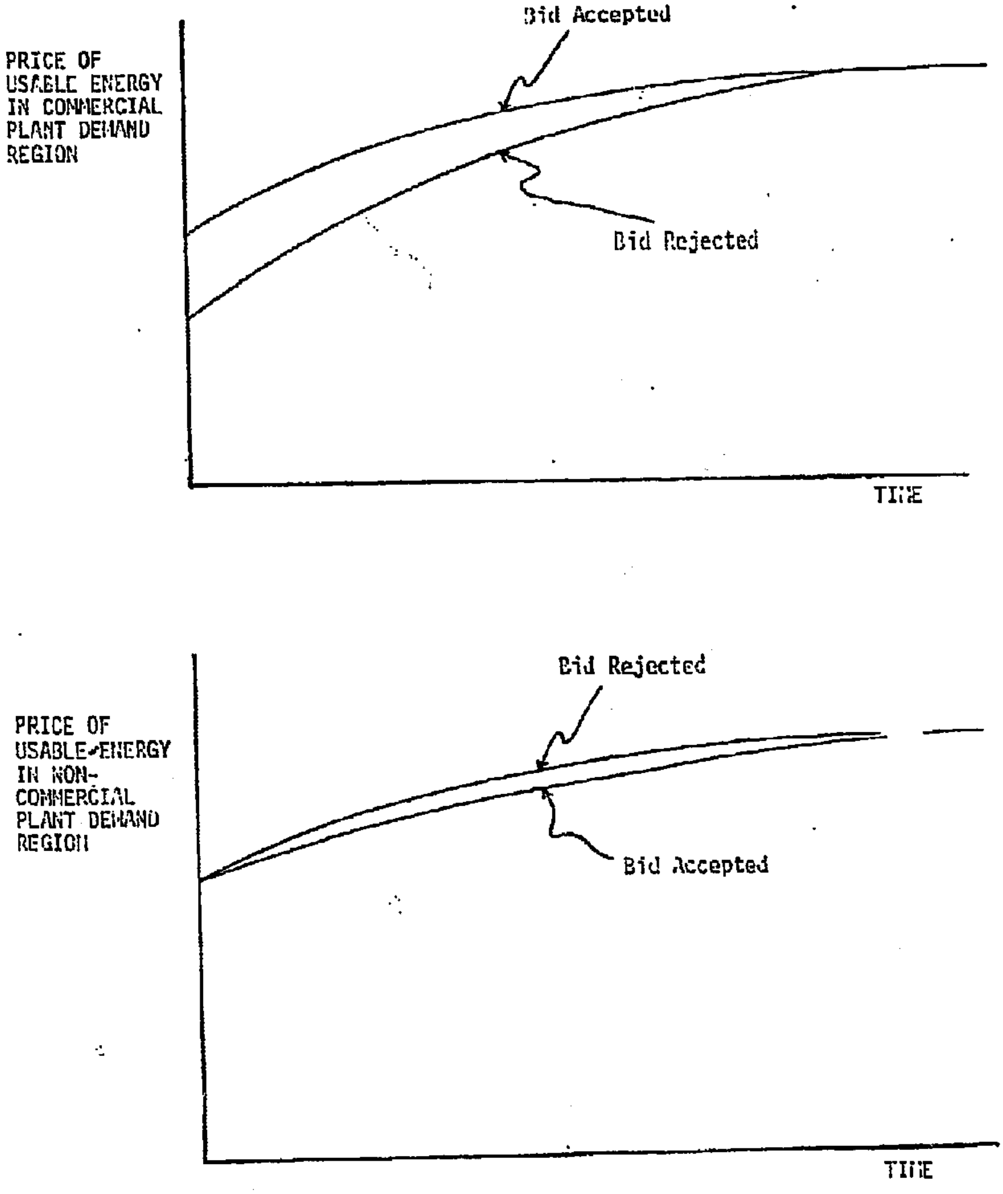

Bid Accepted
PRICE OF USABLE ENERGY IN COMMERCIAL PLANT DEMAND REGION
Bid Rejected
TIME
Bid Rejected
PRICE OF USABLE ENERGY IN NON-COMMERCIAL PLANT DEMAND REGION
Bid Accepted
TIME

Figure 4.29

competition model will be required to obtain the price plots in Figures 4.27 and 4.29.

Just as we did in the commercial plant demand region, we must plot the price of gas over time and the price of usable energy over time in each of the non-commercial demand regions in both the bid acceptance and rejection cases. The bottom plots in Figures 4.27 and 4.29 illustrate the price trajectories in this case. Note in the non-commercial plant demand regions that gas prices are lower if the bid is accepted because they can take advantage of the learning without having to bear the high cost of gas from the first plant. Again, these prices can be influenced by all R&D and commercialization decisions.

The price plots in Figure 4.27 and 4.29 are not sufficient by themselves to calculate economic impacts; the corresponding quantity plots are required. To measure economic impacts we will use the notion of consumers' plus producers' surplus in economic theory. We will proceed through a detailed development of consumers' and producers' surplus and an approximate method for calculating both. We will term the sum of producers' plus consumers' surplus economic surplus.

In the discussion of economic impact, we will focus on the commercial plant demand region. The extension to the non-commercial plant demand regions is straightforward. Referring to the top plot in Figure 4.29, in each year we can think of a single demand curve for usable energy and two supply curves for usable energy, one in the case where the bid is accepted, and one in the case where the bid is rejected. The top plot in Figure 4.30 illustrates the supply/demand situation in a particular year in the commercial plant demand region. The shaded area in that figure represents the dollar loss in that year in the commercial plant demand region as a result of accepting the bid. We will briefly develop the rationale for the assertion that the shaded area represents the economic loss in that region, and then relate it to the better known concepts of producers' and consumers' surplus. We will first discuss the static case (a single year), and then move on to the dynamic case.

ECONOMIC SURPLUS

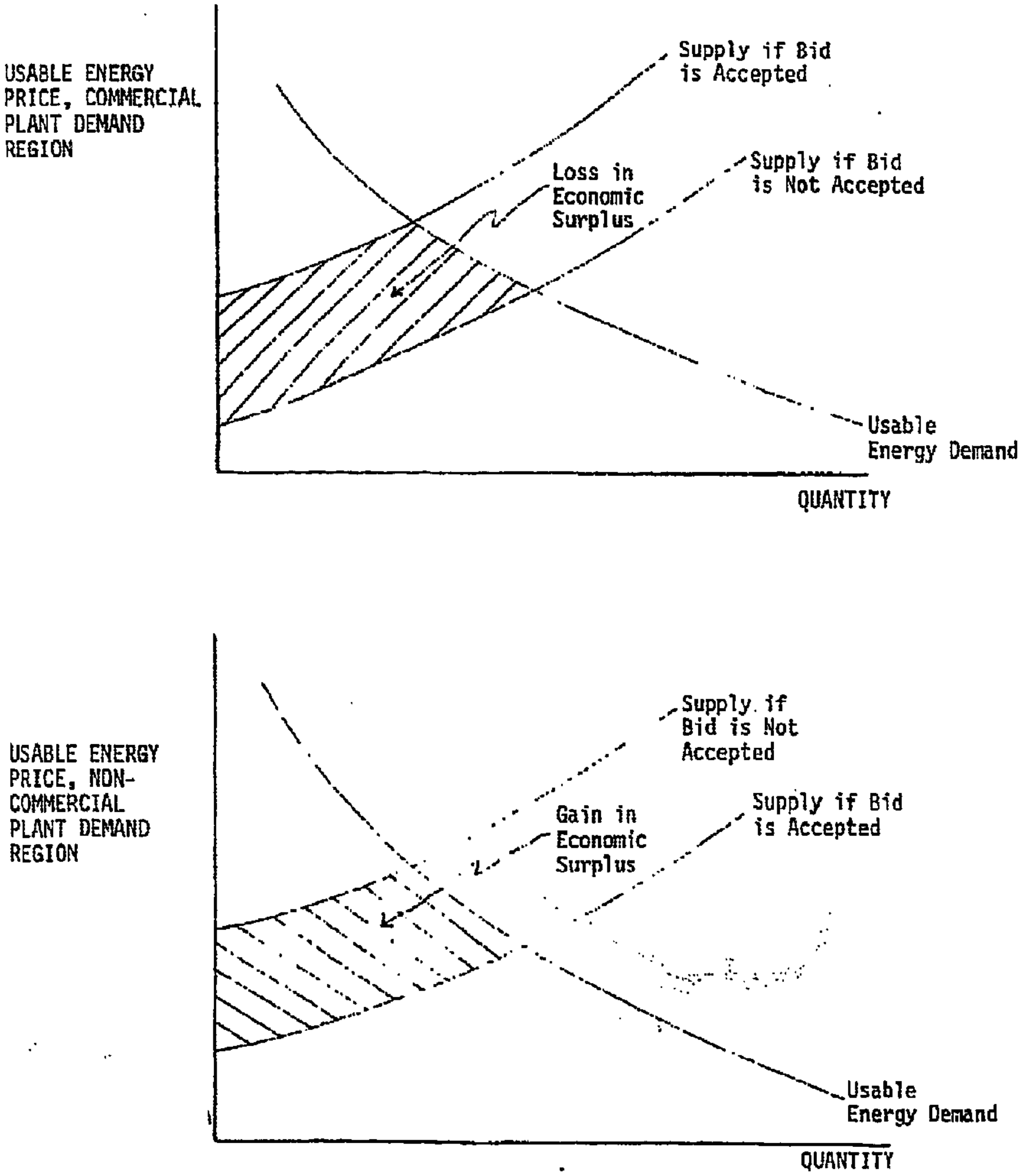


Figure 4.30

STATIC (SINGLE YEAR) ECONOMIC SURPLUS

Assuming the bid is accepted, the supply/demand balance appears as in Figure 4.31. The equilibrium price and quantity in the given year are p* and q* respectively. Suppose we are trying to establish the "value" of the Δq units of energy that lie between q and $q+\Delta q$ in Figure 4.31. The value to the consumer is the price he is willing to pay for the quantity Δq, which is p_D in Figure 4.31. Yet he is asked to pay only p*, leaving him with a surplus benefit of $(p_D-p^*)\Delta q$. The value to the producer is the price he can sell the quantity q for, which is the equilibrium price p*. The cost to produce the quantity Δq is p_S, so the surplus benefit to the producer is $(p^*-p_S)\Delta q$. By adding these consumers' and producers' surplus benefits up for all the energy sold, we have the consumers' surplus -- the area above the equilibrium price p* and below the demand curve -- and the producers' surplus — the area below the equilibrium price and above the supply curve. The sum of the two, the entire shaded area in Figure 4.31, is the economic surplus and represents the total surplus value of the quantity q* of energy sold to all consumers and producers in the economy.

