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Abstract: We propose with this study a linear programming method to minimize Turkey's energy cost. Only available main energy resources such as hard coal, lignite, crude oil, natural gas, and other resources are included in the analysis, and 1994, the last year of "Sixth Five Yearly Development Plan" of Turkey, is used as target year to provide time flexibility. Our study indicates the composition of energy resources should be changed by increasing the share of hydro resources, geothermal resources and low quality ignites to produce electricity for total energy consumption. It is useful to identify critical resources whose usages should be increased or decreased in order to decrease the total energy cost. We feel the model needs to be improved, but it will at least be a good starting point for further studies.

MINIMIZATION OF ENERGY RESOURCES COSTS IN TURKEY

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INTRODUCTION TO OPERATIONS RESEARCH

Instructor : DR. RICHARD F. DECKRO

MINIMIZATION OF ENERGY RESOURCES COSTS IN TURKEY

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ABSTRACT

The purpose of this study is to use linear programming method in solving Turkey's energy minimization problem. In this study only available main energy resources such as hard coal lignite, crude oil, natural gas, geothermal and hydro resoures are included to the analysis, and 1994, the last year of "Sixth Five Yearly Development Plan" of Turkey, is taken as target year to provide time flexibility and because of the data availability.

According to the study result, the composition of energy resources should be changed towards 1994 by increasing the share of hydro resources, geothermal resources and lignite in total energy consumption. At least it is useful to identify critical resources whose usages should be increased or decreased in order to be able to decrease the total energy cost.

Among other studies related to "energy cost minimization problem of a country" linear programming approach is possibly uniqe and new for Turkey, and is one of a few done for other countries. From this point of view this study wiil be a good countribution in this area. On the other hand, the results of this study mainly depend on assumtions made and restrictions faced, therefore the model needs to be improved and at least wiil be a good starting point for next studies.

MINIMIZATION OF ENERGY RESOURCES COSTS IN TURKEY

I. EXECUTIVE SUMMARY

The purpose of this project is to apply linear programming to minimize the costs of energy resources in Turkey for 1994. The optimal composition of energy resources would be determined by taking into considerations the prices of energy resources, the local production capacities, the economic, social and political, environmental, and administrative issues.

As a democratic and developing country, Turkey has an open market policy. Consequently, the government makes policies on social, economic, and political issues based on worldwide situation.

The project group gathered data from Turkey then formulated the data by making assumptions in order to simplify the problem. Assumptions were made to define the standard of energy unit, the coefficients of energy resources due to differences in energy quality, the price unit of each resource (with currency rate of US$1 = 2121 TL), and to reduce variables to a few only for simplification. There exists thousands of variables if real problem is to be solved.

Six kinds of energy resources were chosen as the main variables: hard coal, lignite, crude oil, natural gas, hydro, and geothermal, categorized in to two sources: local and import, and divided in to four areas of usage: heating, transportation, electricity, and industry. Other resources such as nuclear, solar, wind, woods and fossils were not taken into the considerations.

The year of 1994 was chosen as the year of the study. It is the last year of the sixth five-year development plan for the country. The year of 1989 is taken as the standard for the economy index.

Turkey's total energy cost in 1989 was $4.0 billion. The total cost in 1994 will be $5.9 billion, by taking eight percent of energy expansion per year. The model in the study gives the result of $5.4 billion for total energy costs of Turkey in 1994. This means, there is a decrease of $500 million in the total energy cost. More time and further study are required to improve the model to represent more closely to the real situations.

II. INTRODUCTION

The purpose of this project is to apply linear programming to minimize the costs of energy resources in Turkey for 1994. The optimal composition of energy resources would be determined by taking into considerations the prices of energy resources, the local production capacities, the economic, social and political, environmental, and administrative issues.

The subject was chosen due to its importance to Turkey as a developing country. Energy is one of the main factors for the development of the country. Taking care of the energy problem has been the top priority in the country, since energy is used in various sectors of the country.

The year 1994 which is the last year of the sixth five-year development plan of Turkish government is chosen to provide more time and flexibility to change the current composition of energy resources to an optimal composition taking into considerations the economic, social, political, environmental and administrative issues.

To make decision to produce or to import energy resources is a complex process. Not only economic issues should be considered, but also social and political issues. Therefore it is not unusual that energy resources which are not economical are used due to social, political, environmental and administrative reasons. The model developed in this study would take these issues into consideration.

The primary energy resources available in Turkey which have been used recently are hard coal, lignite, crude oil, natural gas, hydro and geothermal. This study would consider the composition of these energy resources only. In other words, new energy resources such as nuclear, solar and wind energy are not included in this study. In addition to these energy resources, there are some non-tradeable resources, i.e. woods and fossil which have insignificant economic costs but might have high environmental costs. These resources are not included in the GNP and thus are not considered in this study.

The primary energy resources of Turkey are usually consumed after changing process from raw material to final energy depending on the usage area.

III. ENERGY RESOURCES OF TURKEY

A. HARD COAL

1. LOCAL HARD COAL

Local hard coal in Turkey has been mined by Turkey's coal company in Zonguldak city. Looking at the socio-economic structure of the city, hard coal mining is the main industry in the area. This city has no other economic activity except hard coal mining. In other words, people of the city are born and die as miners. There are also very limited job opportunities for those people.

There are 46,000 people working for the company. 16,000 workers are the underground workers who directly participate in the mining. They are divided into two groups. Each group consists of 8,000 workers. While one group work for one month the other group is assigned for time-off. The other 30,000 workers are supporting workers and most of them are employed because of social policy.

Compared with the other countries, Turkish hard coal workers mine less than 500 tons per year while South African hard coal workers mine almost 10,000 ton per year. Yield is very low because of geological structure of the region and weak coal beds. This hard geological condition causes difficulties in using more effective exploration methods. Another important factor is the ineffective mining infra-structure which has been formed for almost a century. This infra-structure is also an obstacle to the use of new and more efficient methods in the existing mine fields.

Moreover, quality of Turkey's hard coal contains 25 % ashes more than that of imported hard coal. Due to lack of quality, local hard coal can not compete with imported hard coal. This local hard coal production is mostly used in governmental companies.