Using the concept of consumers' and producers' surplus, we can now quantify the economic loss in the commercial plant demand region in each year if the bid is accepted. Figure 4.32 illustrates graphically how this is accomplished. The <u>loss</u> in consumers' surplus in going from the bid rejected to the bid accepted case is the sum of Areas A and B. The loss in producers' surplus in going from the bid rejected to the bid accepted case is Area C minus Area A. That is

$$\Delta \text{ Consumers' surplus} = -(A+B)$$
$$\Delta \text{ Producers' surplus} = -(C-A)$$

hence, the change in economic surplus is

$$\Delta \text{ Economic surplus} = -(B+C),$$

which is the area shaded in Figure 4.30. Thus, in the case where the prices in Figure 4.29 are given by the crossing points of supply and demand curves

MOTIVATION FOR ECONOMIC SURPLUS

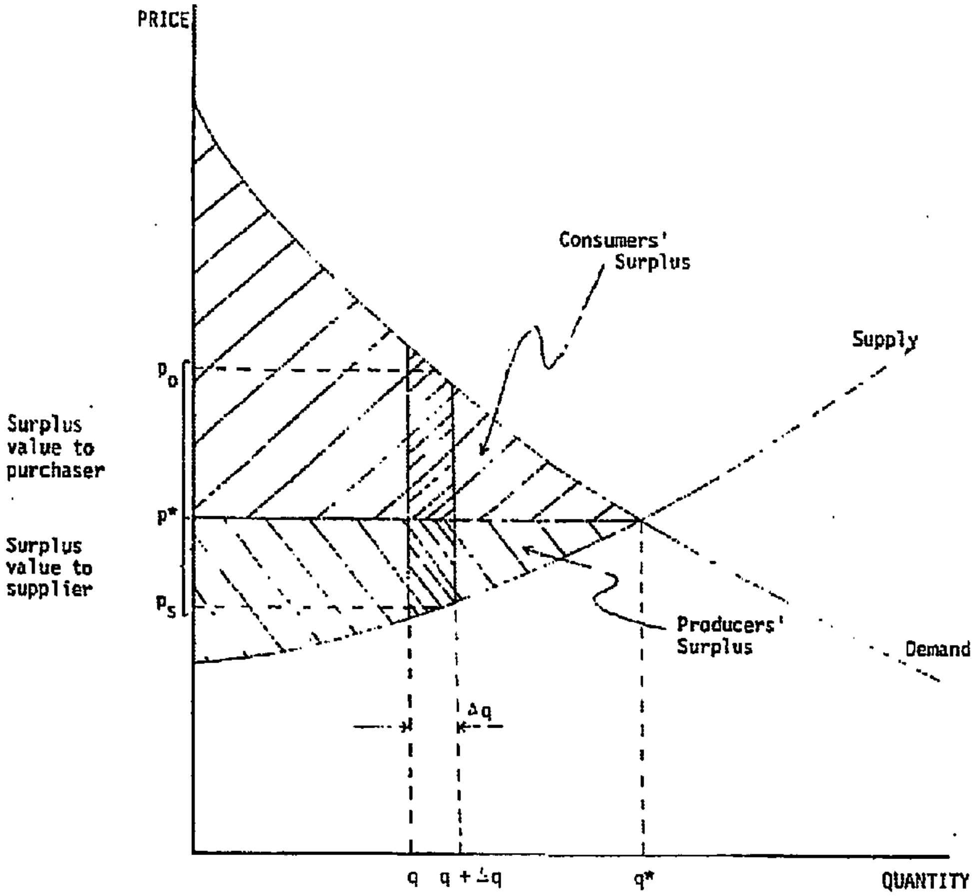


Figure 4.31

CHANGE IN ECONOMIC SURPLUS

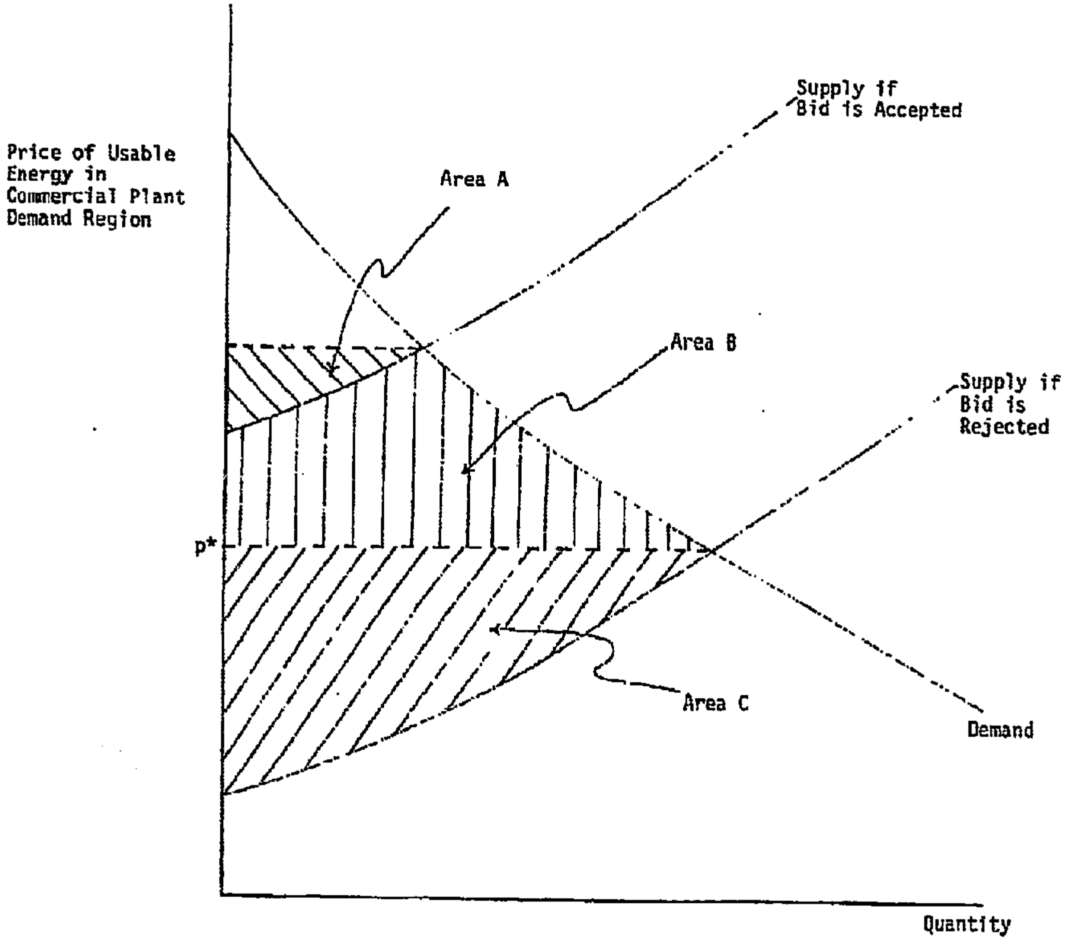


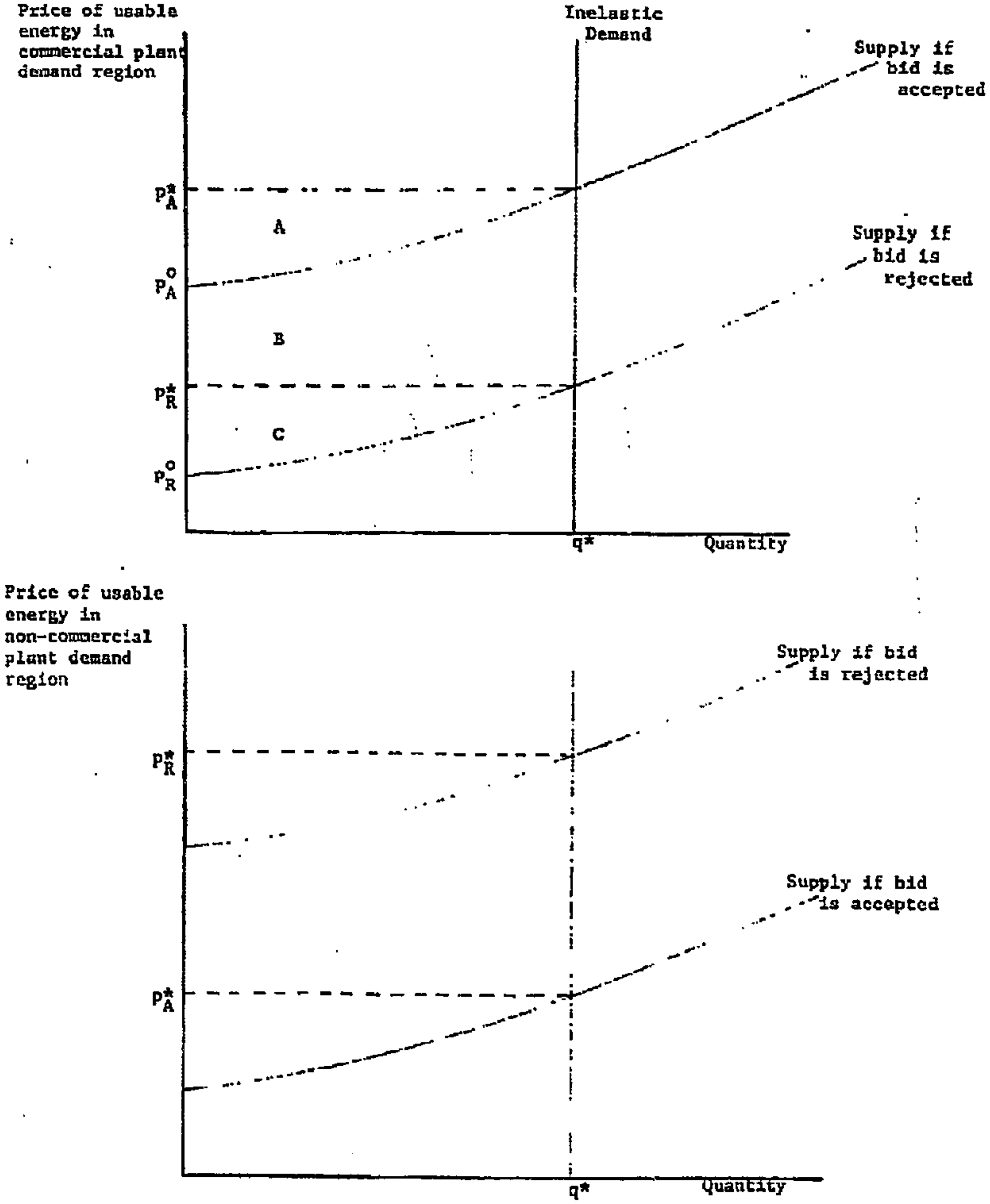
Figure 4.32

in each year, the economic effect of accepting the bid is straightforward. There are, however, several nuances regarding the methodology used in this study that simplify the calculation significantly.

First, suppose the demand for usable energy is inelastic over the price ranges introduced by accepting or rejecting the bid. Even if the level of economic activity remains fixed, the total national energy bill will still be a small fraction of the level of economic activity over this price range. Thus, it makes sense to assume demand for usable energy is inelastic and Figure 4.30 then appears as in Figure 4.33. Note that the change in consumers' surplus is trivial in this case; it is simply the sum of Areas A and B, which is the rectangular region enclosed between the inelastic demand curve and the two equilibrium prices. The change in consumers' surplus is thus simply $(p_A^*-p_R^*)q^*$ in the top plot in Figure 4.33, which is the sum of Areas A and B. Note that the change in consumers' surplus $(p_A^*-p_R^*)q^*$ is simply the change in the usable energy bill in the commercial plant demand region.

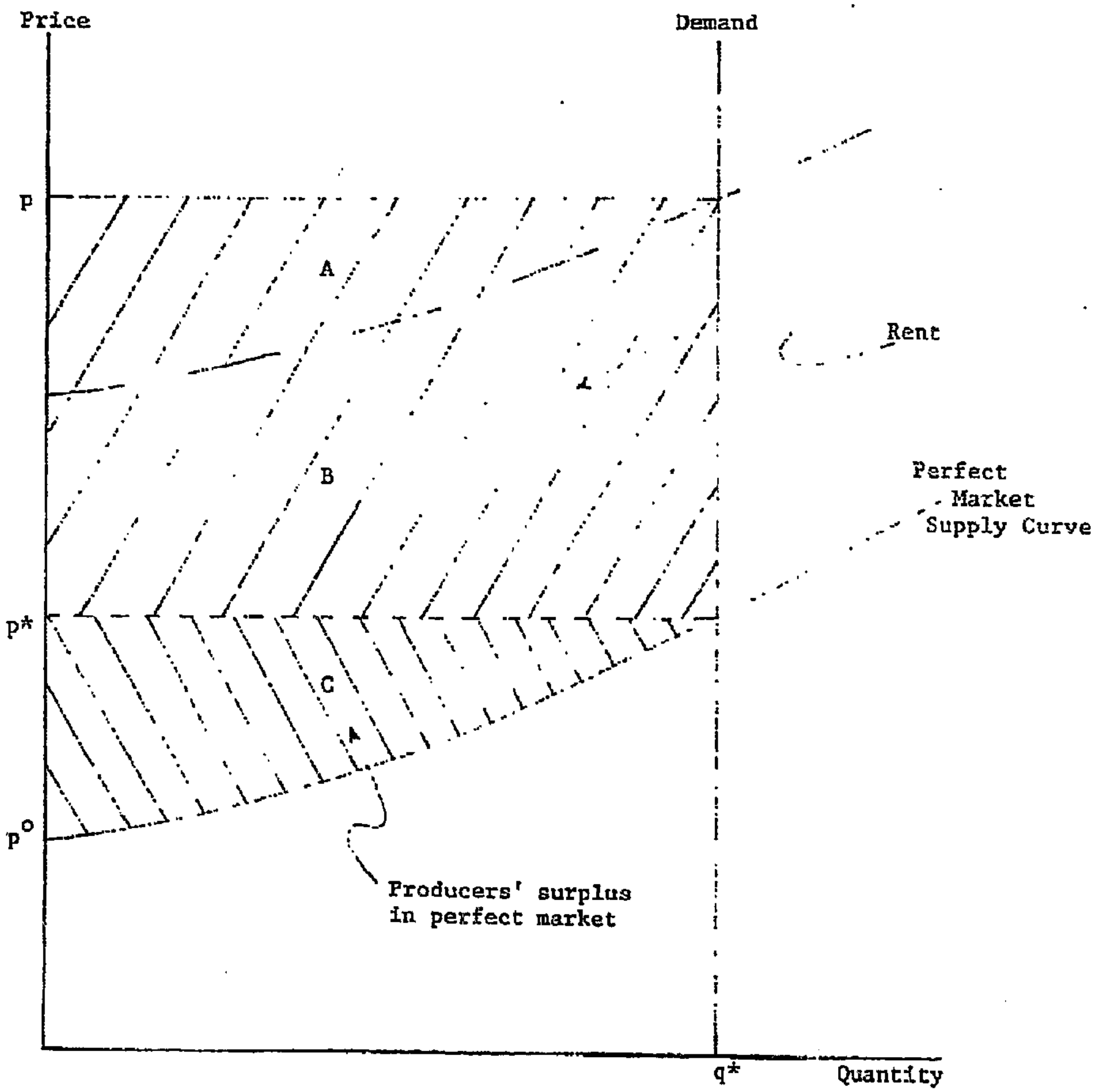
The change in producers' surplus, Area C minus Area A, is not so simple. Producers' surplus arises from two effects: (1) the elasticity of the supply curve, and (2) the ability of the producers to earn economic rent, i.e., to price above marginal cost. We will discuss how both enter into our producers' surplus calculation.

Suppose the supplier of a resource is able to sustain a price p* that is higher than his marginal cost of production mc. This might occur in situations where one supplier dominates the market (monopoly or oligopoly) or where producers withhold production until some future time when higher prices prevail. We can think of such a supplier as being able to "shift" his supply curve up from the marginal cost curve to a higher level as shown in Figure 4.34. The total producers' surplus in this case is the shaded area in the figure. We have broken it down into two components -- economic rant (Areas A+B in Figure 4.34) and producers' surplus in the perfect market (Area C in Figure 4.34). Briefly, economic rent denotes the producers' surplus earned by pricing above the free market price, mc.



INELASTIC DEMAND

Figure 4.33



PRODUCERS' SURPLUS WITH RENT

Figure 4.34

We will now develop an approximate method for calculating both components of producers' surplus -- Areas A and B (rent) and Area C (surplus) in Figure 4.34. Area A+B is trivial; it is simply the area of the rectangle to the left of the inelastic demand curve and between the price p^* and the marginal cost mc. Hence,

$$\text{Rent} = q^*(p^*-mc)$$

To approximate Area C, assume the perfect market supply curve is linear from the point where it crosses the vertical axis at mc_o to the point where it crosses the demand curve at mc. Area C can be approximated by the area of the enclosed triangle in Figure 4.34, which is

$$\text{Perfect Market Producers' Surplus} = 1/2q^*(mc-mc_o)$$

Hence the total producers' surplus in this case is

$$\text{Producers' Surplus} = q^*(p^*-mc) + 1/2q^*(mc-mc_o)$$

Note that if no rent is earned, p^*-mc and the producers' surplus reduces to our approximation to Area C, which is $1/2q^*(mc-mc_o)$.

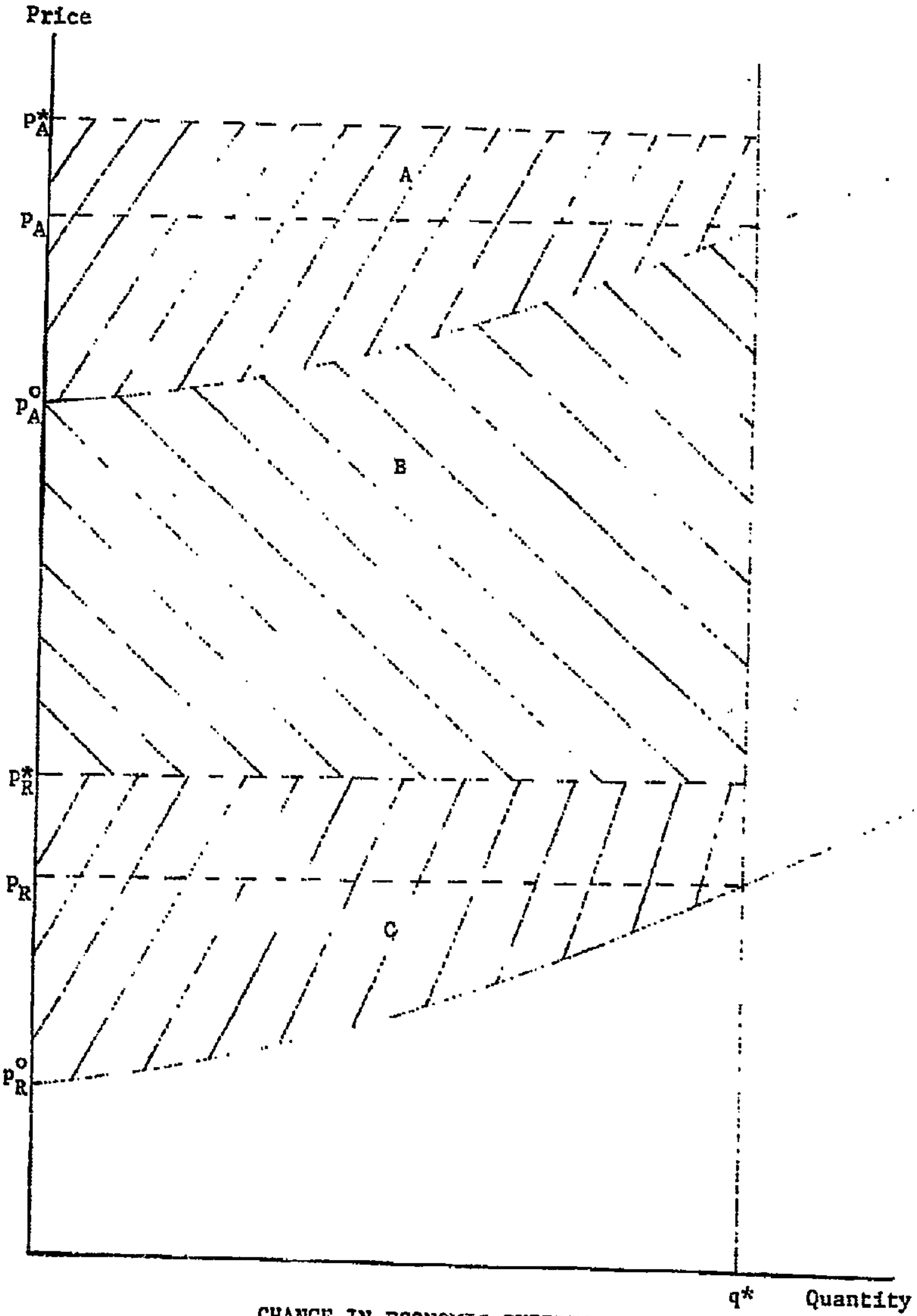
We are now ready to analyze the change in economic surplus in the general case where rents are earned, which is illustrated in Figure 4.35. In the case where we consider bid acceptance relative to bid rejection, the changes in consumers' and producers' surplus are given by the following areas in Figure 4.35:

$$\Delta \text{ Consumers' Surplus} = -(A+B)$$
$$\Delta \text{ Producers' Surplus} = A-C$$

Note that the change in producer's surplus is the difference in rents plus the difference in perfect market producers' surplus. Hence the change in economic surplus is:

$$\Delta \text{ Economic Surplus} = -(B+C)$$

which is <u>exactly</u> the change in economic surplus if rents are omitted from the calculation. Hence, if we calculate the change in economic surplus using the marginal cost curves, we will obtain the correct change in producers' surplus each year.