Therefore, hard coal mining in Turkey is not profitable. Compared to the world prices, production cost of local hard coal is very high. However, due to social considerations described above, it would be a problem to close down hard coal plant or to decrease the activities below a certain level. Also, due to the strategic importance of hard coal, it does not seem logical to stop hard coal mining. Because of the geological properties, it is also too expensive and difficult to reopen a mine after closing it.

To continue the mining the government subsidies the company with capital fund or adding funds charged from imported hard coals. Today there is $7 per ton Government Fund charged from imported hard coal except for Steel and Iron Company uses.

Although there are difficulties in hard coal mining in Turkey, due to its strategic importance, some rehabilitation projects have been implemented in order both to decrease costs and to increase production

Hard coal is one of the most important energy input for industry, especially for steel and iron industry, because coke coal, which is required in steel and iron industry, can be obtained from only hard coal which has coke property.

Because Turkey's hard coal production level is not enough, it is necessary to import hard coal to meet industry's demand. Therefore both local and imported hard coal are used for industrial purposes.

In Turkey, hard coal is mainly consumed for steel and iron industries, and this can not be substituted by other energy resources due to economical and political reasons at least until 1994. Although in small industries it can be substituted with other energy resources, it is omitted because the usage is small compared to steel and iron industry.

Due to the growing energy demand in Turkey, Government wants to make use of all available energy resources. From this point of view, hard coal which is not suitable for industry in terms of quality is used to produce electricity in thermo-electricity plants. There are also proposals to build new plants in which imported low-price hard coal will be used to produce electricity.

Transportation is another special usage of hard coal, which has been decreased for the last few years. The decrease in the usage of hard coal for transportation will continue in accordance with replacing of hard coal with new resources.

2. IMPORTED HARD COAL

Because the country does not have enough hard coal resources, imported hard coal is necessary to continue the economic life. Hard coals are imported from several countries by the steel and iron industry, cement industry, fertilizer industry, etc. In import, international market prices or clearing prices are the basis.

B. LIGNITE

Lignite is mostly mined by the Turkey's Lignite Company. There is small production capacity of private sector.

Lignite is primarily used for four purpose : for industrial purpose, for transportation purpose, for heating purpose and for energy purpose to produce electricity.

There are many different kinds of lignite with the calorific values range from 1,000 kcal/kg to 4,500 kcal/kg. In general high quality lignite is used for industry and heating. Medium quality lignite is used for heating. Low quality lignite is used for producing electricity.

In practice, it is very difficult to define borders among above groups. Because of the low efficiency of thermo electricity plants in energy transformation process (from lignite to electricity), to use lignite to produce electricity is not economical unless it is a necessity. From this point of view low quality lignites which have a calory value of under 1,200-1,300 kcal/kg are not suitable for industrial or heating usage. In other words, for this group of lignites, producing electricity is the most suitable usage area.

For medium and high quality lignites, it is very difficult to define separate usage areas. Although, high quality lignites should be used for industrial purposes, the range used by industry is very large, starting from medium to high quality. In the same manner, high quality lignites can be used for heating purpose as well.

As a result we can say that lignite for heating and lignite for industry can be substituted by each other, while lignite for electricity can not be substituted by others. Although there are plants in which some medium quality lignites are used, the latter is true also because of the technological and economical difficulties in changing design characteristics of thermo-electricity plants (i.e. energy plant is designed for a specific quality of lignite having specific range of calory value, humidity, gas content, and ash content). Moreover, these plants use usually a huge amount of lignite and are built where enough reserves are available. Assuming substitution will result in assuming huge amount of transportation, because lignite reserves in Turkey are spread out throughout the country.

Another important point is that Turkey's lignite reserves usually contain high level of sulphur. In burning process, sulphur in coal is transformed to sulphur dioxide (SO2) which is harmful to the environment and human life. That is why sometimes to use imported lignite which contains lower sulphur becomes a necessity to prevent air pollution, especially in some cities such as Ankara, Bursa, and Erzurum. Because the amount is small, imported lignite are not considered in the model.

The amount of low quality lignite needed for electricity is determined by the rate of rain. If there is a lot of hydro resources the amount needed will be smaller. If raining rate is low, the amount needed will be higher.

C. CRUDE OIL

Crude oil demand for Turkey is met mainly by two different sources : local production and imports. Crude oil is used after refinery process. In our model products of crude oil for heating, transportation, electricity and industry are defined in terms of their crude oil equivalence.

D. NATURAL GAS

Although there is local natural gas production, we ignored it in our model because the amount is too small. Natural gas is mainly imported from Russia. There is a clearing agreement between Turkey and Russia. According to the agreement, Turkey will increase the gas bought from Russia.

E. HYDRO

Hydro resources are used to produce electricity. To produce electricity by using hydro resources is the cheapest way, but the amount of electricity produced by using these resources mainly depends on rain conditions. That is why, the Government wants to make use of all available hydro resources as much as possible, and then remaining electricity demand is met by electricity coming from other energy resources and imported electricity.

F. GEOTHERMAL

In addition to the widely used energy resources including hard coal, lignite, crude oil, natural gas and hydro resources; geothermal resources are also used for energy purpose, although the amount is small compared with the total energy consumption and/or demand.

IV. DATA

Several problems are encountered in collecting and using the data. It is very time consuming to collect the data needed in this study because the data is collected from Turkey. The difficulties are also faced because each energy resources has different unit of measurement. While some resources are measured in tons, another is measured in M3 (cubic meter) and the other is measured in GWh. Moreover, another problem arises due to the differences in energy quality of these resources. Some have high amount of energy while others have low. Therefore it is necessary to have a common unit of measurement for various energy resources. The Crude Oil Equivalent is chosen as the standard unit of measurement, because the information has already been available. To convert original unit of measurements to Crude Oil Equivalent, technology coefficient factors are required.

The data are summarized into three groups: demand and capacities, technology coefficient, and prices of energy resources.

A. DEMAND AND CAPACITIES

The realization of energy resources demand in 1989 and the forecast of energy resources demand in 1994 is given in Exhibit-1. The data have been converted to thousand tons of crude oil equivalent [1] (see Exhibit-2). The 1989 data is given and used in model formulation because it is the base year for 1994 demand forecast. The 1994 energy demand forecast is derived by multiplying the realization of energy resources demand in 1989 by growth factors of the plan period. The growth factors of sectors are given in Exhibit-3. [1]

B. TECHNOLOGY COEFFICIENTS

Technology coefficients are the conversion factors of energy resources' original unit of measurement to crude oil equivalent. Exhibit-4 shows the technology coefficients to convert the energy resources unit of measurement to crude oil equivalent.

Every energy resource has an energy value or a calory value. These values are associated with resource classification. For example, hard coal for industry use has a 6,500 kcal/kg while crude oil has 10,500 kcal/kg and natural gas has 9,100 kcal/m3. [2]

Another consideration to determine the technology coefficient is plant loss. For example, while crude oil is converting to usable resource (refinery process) it loses approximately 5.4 % in Turkey's refinery plants.

The energy resources' unit of measurements are converted to crude oil equivalent by dividing them by technology coefficients. Crude oil is also changed to usable crude oil equivalent by considering refinery losses.

Technology coefficients are not directly used in the model. To make the model easily understandable technology coefficients are not included in the equations, but the resource prices are changed to crude oil equivalent prices.

C. PRICE COEFFICIENTS

After classifying energy resources associated with their quality, local or imported specialty and usage area, the prices of energy resources in Turkish liras (TL) and US.$ for their original units of measurement are determined. The average exchange rate in 1989 (US.$1 = 2,121 TL) is for the conversion to US.$.[3] The prices for local energy resources are given in million of TL per thousand tons of original units and then divided by the exchange rate to get the prices in thousand US.$ per thousand tons of original units. The prices of imported energy resources are given directly in thousand US.$ per thousand tons of original units. The data is shown in Exhibit-5. Later, all the prices are converted to prices in thousand US.$ per thousand tons of crude oil equivalent by dividing them technology coefficients (see Exhibit-6).

V. ASSUMPTIONS

Due to the complexity of the real situation, the difficulties in gathering the data, some assumptions and simplifications have been made in this study. The followings are the list of some general assumptions. Some more specific assumptions will be described in the explanation of the constraints.

1. Marginal Cost = Marginal Revenue.
2. No limitation on exports and imports for energy resources in accordance with Turkey's open market policy.
3. Turkish government has enough budget to import energy resources.
4. Local production will be continued and maintain at a certain minimum level due to social, political, and technological considerations.
5. The cost of technological changes is not considered in the model.
6. Transportation cost is not considered in this model.
7. There is no significant activities in inventory.
8. There are only four main areas of usage: heating, transportation, electricity, and industry.
9. The social, economic and political situations in the resource imported countries will not be changed. Clearing agreements will be renewed as same as the 1989 conditions.
10. There will not be energy crisis in the world. The prices of the resources will be the same as that in 1989.
11. By 1994, Turkish government do not consider additional new energy resources such as nuclear, solar or wind energy.
12. There will be no change in government's policy on energy and economy.

VI. THE MODEL

A. VARIABLES

There are 25 variables used in this model to represent the amount of energy resources used for the sectors. The variables are labeled with 4 characters.

The first two characters are used to denote the energy sources. There are 6 energy resources considered in this model.

HC = Hard Coal

LG = Lignite

CO = Crude Oil

NG = Natural Gas

HY = Hydro

GT = Geothermal

The third character denotes the origin of the energy resources, whether local or imported.

L = Local.

I = Imported.

The last or the fourth character denotes the sectors. There are primary 4 sectors considered in this model.

H = Heating.

T = Transportation.

E = Electricity.

I = Industry.

The complete list of all variables are as follows:

HCLH = The amount of Local Hard Coal for Heating.

HCLT = The amount of Local Hard Coal for Transportation.

HCLE = The amount of Local Hard Coal for Electricity.

HCLI = The amount of Local Hard Coal for Industry.

HCIH = The amount of Imported Hard Coal for Heating.

HCIT = The amount of Imported Hard Coal for Transportation.

HCIE = The amount of Imported Hard Coal for Electricity.

HCII = The amount of Imported Hard Coal for Industry.

LGLH = The amount of Local Lignite for Heating.

LGLE = The amount of Local Lignite for Electricity.

LGLI = The amount of Local Lignite for Industry.

COLH = The amount of Local Crude Oil for Heating.

COLT = The amount of Local Crude Oil for Transportation.

COLE = The amount of Local Crude Oil for Electricity.

COLI = The amount of Local Crude Oil for Industry.

COIH = The amount of Imported Crude Oil for Heating.

COIT = The amount of Imported Crude Oil for Transportation.

COIE = The amount of Imported Crude Oil for Electricity.

COII = The amount of Imported Crude Oil for Industry.

NGIH = The amount of Imported Natural Gas for Heating.

NGIE = The amount of Imported Natural Gas for Electricity.

NGII = The amount of Imported Natural Gas for Industry.

HYLE = The amount of Local Hydro for Electricity.

HYIE = The amount of Imported Hydro for Electricity.

GTLE = The amount of Local Geothermal for Electricity.

B. OBJECTIVE FUNCTION

The objective is minimize the costs of energy resources of Turkey in 1994.

MIN 94.4 HCLH + 94.4 HCLT + 107.7 HCLE + 94.4 HCLI +

79.4 HCIH + 79.4 HCIT + 79.4 HCIE + 79.4 HCII +

71.2 LGLH + 51.1 LGLE + 71.2 LGLI +

136.2 COLH + 136.2 COLT + 136.2 COLE + 136.2 COLI +

136.2 COIH + 136.2 COIT + 136.2 COIE + 136.2 COII +

62.8 NGIH + 62.9 NGIE + 62.9 NGII +

0.2 HYLE + 0.2 HYIE +

0.2 GTLE

C. CONSTRAINTS.

The constraints are built based on the explanations and assumptions given above. The followings are the brief explanations and the rationales of the constraints and they should be read in conjunction with the previous sections.

The number will start from 2 to refer to the number of the constraint in the model.

2. Considering the employment and social impacts, it is assumed that Turkey's government would not close down the local hard coal mines. It is also assumed that the government would not reduce the mines' production activities from 1989 activities level to prevent the workers lay off.