CHANGE IN ECONOMIC SURPLUS

Figure 4.35

DYNAMIC APPROXIMATION TO ECONOMIC SURPLUS

In this section, we will present a scheme for calculating the net present change in consumers' surplus and the net present change in producers' surplus. The former is a straightforward extension of the static case discussed above, but the latter is significantly more complex. This section is central to our long run economic benefit calculation and should be understood.

The concept of consumers' surplus over time is greatly simplified by assuming that excess demand curves are "separable" over time. This is true of totally inelastic demand curves with totally elastic supply curves. Since the demand curves used in this study are quite inelastic and the supply curves are quite elastic, this assumption appears valid in the long run. Separability over time simply means that the excess demand curve at time t does not depend on the excess demand curves at time t-1 or t+1. Assuming the excess demand curves are separable over time, the supply/demand balance in the commercial plant demand region in year t appears as in Figure 4.36.a. The change in consumers' surplus in year t, ΔCS(t), is the shaded area in that figure. It is approximately

$$\Delta CS(t) = -1/2[q^*_A(t) + q^*_R(t)][p^*_A(t) - p^*_R(t)].$$

This approximation assumes that the demand curve is linear between the two crossing points. The net present consumers' surplus in 1975 is thus

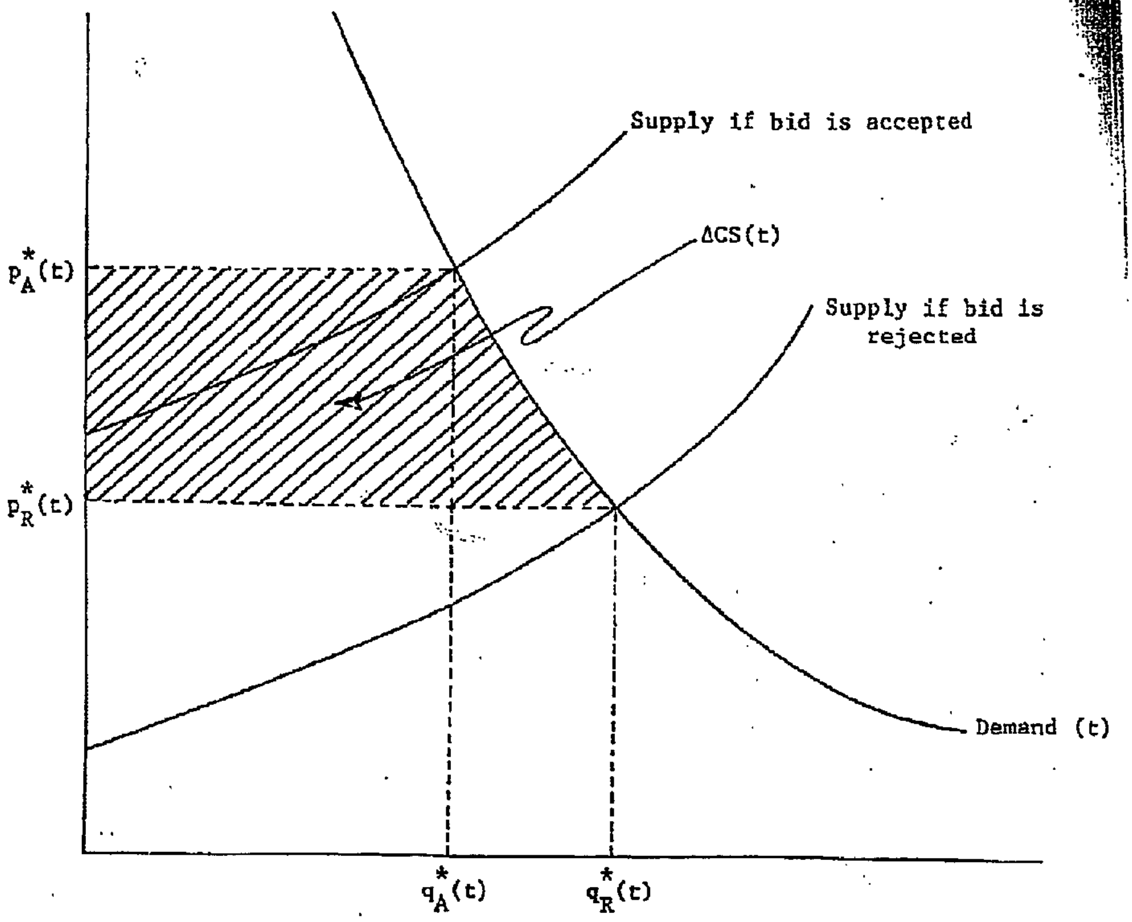
$$\text{Net present change in consumer's surplus} = \sum_{t=1975}^{\infty} \Delta CS(t) \cdot \left(\frac{1}{1+r}\right)^{t-1975}$$

$$= \sum_{t=1975}^{\infty} -1/2[q^*_A(t) + q^*_R(t)][p^*_A - p^*_R(t)]\left(\frac{1}{1+r}\right)^{t-1975}$$

where r is the "social" time preference rate.

CHANGE IN CONSUMERS' SURPLUS IN YEAR t

FIGURE 4.36.a



Note that if demand is inelastic, i.e.

$$q_A^*(t) = q_R^*(t),$$

the net present change in consumers' surplus reduces to

$$\sum_{t=1975}^{\infty} q^*(t)[p_A^*(t) - p_R^*(t)]\left(\frac{1}{1+r}\right)^{t-1975},$$

which is the net present change in the usable energy bill. In this study, we have used the more robust representation in the first equation above. In the next section, where our actual scenario is analyzed, we will illustrate the use of the first equation.

In order to understand the concept of producers' surplus over time, it is necessary to understand the dynamics of primary resource production. Whether we are considering a natural gas well, a crude oil well, a coal mine, a shale mine, or a uranium enrichment facility, the decision to produce a primary resource is an inherently dynamic decision. The owner of any resource always has the alternative of withholding production of that resource in anticipation of higher prices in the future. If, by so doing, the owner of that resource makes more money than he would by producing now, a producers' surplus accrues to him. The concept of producers' surplus, as we saw above in the static case, is related to the idea that the producer of the resource can receive a price in excess of his marginal cost of production including a nominal rate of return.

The dynamics of resource production are further compounded by the fact that the decision to produce one unit of the resource today involves installing one unit of production capacity that lasts for, say, thirty years. In other words, the decision to open a coal mine today is in effect a decision to produce coal from that mine for thirty years. Expressed differently, the decision to install a unit of capacity today is a decision to <u>commit</u> to a level of production from that unit of capacity over its entire life. Arising from this notion is the concept of "proved reserves" which simply takes into account the fact that, say, the gas industry can produce additional gas from the wells already in service without adding new capacity. The idea of producers' surplus arises in part because the price of gas changes across the commited life of each gas well. Suppose a natural gas well opens today at a marginal cost of 70¢ per Mcf. One might assume that production of gas from that well would cost no more than 70¢ per Mcf across the entire life of that well. Yet, if we project natural gas prices in the future, the wellhead price of natural gas will likely rise from today's 70¢ per Mcf to prices on the order of $1, $2, or even $3 per Mcf at the wellhead.* Hence, the owner of the natural gas well who can produce natural gas at 70¢ per Mcf will be able to sell that gas at the market price of $1 to $3 per Mcf and earn a producers' surplus -- an economic rent.

We shall now develop a methodology for quantifying the producers' surplus from a primary resource production process. To begin with, let us denote:

$p(t)$ = wellhead price of natural gas over the next fifty years;

$mc(t)$ = marginal cost of the new natural gas well at time t;

BL = book life of natural gas well (assume for simplicity that the natural gas well produces uniformly across its book life).

Let us assume that a new natural gas well is brought into production at time T. The marginal cost of production of gas from that well is mc(T), and the wellhead price of gas in that year is p(T). Hence, the producers' surplus or economic rent earned in year T is simply

$$p(T) - mc(T)$$

But recall that the natural gas well which began production at time T will still be producing at T+1. The price of natural gas at time T+1 is now p(T+1) while the marginal cost of production remains fixed at mc(T). Hence, for the gas well which originally began production at time T, a rent accrues at time T+1. The rent that accrues at time T+1 is

$$p(T+1) - mc(T)$$

---

* We will ignore inflation in this discussion.

Continuing this logic, the rent that accrues k years after the gas well is open is

$$p(T+k) - mc(T) \,,$$
$$k = 0, \ldots, BL - 1$$

It is interesting to note that if the price is some future year p(T+k) falls below the marginal cost of the gas well mc(T), the rent is actually negative. In this situation, the owner of the gas well is actually facing prices lower than his marginal cost as the well nears the latter stages of its life. A situation in which this might occur is one in which synthetic natural gas becomes significantly cheaper over time due to technological change. In the early years of the SNG industry, the new natural gas wells will be just competitive with SNG. However, as time progresses and SNG becomes cheaper, those gas wells which still operate will face prices that are lower than their marginal costs and the owners of those wells lose rent. Of course, if the price p(T+k) is always increasing and is always above the marginal cost of production, then the rent is always positive.

To develop a relationship to calculate the economic rent that accrues at a given time, we must look at the pattern of additions of gas well capacity. Denote

n(T) = new natural gas well capacity brought into production at time T.

The total economic rent or producers' surplus earned at time T+k from all natural gas well capacity brought on stream at time T can thus be expressed

$$n(T)[p(T+k) - mc(T)]$$

In order to determine the total rent that accrues at time t, one must collect the terms in the above equation for which t = T+k. Collecting the terms in this fashion, we obtain the following expression for the total economic rent or producers' surplus that accrues at time t:

$$\text{producers' surplus } (t) = n(t-k)[p(t) - mc(t-k)]$$
$$k = 0, \ldots, BL-1$$

Note that the producers' surplus that accrues in year t depends both on the history of capacity additions that leads to the production level at time t as well as the marginal cost of gas from each of those capacity additions. Equation (2) is best illustrated in terms of Figure 4.36.b. The figure shows how the producers' surplus at time t is calculated for a well that is k years old.

In order to calculate the change in producers' surplus, we calculate the total producers' surplus in the bid acceptance case $PS_A(t)$ and the total producers' surplus in the bid rejected case $PS_R(t)$, and subtract:

$$\Delta PS(t) = PS_A(t) - PS_R(t).$$

Thus the net present change in the producers' surplus is

$$\text{Net present change in producers' surplus} = \sum_{t=1975}^{\infty} [PS_A(t) - PS_R(t)] \left(\frac{1}{1+r}\right)^{t-1975} \qquad (3)$$

These concepts will be illustrated shortly when we outline the long run economic evaluation of a hypothetical bid.

It is important to note that if supply curves are very elastic, the price and marginal cost curves will be close together in Figure 4.36.b and the net present producers' surplus will be zero.