   2) HCLH + HCLT + HCLE + HCLI >= 1868

3. It is assumed that the maximum local production capacity of hard coal in 1994 is 2745 thousand tons of COE.

   3) HCLH + HCLT + HCLE + HCLI <= 2745

4. Hard coal for industrial purpose can not be substituted by hard coal used for other purposes due to quality requirement and also can not be substituted by other resources due to technological and economical reasons.

   4) HCLI + HCII = 5600

5. Hard coal used for producing electricity can not be substituted by hard coal used for other purposes due to the design characteristic of the plant. But electricity can be produced by using other resources.

5) HCLE + HCIE <= 2400

6. Local hard coal used for producing electricity is low quality hard coal and can not be used for other purposes. It is assumed that this amount would not be smaller than 1989 figures (210 thousand tons of COE) due to increasing local production.

   6) HCLE >= 210

7. Hard coal used for transportation can not be substituted by other resources due to technological reasons.

   7) HCLT + HCIT = 70

8. Lignite used for heating and Industry are substitutable. It is assumed that the maximum production capacity in 1994 is the same as the amount of the demand (7800 thousand tons of COE).

   8) LGLH + LGLI <= 7800

9. Due to social and technological considerations, the government would not close down the mine. It is assumed that the minimum production would be the same as 1989 figure (5840 thousand tons of COE).

   9) LGLH + LGLI >= 5840

10. Lignite is primary energy resource for heating. It is assumed that the demand would not be lower than 1989 demand (3200 thousand tons of COE).

    10) LGLH >= 3200

11. Lignite used for electricity can not be substituted by lignite used for other purposes due to quality requirement and plant design characteristics. However the electricity can be produced by other resources. The maximum plant capacity to produce

electricity from lignite is assumed to be the same as demand forecast in 1994 (6975 thousand tons of COE).

11) LGLE <= 6975

12. Due to social and technological considerations, the government would not close down the plant. It is assumed that the minimum production activities would be maintain at least the same as 1989 activity level (3900 thousand tons of COE).

12) LGLE >= 3900

13. The maximum plant capacity to produce local crude oil in 1994 is assumed to be the same as the demand (3281 thousand tons of COE).

13) COLH + COLT + COLE + COLI <= 3281

14. Due to social consideration, it is assumed that the government would not reduce local crude oil production level from 1989 production level (2788 thousand tons of COE).

14) COLH + COLT + COLE + COLI >= 2788

15. It is assumed that minimum demand of local crude oil for heating purpose in 1994 would be the same as 1989 demand (352 thousand tons of COE).

15) COLH >= 352

16. Crude oil used for transportation can not be substituted by other resources.

16) COLT + COIT = 11330

17. Crude oil is the main energy resource for industry. It is assumed that the demand in 1994 would not be lower than 1989 demand (8905 thousand tons of COE).

17) COLI + COII >= 8905

18. It is assumed that natural gas demand for producing electricity in 1994 would not be lower than 1989 demand (1700 thousand tons of COE).

18) NGIE >= 1700

19. It is assumed that natural gas demand for industry in 1994 would not be lower than 1989 demand (810 thousand tons of COE).

19) NGII >= 810

20. It is assumed that local hydro resources in 1994 would not be less than 1989 demand (6050 thousand tons of COE).

20) HYLE >= 6050

21. The maximum plant capacity to produce electricity from hydro resources in 1994 is assumed to be the same as the forecasted demand (8750 thousand tons of COE).

21) HYLE + HYIE <= 8750

22. The maximum geothermal resource available in 1994 is assumed to be the same as the forecasted demand (15 thousand tons of COE).

22) GTLE <= 15

23. The minimum geothermal resource available in 1994 is assumed to be the same as 1989 demand (10 thousand tons of COE).

23) GTLE >= 10

24. The demand of energy resources for heating in 1994 is forecasted to be 9600 thousand tons of COE.

24) HCLH + HCIH + LGLH + COLH + COIH + NGIH = 9600

25. The demand of energy resources for transportation in 1994 is forecasted to be

11400 thousand tons of COE.

25) HCLT + HCIT + COLT + COIT = 11400

26. The demand of energy resources for electricity in 1994 is forecasted to be 21700 thousand tons of COE.

26) HCLE + HCIE + LGLE + COLE + NGIE + HYLE + HYIE + GTLE + COIE = 21700

27. The demand of energy resources for industry in 1994 is forecasted to be 26400 thousand tons of COE.

27) HCLI + HCII + LGLI + COLI + NGII + COII = 26400

D. THE MODEL

MIN 94.4 HCLH + 94.4 HCLT + 107.7 HCLE + 94.4 HCLI +

79.4 HCIH + 79.4 HCIT + 79.4 HCIE + 79.4 HCII +

71.2 LGLH + 51.1 LGLE + 71.2 LGLI +

136.2 COLH + 136.2 COLT + 136.2 COLE + 136.2 COLI +

136.2 COIH + 136.2 COIT + 136.2 COIE + 136.2 COII +

62.8 NGIH + 62.9 NGIE + 62.9 NGII +

0.2 HYLE + 0.2 HYIE +

0.2 GTLE

SUBJECT TO

2) HCLH + HCLT + HCLE + HCLI >= 1868

3) HCLH + HCLT + HCLE + HCLI <= 2745

4) HCLI + HCII = 5600

5) HCLE + HCIE <= 2400

6) HCLE >= 210

7) HCLT + HCIT = 70

7) LGLH + LGLI <= 7800

9) LGLH + LGLI >= 5840

10) LGLH >= 3200

11) LGLE <= 6975

12) LGLE >= 3900

13) COLH + COLT + COLE + COLI <= 3281

14) COLH + COLT + COLE + COLI >= 2788

15) COLH >= 352

16) COLT + COIT = 11330

17) COLI + COII >= 8905

18) NGIE >= 1700

19) NGII >= 810

20) HYLE >= 6050

21) HYLE + HYIE <= 8750

22) GTLE <= 15

23) GTLE >= 10

24) HCLH + HCIH + LGLH + COLH + COIH + NGIH = 9600

25) HCLT + HCIT + COLT + COIT = 11400

26) HCLE + HCIE + LGLE + COLE + NGIE + HYLE + HYIE + GTLE + COIE = 21700

27) HCLI + HCII + LGLI + COLI + NGII + COII = 26400

END

VII. THE OUTPUT

The computer output is listed in Appendix-A.

The optimal solution of the model are as follows :

OBJECTIVE FUNCTION VALUE = $ 5,399,247,000

HCLH = 0

HCLT = 70 thousand tons of COE = 113 thousand tons

HCLE = 210 thousand tons of COE = 498.5 thousand tons

HCLI = 1,588 thousand tons of COE = 2,565.4 thousand tons

HCIH = 0

HCIT = 0

HCIE = 0

HCII = 4,012 thousand tons of COE = 6,481.4 thousand tons

LGLH = 3,200 thousand tons of COE = 10,666.7 thousand tons

LGLE = 6,975 thousand tons of COE = 43,376.9 thousand tons

LGLI	= 2,640	thousand tons of COE	=	8,800	thousand tons
COLH	= 352	thousand tons of COE	=	363.3	thousand tons
COLT	= 2,929	thousand tons of COE	=	3,022.7	thousand tons
COLE	= 0				
COLI	= 0				
COIH	= 0				
COIT	= 8,401	thousand tons of COE	=	8,669.8	thousand tons
COIE	= 0				
COII	= 8,905	thousand tons of COE	=	9,189.9	thousand tons
NGIH	= 6048	thousand tons of COE	=	6,978.2	thousand M3
NGIE	= 5750	thousand tons of COE	=	6,634.4	thousand M3
NGII	= 9255	thousand tons of COE	=	10,678.4	thousand M3
HYLE	= 8750	thousand tons of COE	=	39,167.4	GWh
HYIE	= 0				
GTLE	= 15	thousand tons of COE	=	67.1	GWh

VIII. ANALYSIS OF OUTPUT

Based on the model output, objective function value is $5,399,247,000, and energy resources recommended to be used in 1994 will be as follows :

Amount (in thousand

tons of crude oil)

HCLT : local hard coal for transportation	70
HCLE : local hard coal for electricity	210
HCLI : imported hard coal for industry	1,588
HCII : imported hard coal for industry	4,012
HCLH : local hard coal for heating	3,200
LGLE : local lignite for electricity	6,975
LGLI : local lignite for industry	2,640
COLH : local crude oil for heating	352
COLT : local crude oil for transportation	2,929
COIT : imported crude oil for transportation	8,401
COII : imported crude oil for industry	8,905
NGIH : imported natural gas for heating	6,048
NGIE : imported natural gas for electricity	5,750
NGII : imported natural gas for industry	9,255
HYLE : local hydro resources for electricity	8,750
GTLE : local geothermal energy for electricity	15

TOTAL CONSUMPTION	69,100

The usage of following resources will not be economical, and their amount to be used are zero :

- Local hard coal for heating

- Imported hard coal for heating
- Imported hard coal for transportation
- Imported hard coal for electricity.
- Local crude oil for electricity
- Local crude oil for industry
- Imported crude oil for heating
- Imported crude oil for electricity
- Imported hydro for electricity

As explained before, unless it is a necessity, using cokeable hard coal for purposes other than industrial is not optimal due to its strategic importance for industry. Therefore, in this model the usage of hard coal for heating, transportation and electricity is restricted as much as possible. Because of the composition of local hard coal, some amount (about 210,000 tons COE) is suitable for thermo electricity plants. Also, current structure of transportation sector will require 70,000 tons of hard coal (crude oil equivalent) in 1994. That is why this model give these minimum amounts. On the other hand, it is possible to control the quality of imported hard coal, and importing hard coal for only industrial purposes is logical. It is also not considered to allocate hard coal for heating purpose.

Energy needs of 3200 tons of COE for heating, 6975 tons of COE for electricity and 2640 tons of COE for industry will be met by using lignite resources. In this model, it is assumed that there is no difference between local crude oil and imported crude oil in terms of quality and price. Therefore, although the results show for example not to use local crude oil for heating purpose, in reality the needs for industry or heating will be met by both local and imported crude oil. Because there is capacity limitation on local production, and we do not have data in terms of proportion of usages of local and imported crude oil for different purposes, their bounds could not be defined. In other words, there is no contradiction between reality and our results.

The usage of natural gas for heating, producing electricity and industry will be as follow respectively: 6,048 tons, 5,750 tons, and 9,255 tons of COE. As explained before, using natural gas for heating, industry, and producing electricity is very attractive in terms of burning efficiency and costs. This will be reflected by this model, and therefore usage of natural gas will increase in 1994.

In the same manner, available capacity of hydro and geothermal resources will be used to produce electricity due to their lower costs and there will be no need for imported electricity.

IX. SENSITIVITY ANALYSIS

A. RHS VALUES CHANGES

Allowable changes (decrease or increase) in the RHS values of constraints and their shadow prices are shown in following table with shadow prices of the constraints.

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE	SHADOW PRICE
2	1868	877	1588	- 15
3	2745	INFINITY	877	0
4	5600	8445	4012	- 16.5
5	2400	INFINITY	2190	0
6	210	1588	210	- 29.8
7	70	0	0	- 79.4
8	7800	INFINITY	1960	0
9	5840	1960	2640	- 8.3
10	3200	2640	3200	- 0.1
11	6975	4050	3075	11.8
12	3900	3075	INFINITY	0
13	3281	8401	493	0
14	2788	493	INFINITY	0
15	352	2929	352	- 73.4
16	11330	0	0	-136.2
17	8905	8445	8905	- 73.3
18	1700	4050	INFINITY	0
19	810	8445	INFINITY	0
20	6050	2700	INFINITY	0
21	8750	4050	2700	62.7
22	15	4050	5	62.7
23	10	5	INFINITY	0
24	9600	INFINITY	6048	- 62.8
25	11400	0	0	0