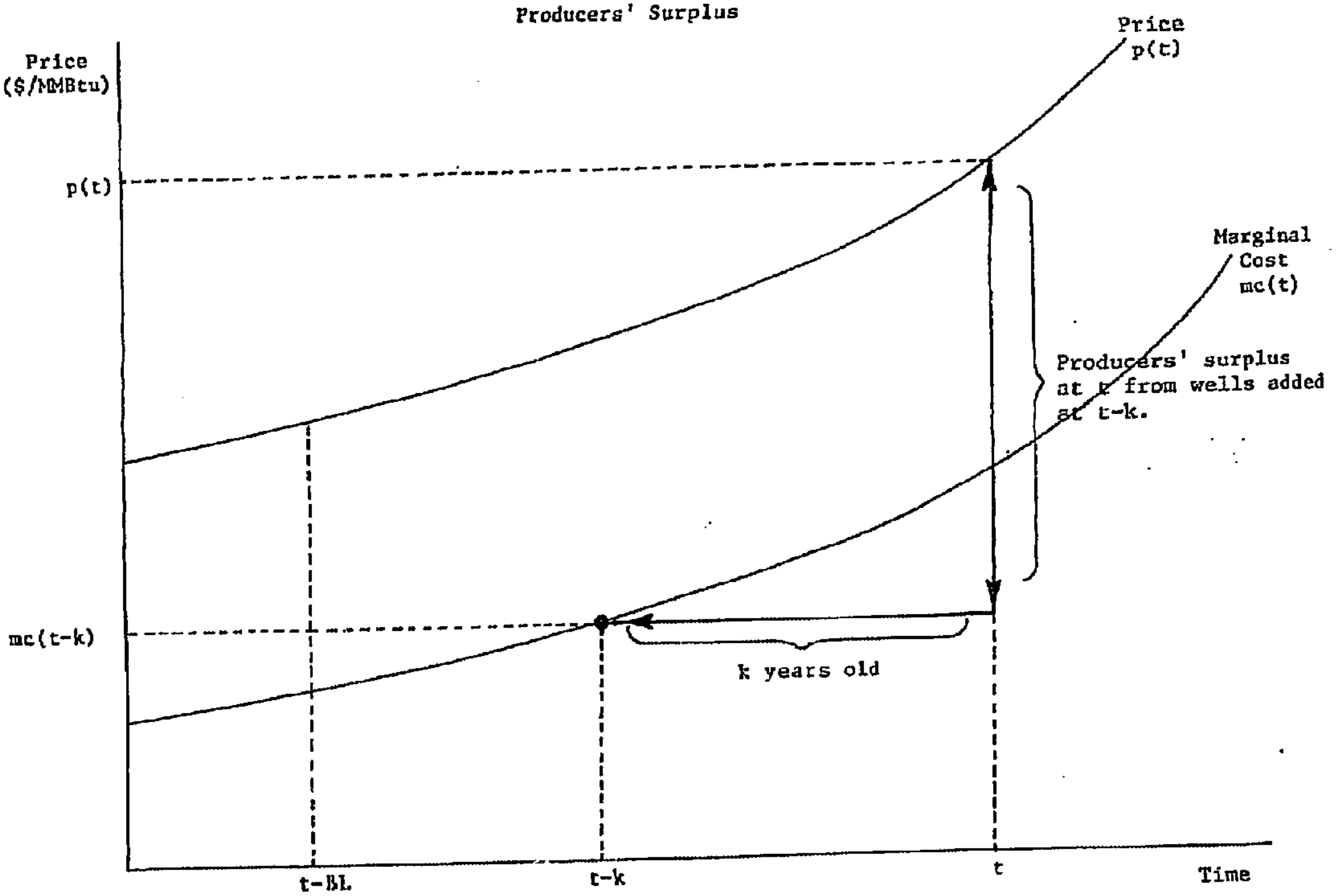
Appendix D of this report gives a brief description of how the price curve and marginal cost curve in Figure 4.36.b are calculated for each primary resource by the SRI National Energy Model.

BASE CASE RESULTS - ECONOMIC EFFECTS

The economic consequences of a synthetic fuels commercialization program have been broken into the two components discussed above. The first Lurgi plant produces gas that will be consumed by customers in the commercial plant demand region. To the extent that this gas is more expensive than competing gas, these customers will suffer a loss in economic surplus. This determines the economic cost of the first plant. However, a commercialization program may accelerate the availability of technologies

FIGURE 4.36.b

Producers' Surplus



based on gasification. This has the potential of reducing energy prices to consumers in all demand regions, resulting in an increase in consumers' surplus. The gas producers, however, will lose producers' surplus as prices are decreased.

COST OF FIRST LURGI PLANT (SHORT RUN ECONOMIC EFFECTS)

Our base case assumes that the plant is located in the Powder River Basin and that the gas is pipelined one thousand miles for consumption in the Chicago-Detroit area. We assume that the gas from the plant begins to flow in 1983. This first Lurgi plant will deliver a small amount of gas relative to the total quantity of gas consumed in the East North Central demand region (Chicago-Detroit). For example, the SRI National Energy Model projects about 4.9 quads of gas consumption in 1986 in the East North Central region while each Lurgi plant delivers only about 0.08 quads. Thus the change in the average price of gas in the demand region as a result of having the Lurgi plant is small, even if Lurgi gas is twice or three time as costly as natural gas. Because the average price of gas changes little, and because gas supply is relatively elastic, we would expect the change in producers' surplus to be unaffected by the introduction of one Lurgi plant. We have assumed it to be zero in our calculation of the first plant cost. On the other hand, for small changes in gas price, we might expect a small change in gas demand. Therefore, we have assumed that gas demand is inelastic over the small price changes introduced by the first Lurgi plant and therefore that the change in consumers' surplus is simply the change in average gas price with and without the Lurgi plant times the total quantity of gas delivered. It can be easily shown that this is merely the price of delivered Lurgi gas minus the price of alternative gas times the quantity of Lurgi gas delivered. We will illustrate the consumers' surplus calculation in detail below.

The essential elements of the surplus calculation for the first plant are thus:

1) The price over time of delivered Lurgi gas from the first plant in the demand region;
2) The quantity over time of delivered Lurgi gas from the first plant in the demand region;
3) The price over time of alternative sources of gas in the demand region.

We will discuss how each of these three quantities are obtained and then show how they are used to calculate the base case economic impact.

To begin the calculation of the economic cost of the first Lurgi plant, we return to the financial model discussed above. The plant gate gas prices and quantities from a Lurgi plant in the Powder River Basin were calculated in an elaborate financial model and a plant model, and were listed in Table 4.24 and plotted in Figure 4.14. Because this gas must be transported 1000 miles in a gas pipeline, the price of gas delivered in Chicago or Detroit is higher and the quantity delivered is lower than that in the Powder River area. The reasons are that some gas must be consumed in the pipeline and that the capital and operating cost of the pipeline must be recovered. Thus we require a simple model of gas pipeline economics. The gas pipeline model assumes an efficiency of 92% per 1000 miles, an operating cost of $0.06/MMBtu per 1000 miles, and a capital charge of $0.20/MMBtu per 1000 miles. The result of applying this simple pipeline model is illustrated in the right-hand columns of Table 4.32. These prices and quantities are the prices in 1) and the quantities in 2), alluded to above.

Returning to 3) above, we require projection of gas prices over time in the East North Central demand region from all sources -- natural gas, synthetic gas, LNG, Canadian gas, and so forth. This projection is taken from a scenario called the "Early SNG" case computed by the SRI National Energy Model. These prices appear in Table 4.33. It should be recognized that they are the result of an extremely complicated calculation, and are based on a number of assumptions to be described below.

As discussed above, the loss in economic surplus in each year is simply the difference between the price of Lurgi gas and alternative natural gas times the quantity of Lurgi gas consumed. Thus, using Tables 4.32 and 4.33 for the year 1995, the change in surplus is

PRICES AND QUANTITIES OF FIRST LURGI PLANT GAS

	Plant Gate, Powder River Basin		Delivered, East North Central Demand Region	
Year	Price ($/MMBtu)	Quantity (Quads/year)	Price ($/MMBtu)	Quantity (Quads/year)
1983	7.31	.041	8.21	.039
1986	4.07	.082	4.68	.079
1989	3.65	.082	4.23	.079
1992	3.30	.082	3.85	.079
1995	3.02	.082	3.54	.079
1998	2.79	.082	3.29	.079
2001	2.59	.082	3.07	.079
2004	2.32	.082	2.78	.079
2007	2.08	.082	2.53	.079

TABLE 4.32

EAST NORTH CENTRAL DEMAND REGION

High Btu Gas Price

Year	Price, $/MMBtu
1983	2.94
1986	3.17
1989	3.22
1992	3.22
1995	3.21
1998	3.20
2001	3.17
2004	3.12
2007	3.07

TABLE 4.33

(\$3.54/MMBtu - \$3.21/MMBtu) x .079 quads/year = \$26 million/year

This calculation has been carried out for each year the first Lurgi plant is assumed to operate and the results are presented in Table 4.34. Note that the price of Lurgi gas is higher than the price of alternative gas in the early years of plant operation, resulting in a loss of consumer surplus. However, in the last few years of plant operation, the rate base has been amortized and eroded by inflation sufficiently to allow the delivered price of gas from the first Lurgi plant to fall below the price of gas existing in the demand region at that time. This results in a gain in consumer surplus, denoted by a negative loss in Table 4.34. The present value of the loss stream in 1977, discounted at ten percent, is \$526 million. This represents the real economic cost of the first Lurgi plant.

SENSITIVITY ANALYSIS

Sensitivity analysis has been performed by varying two different classes of assumptions. First, various operating and financial assumptions are changed. Second, the location of the plant and commercial plant demand region are varied. A plant is considered for Four Corners coal, for which the product gas is transported 500 miles to consumers on the West Coast.

Table 4.35 shows how the loss in consumer surplus changes as a number of operating and financial assumptions are varied for a gas plant delivering gas to the East North Central demand region. The plant gate and delivered prices are shown for each case. These quantities should be compared with those in Table 4.32. In the capital cost + 20% case, we have increased the required capital investment to build the plant by 20 percent, from \$1,100 million to \$1,320 million. In the "higher capital cost" case, we have increased the return on equity from 15% to 18% and the cost of debt from 9% to 11%. In the base case, maintenance cost is assumed to be 2% of the capital cost. The "higher maintenance cost" case considers a higher figure of 8%. The "coal cost +50%" case considers the situation in which the input coal price is \$10.50/ton rather than \$7/ton. Table 4.36 lists similar sensitivity results for the West Coast demand region.

It is significant to note that the loss in economic surplus (the cost of the first Lurgi plant) is approximately the same for the two regions,

LOSS IN CONSUMER SURPLUS DUE TO FIRST LURGI PLANT

Year	Million $/year
1983	206
1986	119
1989	80
1992	50
1995	26
1998	7
2001	- 7
2004	-27
2007	-43

TABLE 4.34

SHORT RUN EFFECTS OF FIRST LURGI PLANT
EAST NORTH CENTRAL DEMAND REGION

Case	Ave. Price ($/MMBtu) Plant	Ave. Price ($/MMBtu) Delivered	Net Present Economic Cost ($M, Demand Region)
BASE	3.18	3.72	526
CAPITAL COST + 20%	3.50	4.06	728
HIGHER COST OF CAPITAL	3.44	4.00	706
HIGHER MAINTENANCE COST	4.01	4.62	936
COAL COST + 50%	3.50	4.06	677

TABLE 4.35

SHORT RUN EFFECTS OF FIRST LURGI PLANT
WEST COAST DEMAND REGION

Case	Ave. Price ($/MMBtu) Plant	Delivered	Net Present Economic Cost ($M, Demand Region)
BASE	3.18	3.45	562
CAPITAL COST + 20%	3.50	3.77	763
HIGHER COST OF CAPITAL	3.44	3.72	742
HIGHER MAINTENANCE COST	4.01	4.31	973
COAL PRICE + 50%	3.50	3.77	763

TABLE 4.36

meaning that the bid selection decision will be made based on small economic differences. It is further significant that the absolute level of economic cost is sensitive to all of the changes listed. This result might indicate that the selection among alternative bids requires the level of detail we have included here.

Table 4.37 presents some additional sensitivity cases. Here, the effects of investment tax credit and surcharge on consumer surplus are shown for the two demand regions. The surcharge method of financing plant construction, although it substantially reduces the exposure of the gas utility, increases the surplus loss somewhat. Passthrough of ITC provides about a $50M benefit to the gas consumers in the commercial plant demand region. These changes are typically of smaller magnitude than the changes discussed in previous sensitivity cases. However, if the gas-consuming population consists of ten million people, the ITC passthrough alone would pay five dollars in benefits in 1977 when the gasification plant receives approval. Nonetheless, even if the gas utility receives tax benefits at the expense of the consumer, the cost of the program is changed less dramatically than in cases where basic gas plant economics are changed.

LONG RUN BENEFITS

In this section, we will illustrate, using hypothetical but reasonable numbers, the calculation of long run national economic benefits. A word of caution is necessary to avoid potential controversy that might surround the implications of these numbers. Because there are no concrete proposals for Lurgi plants, there are no concrete numbers. Therefore, to test our framework and obtain insights to help ERDA write its gasification RFP, we have used numbers that are representative of the numbers given to us by the five announced candidates for Lurgi gas plant loan guarantees. These numbers are neither the official estimates of any of those candidates, the official estimates of ERDA, nor the official estimates of SRI.

The economic estimates used in the SRI National Energy Model are to be regarded as defendable. This is not to state that they are certain, but it is to state that they fall within the range of uncertainty of many

DISCOUNTED LOSS IN CONSUMER SURPLUS, $M

CASE		LOCATION	
ITC PASSTHROUGH	SURCHARGE	EAST NORTH CENTRAL	WEST COAST
NO	NO	526	562
NO	YES	557	593
YES	NO	475	511
YES	YES	506	542

TABLE 4.37

energy economists' estimates. Over the past six months, SRI internal energy experts have undertaken a thorough and exhaustive review of the data base used in the SRI National Energy Model. This data base has been communicated to and reviewed by a number of different organizations, public and commercial (ERDA included). Certainly such a review does not lead to unanimity; however, it allows us to highlight important differences of opinion at a relatively detailed level and to thus identify areas for sensitivity analysis. Because of the scope of this project -- to develop a methodology for discriminating among alternative coal gasification bids -- an exhaustive set of sensitivities was not compiled due to the high cost of running sensitivities in the SRI National Energy Model. What we will do in this section, then, is to illustrate the capability of our framework, along with the SRI National Energy Model, to calculate economic impacts of commercialization and to focus attention on the key variables.

The most compelling reason for not attempting to advocate decisions using these numbers is that all the numbers we will present represent but a single scenario -- a single, self-consistent set of assumptions. Few would disagree that the energy market is highly uncertain. In order to recommend decisions, this uncertainty must be accounted for explicitly and in detail. It is easy to postulate scenarios for high Btu gas that lead to very large long run benefits. A combination of dramatic learning about gasification technology as a result of commercialization, coupled with a very much smaller natural gas resource base than we presently anticipate and coupled with very high prices for imported LNG, would lead to very high benefits from commercial demonstration. Conversely, it is not difficult to construct a case where commercial demonstration pays no benefits. A combination of a large natural gas resource base, relatively cheap imported LNG, and virtually no learning about SNG as a result of this program would lead to such a conclusion. To fully analyze the benefits of commercial demonstration, then, a number of such scenarios would have to be examined in detail and probabilities would have to be attached by estimating probabilities for the various elements of the energy system. In order to address questions such as "Should the nation commercialize a Lurgi plant?" we would have to fully implement the decision tree outlined in Figure 3.2 and find an expected benefit minus cost. Recalling that the charter of this study was to develop a framework to discriminate among a number of Lurgi plant bids, we have not attempted to implement the decision tree.

ENERGY MODEL ASSUMPTIONS AND RESULTS

Before proceeding to the detailed numerical results, it is useful to discuss some of the more important assumptions underlying the energy model runs, the short term model, and how both affect the results. The scenario presented is one in which world energy prices as a whole are relatively high. The SRI National Energy Model assumes that the price of imported LNG and the price of imported crude oil are set jointly with a constant 50¢ per million Btu differential between the two. The numbers we will present below assume that imported crude oil is priced on the order of twelve to twenty dollars a barrel ($2 to $3 per million Btu), and landed and regasified LNG is priced at about $2.50 to $4.00 per million Btu. As we shall see shortly, at these prices imported LNG is not competitive with second generation synthetic gas from coal. Thus, as a result of this assumption, imported LNG is not a major factor in the gas picture for the nation as a whole.

The domestic and North Slope natural gas resource bases are more difficult to document. The SRI National Energy Model requires as input "marginal cost curves" describing the price and availability of natural gas in each of eight natural gas-producing regions. Intuitively, those curves describe how much gas could ultimately be produced for wellhead prices of 50¢/Mcf, $1/Mcf, $3/Mcf, and so forth. The model performs a relatively complicated calculation to superimpose economic rent upon these marginal curves in calculating gas prices. To give some idea of the wellhead prices of natural gas and the quantities assumed available over time at those prices, we have constructed Table 4.38, which contains the wellhead price and the annual production of gas for each of the natural gas-producing regions in the country over the next fifty years. Note that the North Slope makes a significant contribution and production in many of the

Table 4.38

NATURAL GAS WELLHEAD PRICES AND QUANTITIES BY PRODUCING LOCATIONS

Material No. 35 – High Btu Gas

Reg. #	Region	1975 Quad Btu	1975 $/MMBtu	1980 Quad Btu	1980 $/MMBtu	1985 Quad Btu	1985 $/MMBtu	1990 Quad Btu	1990 $/MMBtu	1995 Quad Btu	1995 $/MMBtu	2000 Quad Btu	2000 $/MMBtu	2025 Quad Btu	2025 $/MMBtu
17	Appalachian	0.497	2.09	0.700	2.53	0.699	2.84	0.602	3.08	0.328	3.43	0.317	4.15	0.112	3.97
20	South Alaska	0.0	0.66	0.0	.55	0.149	.82	0.328	0.98	0.878	1.10	1.33	1.19	1.720	1.30
23	Mid-Continent	3.380	1.94	3.120	2.35	2.745	2.57	2.030	2.75	1.257	3.07	8.43	3.45	0.153	3.15
24	Pacific Coast	0.428	1.97	0.733	2.28	6.69	2.47	0.485	2.7[illegible]	0.288	3.09	1.94	3.57	0.030	3.73
25	Atl. Offshore	0.0	2.06	0.231	2.53	0.495	2.795	0.442	3.05	0.627	3.33	0.463	3.55	0.000	3.33
26	West Texas	2.817	1.92	2.427	2.20	2.25	2.53	1.950	2.8[illegible]	1.540	3.26	1.081	3.59	0.224	3.46
27	North Shore	0.0	0.90	0.0	0.27	0.101	1.235	1.70[illegible]	1.[illegible]	2.957	1.38	4.165	1.42	1.049	1.87
28	Rocky Mountain	1.006	1.58	1.877	1.90	2.635	2.075	2.323	2.49	2.430	2.51	2.808	2.45	1.873	2.55
30	Gulf Coast Oil & Gas	10.590	1.80	10.393	2.09	9.818	2.42	7.506	2.805	5.560	3.12	4.467	3.305	0.653	3.37

Lower Forty-eight regions begins to decline in just a few years. It is important to note that these prices and quantities are calculated assuming absolutely no price regulation of any kind. In testing the overall benefits of commercial demonstration of the Lurgi technology under a number of scenarios, it would certainly be necessary to include different assumptions about regulation of gas prices at the wellhead. The methodology has this capability, but we have not developed it fully because gas regulation tends to affect all bids roughly equally. In examining the prices in Table 4.38, it is important to note that the prices are equilibrium prices, set in competition with all other sources of energy, including synthetic gas, imported gas and liquids, domestic liquids, synthetic liquids, electric power, and so forth. Note that these gas prices rise from on the order of $1.75 to $2.00/MMBtu at the wellhead in 1975 to prices on the order of $3.00/MMBtu at the wellhead in 2025. This ultimate price of $3.00 is the price at which the next most attractive source of gas begins to compete. That source, in the base case, is second generation synthetic gas from coal.

One of the other major competitors with synthetic gas is imported LNG. Table 4.39 illustrates the prices and quantities of LNG assumed in the base case model run. Note that these prices are very high and that the quantities are very low, reflecting the base case assumption that LNG is not competitive. In that respect, the base case is favorable to early introduction of synthetic gas.