26	21700	INFINITY	4050	- 62.9
27	26400	INFINITY	8445	- 62.9

Energy Resources	One Thousand Tons Crude Oil Equivalence Increase	Decrease	Marginal Cost Change (Thousand $US)
HCL Production	*		15.0
HCL "		*	0.0
HC Use Industry	*		16.5
HC " Electricity		*	0.0
HCLE	*		29.8
HCLE		*	0.0
HC USE Transportation	*		79.4
LGLH+LGLI		*	0.0
LGLH+LGLI	*		8.3
LGLH	*		0.1
LGLE		*	11.8
LGLE	*		0.0
COL Production		*	0.0
COL Production	*		0.0
COLH	*		73.4
CO Use Transportation	*		136.2

CO Use Industry	*		73.3
NGIE	*		0.0
NGII	*		0.0
HYLE	*		0.0
HYLE+HYIE		*	62.7
GTLE		*	62.7
GTLE	*		0.0
Heating Demand	*		62.8
Transportation Demand	*		0.0
Electricity Demand	*		62.9
Industry Demand	*		62.9

The changes in the RHS values of non-binding constraints in allowable range will not affect the objective function values. The non-binding constraints are listed in the following table.

COSTRAINT NUMBER	CONSTRAINT DEFINITION
3	local hard coal production capacity
5	local and imported hard coal needs for producing electricity
8	

8	local lignite for heating and industry
12	local lignite for electricity
13	local crude oil demand
14	local crude oil production capacity
18	imported natural gas for producing electricity
19	imported natural gas for producing industry
20	hydro resources for electricity
23	geothermal energy for electricity
25	transportation demand

On the other hand, changes in RHS values of binding constraints will affect the objective function value. The increases in the RHS values of following constraints will increase the objective function value which is not desired, while the decrease will decrease (improve) the objective function values which is desired.

CONSTRAINT NUMBER	CONSTRAINT DEFINITION
2	minimum local hard coal production

4	hard coal for industry (local and imported)
6	local hard coal for electricity
7	hard coal for transportation (local and imported)
9	local lignite for industry and heating
10	local lignite for heating
15	local crude oil for heating
16	crude oil for transportation (local and imported)
17	crude oil for industry (local and imported)
24	energy demand for heating
26	energy resource demand for electricity
27	energy demand for industry

Among these scarce resources, the constraints that have the most negative shadow price would cause the most increase in the objective function value. From this point of view, if it is possible to decrease RHS values of these constraints, the priority should be as follows in terms of their contribution to the decrease of objective function value:

PRIORITY	CONSTRAINT
1	16
2	7
3	15
4	17
5	26 and 27
6	24
7	6
8	4
9	2
10	9
11	10

If the RHS values of these constraints are increased, their affects on objective function value will be not desirable (increasing the cost). Therefore the above priority should be reversed for the increase of RHS values.

On the contrary, the increases in the RHS value of the following constraints will result in the decrease (improvement) of objective function value (desirable) and the decreases will increase the objective function value (not desirable).

CONSTRAINT
11 (local lignite for electricity)
21 (electricity from hydro resources and imports)
22 (geothermal resources for electricity)

For these constraints, if the RHS values are increased, the priority in terms of their contribution to the improvement of objective function value will be as follow:

1 - 21 AND 22

2 - 11

B. OBJECTIVE FUNCTION COEFFICIENT

PRICE RANGES :

(Thousand $, Per thousand tons of COE)

RESOURCES	THE LOWEST PRICE	THE CURRENT PRICES	THE HIGHEST PRICE
HCLH	77,8	94.4	INFINITY

HCLT	INFINITY	94.4	94.4
HCLE	77.9	107.7	INFINITY
HCLI	94.4	94.4	111.0
HCIH	62.8	79.4	INFINITY
HCIT	79.4	79.4	INFINITY
HCIE	62.9	79.4	INFINITY
HCII	62.8	79.4	79.4
LGLH	71.1	71.2	71.2
LGLE	INFINITY	51.1	62.9
LGLI	70.1	71.2	62.9
COLH	62.8	136.2	INFINITY
COLT	INFINITY	136.2	136.2
COLE	62.9	136.2	INFINITY
COLI	136.2	136.2	INFINITY
COIH	62.8	136.2	INFINITY
COIT	136.2	136.2	INFINITY
COIE	62.9	136.2	INFINITY
COII	62.9	136.2	136.2
NGIH	INFINITY	68.2	62.9
NGIE	51.1	62.9	794
NGII	54.4	62.9	62.8
HYLE	INFINITY	.2	.2
HYIE	.2	.2	INFINITY
GTLE	INFINITY	.2	62.9

In the sensitivity analysis the price discussed is assigned in a thousand tons of crude oil equivalent.

HCLH price can be changed to as low as $78,000 and be increased to infinity while the total cost stays the same.

On the other hand, HCLT price can go from negative infinity to $94,400 while the total cost stays the same in this range.

HCLE price can be a positive infinity and be as low as $77,900.

HCLI price has the range between $94,400 and $111,000.

The prices of HCIH, HCIT , and HCIE be as low as $62,800, $79,400, and $62,900 respectively, and go up to positive infinity without changing the solution.

The price of HCII can be as low as $62,800 and as high as $79,400.

LGLH has a small flexibility in price change. LGLE has a price range from negative infinity to $62,900. In this way, this resource has an advantage for electricity production.

LGLI has price range from $62,900 to $70,100 with the same total energy cost.

COLH has a price of $62,800 to positive infinity.

COLT has a negative infinite value for lowest price since it can not be substituted by other resources, and has the highest price of $136,200.

HCIE, HCIH, HCIT prices has an infinite value as the highest values, and have $62,800, $136,200, and $62,900 respectively for the lowest values. COII has a price range of $62,900 to $136,200.

COLE also has a price of as high as positive infinity while it can go down as low as $62,900.

Natural gas for heating has an infinite price for highest price. Other lower bounds are $51,100 and $54,400. The other natural gas, except for heating, have highest prices $136,200, $62,900, and $79,400.

Hydro energy for local has a price of minus infinity to $200, while hydro energy for import has $200 to positive infinity.

The last one, is the geothermal energy for electricity which has the range price from negative infinity to $62,900

X. FURTHER STUDY

Some problems were encountered in this study. One of the main problems was to gather data and information from Turkey. The other problem was the limited time frame to finish this study. Due to this problem, the data collected were very limited in term of quantity and quality. Therefore a lot assumptions were set up and a lot of simplifications were made. For further study, this data base should be improved. More accurate and more complete data should be collected to release the assumptions and to make the model more representative to the real situation. Several issues that should be improved are : technological factors, various kinds of energy quality of each resource, additional areas of usage of each resource, and additional cost affected due to decision making for each resource.

The first issue is the technological factors, for example, refineries have various types of plant efficiencies, so that each refinery yields different energy quality even though the crude oil being used is of the same type. The differences in energy quality makes prices different as well.

The second issue is the quality of energy on same resource. For example, hard coal has twenty kinds of ores that each yields different calory value per same unit quantity. The same thing for lignites that have at least twenty types, and for crude oil that has at least five types. Due to the differences in energy quality, prices will be different.

The other thing is additional cost for transportation due to decision on each energy resource. Also the prices of imported resources can vary depending on the origin of the exporter

Additional factor that should also be included in the real model are inventory capacity of each resource, government's subsidy to coal workers which depends on production (the less the production the more the subsidy), budget of the current administration (deficit or surplus), etc.

XI. IMPLICATION OF RESULT

In general, Turkey's energy demand in 1994 will be supplied by 39 percent of local production and 61 percent of imports. The total cost will be $5.4 billion with the domestic cost of $1.4 billion (26 percents) and the import cost of $4.0 billion (74 percents). The estimated total cost for imports on fuels for developing countries in 1990 is $100 billion.[4] So, the energy cost of Turkey alone will comprise four percent of the developing countries' total imported energy cost.

Turkey spent 912 kilograms of crude oil equivalent (kcoe) per capita in the year of 1989. For comparisons, other countries such as Indonesia, Egypt and Syria in the same year spent 317, 578, 1287 kcoe respectively.[5] The economic growth of nations is strongly correlated with increases in the level of per capita energy consumption. In other words, an increase in energy use per capita corresponds to an increase in per capita GNP. Energy GNP ratios may be accounted for by several factors such climate (in cold climates, more fuels is used in the residential and commercial sectors for heating purposes); energy efficiency (efficiency of the energy generation plants and variations in consumption due to the use of different primary energy forms); industrial structure (industrial structure of a country can create major differences in energy GNP ratios since the energy requirements of different industries vary enormously). However, the energy utilization level is not only related to economic structure, but also to population, urbanization, culture, industrialization, wealth and resources of a country, as well as the relative efficiency in converting energy to useful work, etc.[6]

For the consumption of primary sources of energy, Turkey has composition of 27 percent, 30 percent, 31 percent, and 12 respectively in terms of solid, liquid, gas, and electricity. Other countries, such as Egypt has the composition of 5, 80, 9, and 6 percents respectively, Indonesia has 1, 80, 18, and 1 percents respectively, and Syria has 0, 95, 1, 4 percents respectively.[7]

In 1994 Turkey will consume 1200 kcoe per capita (with an estimate of 2.5

percent growth rate per year, the population of Turkey in 1994 will be approximately 64 millions) giving a 5.7 percent annual per capita increase in energy consumption. The annual expansion rate of Turkey's energy consumption is 8 percent. The percentage decrease in per capita consumption is due to the annual population growth rate. Over the century, the global growth of industrialization, population and standards of living has parallel that of energy requirements. Several factors have caused this expansion: modernization of agriculture, migration of rural populations to urban areas, use of various energy consuming machinery (cars, electric appliances, etc.) and the substitution of commercial energy for non-commercial energy. [8]

The total energy cost of Turkey in 1989 was $4.0 billion. If Turkey uses the same resource composition in 1994, with the annual rate of 8 percent, the total energy cost will be $5.9 billion. From the linear programming, the result on total energy cost is $5.4 billion. This gives $500 million lower than that of existing cost.

From the total cost given from the linear programming, Turkey will spend $73.76 per capita for the energy consumption. The estimate GNP per capita in 1994 is $1823. Thus the energy consumption is 4 percent of the total GNP. In 1989, Turkey spent $70.18 per capita with GNP per capita of $1435. The total cost for energy consumption for 1989 was 4.9 percent of the total GNP, higher than that of 1994 due to conservative forecast on GNP growth, which is 5 percent.

If energy resource is all from crude oil, the cost per capita will be increased to $163.44. If the sole resource is from hard coal the cost will be $113.28; and likewise, from lignite the cost will be slightly decreased to $73.38; from natural gas the cost will be $75.36, and finally from hydro resource the cost will be $0.24. Crude oil covers 16.4 percents of the total energy consumed, while hard coal and lignite cover 8.5 and 18.5 percents respectively. Likewise, natural gas and hydro contribute for 43.9 and 12.7 percents respectively. Hydro, the cheapest energy resource with $0.24 per capita and 12.7 percent of total energy, contributes significantly to minimize the total cost making the overall cost per capita down to $73.86.

XII. CONCLUSION

This study shows that Turkey's energy resource composition which will be used in 1994 should be oriented to using hydro resources, geothermal resources, and low quality lignites for producing electricity. In this sense increasing hydro resource usage for electricity up to 11450 thousand tons COE, geothermal resources for electricity up to 20 thousand tons COE, and low quality lignites for electricity up to 10050 thousand tons COE will decrease the total energy cost without affecting optimality of the solution. The priority in increasing the amount of these resources is also determined by taking their shadow prices into consideration as follows:

1- Hydro resources and/or geothermal resources,

2- Low quality lignites.

Moreover, allowable ranges for changing the bounds of every resources (or constraints) and resource prices (objective function coefficients) with their effects on total energy cost are determined.

From these results it is possible to develop policies to decrease the amount of some resources while increasing the amount of above mentioned resources in order to decrease Turkey's total energy cost.