The energy model measures the competitive position of both first generation (Lurgi) and second generation synthetic gas from coal over time. In Table 4.40, we have listed the prices and quantities of synthetic gas from each of these processes in each of the four coal-producing regions of the country over time. That table gives an interesting insight into the interrelationship between the first and second generation high Btu gas from coal. Note that the production of gas from the Lurgi technology comes on for a space of several years, but then is driven down by the advent of second generation technology. The implication is that the

FIGURE 4.39

IMPORTS OF LNG BY IMPORT LOCATION

Region Numbers	Region	1975 Quad Btu	1980 Quad Btu	1985 Quad Btu	1990 Quad Btu	1995 Quad Btu	2000 Quad Btu	2025 Quad Btu
9	Philadelphia	0.0	0.111	0.337	0.608	0.803	0.660	0.123
10	Gulf Coast Port	0.0	0.0	0.002	0.011	0.090	0.148	0.027
11	West Coast Port	0.0	0.001	0.063	0.068	0.058	0.045	0.005
13	Southeast Port	0.0	0.008	0.059	0.181	1.475	0.560	0.111

FIGURE 4.40

SYNTHETIC GAS PRICES AND QUANTITIES
BY COAL PRODUCING REGIONS - QUADRILLION BTU/YEAR

Region	1985		1990		1995		2000		2025	
	Quad Btu	$/MMBtu	Quad Btu	$/MMBtu	Quad Btu	$/MMBtu	Quad Btu	$/MMBtu	Quad Btu	$/MMBtu
FOUR CORNERS										
Lurgi	-	5.41	-	4.43	-	3.24	-	3.19	-	3.03
2nd Generation	-	4.52	-	4.17	-	2.74	0.057	2.65	1.323	2.55
POWDER RIVER										
Lurgi	-	5.00	-	3.99	-	2.85	0.284	2.98	0.147	2.91
2nd Generation	-	4.14	-	3.61	0.224	2.77	2.342	2.49	17.567	2.31
MIDWEST (Illinois)										
Lurgi	-	5.87	-	4.83	-	3.58	-	3.50	-	3.33
2nd Generation	-	4.66	-	4.16	0.370	2.99	0.834	2.81	5.80	2.63
APPALACHIAN										
Lurgi	-	5.83	-	4.81	-	3.67	-	3.59	-	3.47
2nd Generation	-	4.63	-	4.29	0.168	3.07	0.415	2.88	4.963	2.75

Lurgi technology "fills the gap" between the time at which the wellhead price of natural gas rises to the price of Lurgi gas and the time at which second generation gas becomes available. In the base case, it is a very short time span. Thus, we might suspect that the principal benefits of early commercialization of Lurgi plants do not accrue from reducing long run economics from Lurgi plants per se, but accrue much more from reducing the long run economics of <u>second generation</u> gasification plants. As we discussed above in the description of the plant model, many of the components of Lurgi plants and second generation plants are similar. To the extent that early demonstration of a Lurgi plant reduces the cost of any of these common components, benefits will be received by the second generation technology as well.

At this point, it is important to note that the SRI National Energy Model computes only incremental prices (marginal costs) for every technology in the energy system. In other words, the prices computed for synthetic gas from coal are <u>not</u> rate base or utility-type prices but are marginal costs of new capacity. This raises a significant point regarding the decision-making criterion used by the potential builder of Lurgi plants. While he may make his decision as to whether or not to build a Lurgi plant based on marginal cost, he is forced to price at "average cost," i.e., charge a price determined by the rate base formula. Therefore, although the model makes a credible technology selection decision, the prices it computes for synthetic gas are slightly lower in the near term and slightly higher in the long term. In the very long term, because marginal and average prices are not too different for a mature industry, little error results from this assumption. In the near term, some error may be introduced by this assumption. Nonetheless, the framework is capable of dealing with the average cost prices if necessary to understand national costs and benefits of Lurgi demonstration.

Table 4.40 contains a very interesting growth pattern for synthetic gas from coal. Note the extremely rapid growth in second generation high Btu gas produced from Western coal. Its relatively low prices are the reason for that rapid growth. In this model, we assume a 12% <u>current</u> dollar discount rate for gas utilities. Assuming, as the model does, a 5% inflation rate, this corresponds to a 7% real time preference rate by utility decision makers. Using the 7% real discount rate, and assuming the mature second generation high Btu gas plant can be built for on the order of half a billion 1975 dollars, a synthetic high Btu gas price as low as $2.35 would prevail. This low discount rate assumption introduces little error, as it applies equally to all technologies — gases, liquids, and electricity.

A technology such as second generation high Btu gas from coal, growing as rapidly as that technology grows, can pay significant benefits if its price is lowered slightly or perhaps if it is accelerated somewhat. Thus, based on this projection, we would expect the principal benefits from commercial demonstration of Lurgi plants to accrue by accelerating *second generation* gasification technologies. The numerical example we shall discuss below examines the implications of accelerating second generation high Btu gasification of coal by three years and Lurgi by five.

To further explore the total gas picture implied by the base case run of the SRI National Energy Model, it is instructive to look at the prices and quantities of methane delivered to the various demand regions of the country as a function of time. Table 4.41 contains these prices and quantities. This methane originates from any of the above sources — natural gas in the Lower Forty-eight or the North Slope, imported LNG, or synthetic natural gas. Because we have found a good deal of confusion in describing the economics of methane in the long run, we think it is important to document the equilibrium prices and quantities of gas computed by the SRI National Energy Model in each of the demand regions of the country as a function of time. A principal reason for documenting these prices and quantities is to move away from the mentality of projecting only the *quantity* of gas that will be delivered to the customers in the various regions over time. Such projections typically show a declining gas production without mention of pirce. Because commercial demonstration of Lurgi plants pay benefits only if they can change the long run economics of distributed gas,

PRICES AND QUANTITIES OF DISTRIBUTED GAS IN SRI BASE CASE

Material Number 35 - High Btu Gas

Region Number	Region	1975 Quad Btu	1975 $/MMBtu	1980 Quad Btu	1980 $/MMBtu	1985 Quad Btu	1985 $/MMBtu	1990 Quad Btu	1990 $/MMBtu	1995 Quad Btu	1995 $/MMBtu	2000 Quad Btu	2000 $/MMBtu	2025 Quad Btu	2025 $/MMBtu
1	New England	0.236	2.61	0.260	2.99	0.277	3.31	0.283	3.56	0.306	3.77	0.330	3.84	0.727	3.28
2	Middle Atlantic	1.890	2.47	1.967	2.83	2.002	3.15	2.003	3.37	2.037	3.36	2.870	3.62	4.790	3.09
3	South Atlantic	1.394	2.18	1.533	2.55	1.577	2.92	1.603	3.26	1.630	3.60	1.690	3.72	3.213	3.11
4	East South Central	2.115	2.01	2.537	2.35	2.515	2.70	2.317	3.03	1.920	3.44	1.798	3.53	3.847	2.84
5	East North Central	5.720	2.30	5.203	2.69	4.885	3.04	4.590	3.25	4.737	3.29	5.487	3.25	9.417	2.92
6	West South Central	5.920	1.91	5.970	2.72	5.865	2.55	5.557	2.88	5.230	3.29	5.155	3.52	6.510	3.29
7	West North Central	1.776	2.15	1.797	2.47	1.763	2.68	1.671	2.82	1.603	2.94	1.643	2.98	3.830	2.58
8	Pacific	1.874	2.30	1.997	2.53	2.096	2.70	2.253	2.84	2.617	2.93	2.935	3.01	4.023	3.09
15	Mountain	0.903	2.05	1.243	2.19	1.406	2.33	1.507	2.45	1.591	2.56	1.683	2.66	2.983	1.70

it is important to consider both quantity and price. We re-emphasize that these prices of delivered methane assume the low discount rates discussed above. Thus, they are significantly lower than many published estimates even though they yse the same capital and operating costs.

IMPLICATIONS FOR HIGH BTU GAS

At this point, it is useful to review several of the implications of the energy model runs for high Btu gas. First of all, under the base case and early SNG assumptions, high Btu gas does not decline in market share in the long run. The base case is clearly not a case in which high Btu gas is replaced by an alternate fuel form -- liquid fuels, electricity, coal, or hydrogen. In fact, it is very difficult to construct scenarios in which high Btu gas is replaced to a significant degree by another fuel unless first and second generation synthetic gas from coal become significantly more expensive than our base case estimates. Because high Btu gas from coal appears to be one of the more attractive sources of energy in the long run, forces that decrease its price tend to pay benefits in the long run. On the other hand, forces that tend to drive up its price do not pay benefits. The significant question with regard to high Btu gas is not whether a decrease in its price will pay benefits; the question is when will high Btu gas be competitive with natural gas. This question is set principally by the natural gas resource base -- how much natural gas remains to be produced at or less than the price of synthetic gas. The base case shows a very strong need for advanced technologies to produce high Btu gas by 1992, and the early availability case shows that a strong need exists three years earlier as well. Thus, one would expect to see benefits from accelerating second generation high Btu technology.

There are a number of ways to accelerate the development of advanced gasification technologies. One of those ways, and only one, is to commercialize Lurgi plants today. Other ways might include R&D, bench scale tests, pilot plants, or demo plants for the various second generation gasification technologies themselves, rather than commercial demonstration of first generation plants today. To understand whether or not the nation ought to demonstrate Lurgi plants, one must carefully consider whether commercial Lurgi demonstration has more effect on accelerating second generation technologies than working directly on those second generation technologies themselves. As of this writing, this issue is largely unresolved. There are those who argue that the key issues in gasification are materials, scale-up, handling, financing, regulation, instrumentation, overall plant design, and a general lack of experience with gasification on a large scale. Because many of these skills are transportable to second generation technologies, they argue that one might learn more about second generation gasification by building a first generation plant and acquiring these skills. In summary, the contention is that the problems of gasification are problems of physics rather than chemistry. The counter argument involves whether or not primary attention should be directed at second generation high Btu gasification plants as integrated facilities. The argument is that by focusing R&D and demonstration efforts on second generation plants as whole facilities we are bound to learn more about those plants. Thus, even though commercial demonstration of Lurgi plants may produce more benefits than costs, that does not imply that as a nation we ought to commercialize Lurgi plants. What it does imply is that we ought to investigate some of the other options for accelerating SNG and compare them to the commercialization option.

One of the key benefits of using an energy model such as the SRI National Energy Model is that it takes care of the interfuel competition problem in a very complete manner. The model chooses among competing technologies to satisfy various categories of usable energy demand based on price. If Technology A can satisfy a usable energy demand cheaper than Technology B, the model tends toward Technology A. In the base case run, synthetic high Btu gas from coal using second generation technology can satisfy many usable energy demand categories cheaper than any other technology, and thus the model tends to select it over the other technologies. Accelerating gas makes it even more competitive. It is also significant to note that synthetic high Btu gas is more attractive than low Btu gas, hydrogen, or methanol which employ gasification. Therefore, one of the key implications of the base case is that the benefits of commercializing high Btu gas from coal accrue mostly in terms of providing cheaper long run high Btu gas from coal, and not in providing more attractive gasification-based technologies.

CALCULATION OF LONG RUN BENEFITS

The manner in which the SRI National Energy Model is used to assess the long run economic and environmental costs and benefits deserves a note of explanation. Suppose one wanted to assess the effect of a program that accelerated high Btu gas by five years. One would construct two cases for the SRI National Energy Model. The first case would be a base case, and the second case would be identical with the base case, with one exception. That exception would be that high Btu gas technologies were available sooner. With this as background, we now present the numerical output from the energy model and the evaluation of the long run economic benefits of accelerated SNG under one scenario. Note that because all other assumptions are identical, we are in effect evaluating only a single scenario. That is, we are evaluating the attractiveness of accelerating high Btu gas under one set of assumptions. As alluded to above, in order to exhaustively determine the implications of accelerating high Btu gas, one would have to look at a number of different scenarios, each of which would involve at least two energy model runs.

This discussion will be "step-by-step" so that the reader can become familiar with the calculations being performed as well as the insights. This should minimize confusion about how such evaluations should be made. In the discussion, we will first discuss the calculation of national long run changes in consumer surplus, and then discuss the national long run changes in producer surplus. In Table 4.42, we have displayed the usable energy prices and quantities for all forms of usable energy in the base case. In that table, we distinguish between usable energy in the automotive transportation sector and all other forms of usable energy. The reason is simply that the units of usable energy in the automotive are in the form of vehicle miles of auto travel while all other sectors are expressed in terms of Btus of usable energy delivered. As we shall point out shortly, however, the units of the various categories of usable energy are inconsequential because the changes in consumer surplus will be expressed in terms of dollars.

CONSUMERS' SURPLUS

In order to assess the changes in consumer surplus under the particular secnario we denoted "early availability of SNG" above, we require the same usable energy prices and quantities for that case. Table 4.43 contains those prices and quantities of usable energy in the early SNG availability case for both automotive and non-automotive usable energy demands. The numbers in Tables 4.42 and 4.43 are sufficient to determine the net present change in consumers' surplus in the early SNG availability scenario.

To illustrate the consumers' surplus calculation, note that in the year 2001 in the non-automotive usable energy demand category, the prices and quantities are as follows:

P_a = \$6.525/MMBtu

Q_a = 67.62 quads/year

P = \$6.536/MMBtu

Q = 67.49 quads/year

In order to compute the change in consumers' surplus between the two cases in the year 2001, we plot the two price/quantity pairs, one for each case, in Figure 4.37. We know that these equilibrium points fall on a single demand curve and represent the point at which two separate supply curves cross that single demand curve. In Figure 4.37 we denote the demand curve by a dotted line. By simply assuming that the demand curve between the two points in that figure is linear, we can calculate an approximation to the change in consumers' surplus between the two cases. The change in consumers' surplus in 2001 under such an assumption is simply the area of the shaded trapezoid in Figure 4.37. Returning to equation (1) in the

PRICES AND QUANTITIES OF USABLE ENERGY

Base Case

	AUTO		NON-AUTO	
	Price ($/Mi)	Quantity (Tril. Mi/Yr)	Price ($/MMBtu)	Quantity (QBTU/Yr)
1975	.240	1.244	6.842	28.725
1977	.250	1.335	6.576	31.635
1980	.238	1.471	6.082	35.994
1983	.232	1.607	6.152	40.348
1986	.230	1.720	6.235	44.783
1989	.229	1.805	6.325	49.300
1992	.229	1.805	6.430	53.835
1995	.229	1.967	6.459	58.369
1998	.229	2.048	6.355	62.901
2001	.230	2.125	6.536	67.490
2004	.230	2.197	6.561	72.133
2007	.230	2.268	6.563	76.272
2010	.233	2.339	6.504	81.438
2013	.230	2.411	6.637	86.075

TABLE 4.42

PRICES AND QUANTITIES OF USABLE ENERGY

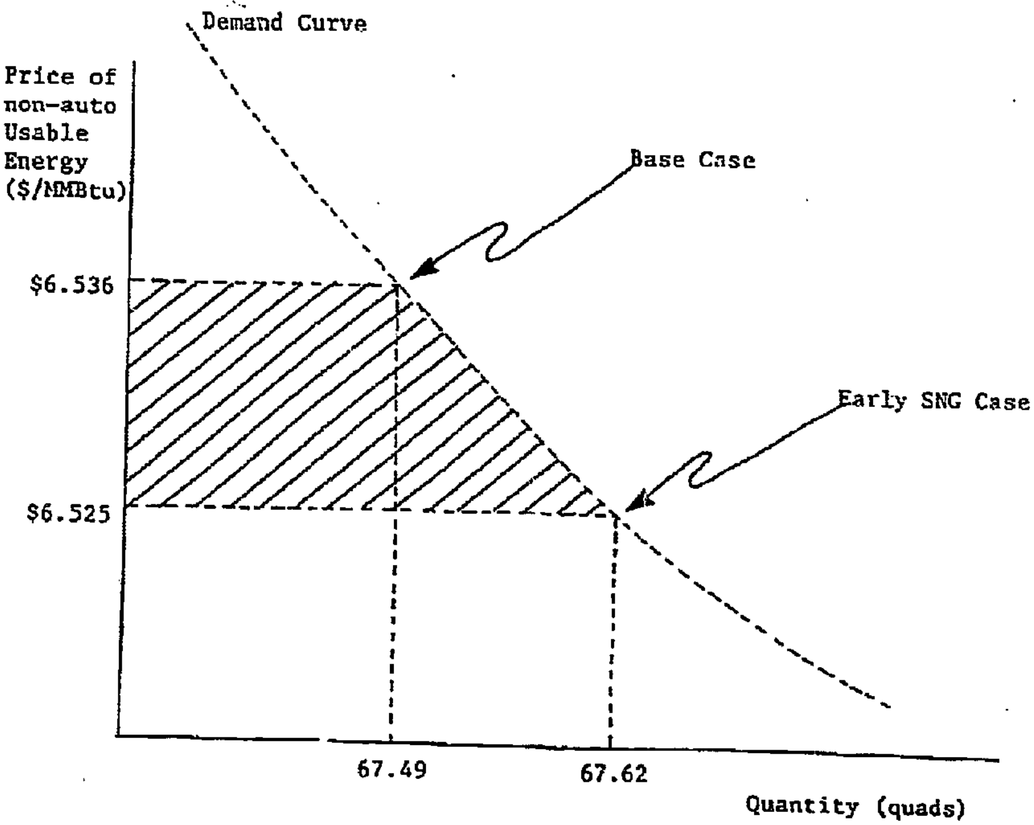
Early SNG Case

	AUTO		NON-AUTO	
Year	Price ($/Mi)	Quantity (Tril. Mi/Yr)	Price ($/MMBtu)	Quantity (QBTU/Yr)
1975	.240	1.244	6.846	28.725
1977	.249	1.336	6.577	31.635
1980	.238	1.475	6.073	36.010
1983	.232	1.610	6.153	40.350
1986	.230	1.721	6.247	44.748
1989	.229	1.807	6.318	49.291
1992	.229	1.888	6.405	53.893
1995	.229	1.969	6.436	58.463
1998	.229	2.050	6.530	63.025
2001	.230	2.136	6.525	67.621
2004	.230	2.199	6.560	72.247
2007	.230	2.270	6.553	76.892
2010	.233	2.341	6.503	81.507
2013	.230	2.416	6.440	86.051

TABLE 4.43

FIGURE 4.37

Change in Consumers' Surplus in 2001



discussion of consumers' surplus above, the change in consumers' surplus in the non-automotive sector in the year 2001 is

$$1/2(67.49 + 67.62)(6.536 - 6.525) = \$0.74 \text{ billion/year}$$

This calculation has been performed using the prices and quantities in Tables 4.42 and 4.43, and the annual change in consumers' surplus between the two cases has been tabularized in Table 4.44 for both the automotive and non-automotive sectors. Note that in Table 4.44 the change in consumers' surplus in the automotive sector as the result of accelerating SNG is zero. This is because changes in the economics of high Btu gas over such a small range have no effect on the supply/demand balance in the liquid fuels sector and thus the automotive sector is largely unaffected. For the remainder of our discussion of the change in consumers' surplus, then, we will ignore the automotive sector.

Note that these annual changes in consumers' surplus are assumed by the energy model to apply over a three-year time period. In order to calculate the net present consumers' surplus, this fact must be included in the calculations. In order to do so, we must calculate the net present change in consumers' surplus at the beginning of each time period, and then discount these net present surplus measures at the beginnings of the time periods back to the base year, which is assumed to be 1977. We will illustrate both calculations. Assuming that r is the discount rate in constant dollars by which we discount changes in consumers' surplus, the net present value within a three-year time period of an annual change in consumers' surplus ΔCS is

$$\frac{1 - \left(\frac{1}{1+r}\right)^3}{1 - \left(\frac{1}{1+r}\right)} \times \Delta CS \ .$$

This is a straightforward expansion of a geometric series. For the year 2001, assuming 10% discounting in constant dollars and using the annual change in consumers' surplus from Table 4.44, the 2000 to 2003 net present

CHANGE IN CONSUMERS' SURPLUS
(BILLION $/YR)

YEAR	AUTO	NON-AUTO	TOTAL
1975	0	0	0
1977	0	0	0
1980	0	0	0
1983	0	-.04	-.04
1986	0	-.54	-.54
1989	0	.35	.35
1992	0	1.35	1.35
1995	0	1.34	1.34
1998	0	1.57	1.57
2001	0	.74	.74
2004	0	.07	.07
2007	0	.77	.77
2010	0	.08	.08
2013	0	.26	.26

TABLE 4.44

change in consumers' surplus is

$$.74 \times \frac{1 - (\frac{1}{1.1})^3}{1 - (\frac{1}{1.1})} = 2.02$$

Table 4.45 contains the annual changes in consumers' surplus in terms of dollars per year as computed from the previous tables, the time periods under consideration, and the net present change in consumers' surplus within each time period expressed at the beginning of that time period. Note that the net present change within each time period depends upon the discount rate. Lower discount rates lead to higher net present changes within a period. In the case where zero discounting occurs, the net present change within each period is simply three times the annual change for time periods of length three years. The fourth column of that table, the net present change in consumers' surplus by period, then must be discounted to the base year, which is January 1, 1977. Again, for the time period 2000 to 2003, one discounts the net present change within that period -- 2.02 billion dollars -- across the time period from 1977 to 2000, a period of twenty-three years. The result of that calculation is

$$2.02 \times (\frac{1}{1.1})^{23} = 0.23 \text{ billion dollars}$$

The final column in Table 4.45 contains the contribution from each time period to the total present value. To get the net present value in January 1, 1977, one simply adds those numbers. For the present example, at 10% constant dollar discounting, those numbers add up to $2.3 billion.

It is important to note at this point that the SRI National Energy Model arrives at equilibrium prices and quantities using an iterative method. As a result, the accuracy of the numbers depends on the degree to which the model is converged. For these particular cases, we have not spent the money necessary to converge the model to an extremely fine level of detail. Therefore, there is some "noise" in the numbers we have presented here.

NET PRESENT VALUE OF CHANGE IN CONSUMERS SURPLUS

(10% Constant Discounting to 1/1/1977)

	ANNUAL CHANGE (BILLION $/YR)	TIME PERIOD	CHANGE BY PERIOD (BILLION $)	CONTRIBUTION TO PRESENT VALUE
1975	0	1975–1976	0	0
1977	0	1976–1979	0	0
1980	0	1979–1982	0	0
1983	-.04	1982–1985	-.11	-.068
1986	-.54	1985–1988	-1.48	-.69
1989	.35	1988–1991	.96	.34
1992	1.35	1991–1994	3.69	.97
1995	1.34	1994–1997	3.67	.73
1998	1.57	1997–2000	4.30	.64
2001	.74	2000–2003	2.02	.23
2004	.07	2003–2006	.19	.02
2007	.77	2006–2009	2.11	.13
2010	.08	2009–2012	.22	.01
2013	.26	2012–2015	.71	.03

TABLE 4.45