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EXHIBIT - 1

TOTAL DEMAND OF ENERGY RESOUCES FOR TURKEY

	ENERGY DEMAND (Thousand Tons)		RESOURCE GROWT RATES (PERCENTAGE)
RESOURCES	1989	1994	1990-1994
HARD COAL	7980.0	14500	12.7
LIGNITE	41990.0	66300	9.6
CRUDE OIL	21650.0	31560	7.8
NATURAL GAS	3060.0	7250	7.8
HYDRO	24200.0	34500	18.8
GEOTHERMAL	44.8	67.5	8.4
WOOD AND FOSSIL	7750.0	7300	-1.2

Source : The Sixth 5-Year Development Plan, State Planning Organization, Ankara, Turkey, p.132, 1990.

EXHIBIT - 2

ENERGY DEMAND FOR TURKEY

(In Crude Oil Equivalent thousand tons)

	HEATING		TRANSPORT.		ELECTRICITY		INDUSTRY		TOTAL	
RESOURCES	1989	1994	1989	1994	1989	1994	1989	1994	1989	1994
HARD COAL	810	770	130	70	210	2400	3720	5600	4870	8840
-LOCAL	105		130		210		1423		1868	2745
-IMPORTED	705						2297		3002	6095
LIGNITE	3200	4800	10	0	3900	6975	2640	3000	9750	14775
-LOCAL	3200		10	0	3900		2640		9750	
CRUDE OIL	2630	3000	8115	11330	1152	1450	8905	14600	20802	30380
-LOCAL	352		1087		154		1193		2788	3281
-IMPORTED	2278		7028		998		7712		18014	
NATURAL GAS	170	1030	0	0	1700	2110	810	3200	2680	6340
-IMPORTED	170		0		1700		810		2680	
HYDRO	0	0	0	0	6138	8750	0	0	6138	8750
-LOCAL					6050				6050	
-IMPORTED					88				88	
GEOTERMAL	0	0	0	0	10	15	0	0	10	15
-LOCAL					10				10	
TOTAL	6810	9600	8255	11400	13110	21700	16075	26400	44250	69100
-LOCAL	3657		1227		10324		5256		20465	6026
-IMPORTED	3153		7028		2786		10819		23785	6095
FOSSIL	7750	7300	0	0	0	0	0	0	7750	7300
-LOCAL	7750	7300							7750	7300

Sources :

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EXHIBIT - 3

SECTOR GROWTH RATES FOR TURKEY

(At 1968 prices, percentage)

SECTORS	1989 [1]	1990-1994 [2]
Agriculture	-11.1	4.2
Manufacturing	3.1	8.3
Mining	-3.7	6.3
Energy	7.1	11.2
services	3.9	6.9
Average Growth Rate	1.73	7.3

Sources : (1) Main Economic Indicators, State Planning Organization, Ankara, Turkey, p.3, August, 1990.
(2) The Sixth 5-Year Development Plan, State Planning Organization, Ankara, Turkey, p.132, 1990

EXHIBIT - 4

CRUDE OIL EQUIVALENT (COE) OF ENERGY RESOURCES

RESOURCES	HEATING		TRANSPORTATION		ELECTRICITY		INDUSTRY	
	Kcal/ Kg	COE Ratio	Kcal/ Kg	COE Ratio	Kcal/ Kg	COE Ratio	Kcal/ Kg	COE Ratio
HARD COAL								
-LOCAL	6500	0.6190	6500	0.6190	4424	0.4213	6500	0.6190
-IMPORTED	6500	0.6190					6500	0.6190
LIGNITE								
-LOCAL	3150	0.3000	3150	0.3000	1689	0.1608	3150	0.3000
CRUDE OIL								
-LOCAL	10500	0.9690	10500	0.9690	10500	0.9690	10500	0.9690
-IMPORTED	10500	0.9690	10500	0.9690	10500	0.9690	10500	0.9690
NATURAL GAS								
-IMPORTED	9100	0.8667	9100	0.8667	9100	0.8667	9100	0.8667
HYDRO								
-LOCAL					2346	0.2234		
-IMPORTED					2346	0.2234		
GEOTHERMAL								
-LOCAL					2346	0.2234		
-IMPORTED					2346	0.2234		

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EXHIBIT - 5

PRICES OF ENERGY RESOURCES

	HEATING		TRANSPORTATION		ELECTRICITY		INDUSTRY	
RESOURCES	M.TL	Th.US$	M.TL	Th.US$	M.TL	Th.US$	M.TL	Th.US$
HARD COAL								
-LOCAL	123.9	58.4	123.9	58.4	96.2	45.4	123.9	58.4
-IMPORTED		49.1						49.1
LIGNITE								
-LOCAL	45.3	21.4	45.3	21.4	17.4	8.2	45.3	21.4
CRUDE OIL								
-LOCAL	279.9	132.0	279.9	132.0	279.9	132.0	279.9	132.0
-IMPORTED		132.0		132.0		132.0		132.0
NATURAL GAS								
-IMPORTED		54.5				54.5		54.5
HYDRO (*)								
-LOCAL					0.087	0.041		
-IMPORTED						0.041		
GEOTHERMAL(*)								
-LOCAL					0.087	0.041		

Note :
1. M.TL = Million Turkish Liras
2. Th.US$ = Thousand U.S. $
3. Assume 1 US.$ = 2120.78 Turkish Liras
4. For Hard Coal, Lignite, Crude Oil, and Natural Gas, prices are per thousand tons
5. For Hydro and Geothermal, prices are per Gwh.

Sources :
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EXHIBIT - 6

PRICES OF ENERGY RESOURCES

(In thousand US.$ per thousand ton of Crude Oil Equivalent)

RESOURCES	HEATING	TRANSPORTATION	ELECTRICITY	INDUSTRY
HARD COAL				
-LOCAL	94.4	94.4	107.7	94.4
-IMPORTED	79.4			79.4
LIGNITE				
-LOCAL	71.2	71.2	51.1	71.2
CRUDE OIL				
-LOCAL	136.2	136.2	136.2	136.2
-IMPORTED	136.2	136.2	136.2	136.2
NATURAL GAS				
-IMPORTED	62.8		62.9	62.9
HYDRO				
-LOCAL			0.2	
-IMPORTED			0.2	
GEOTHERMAL				
-LOCAL			0.2	

Sources :

1. 1989 Annual Activity Report, Turkey Electricity Company, Ankara, Turkey, pp. 165-167, 1990.
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APPENDIX-A

LP OPTIMUM FOUND AT STEP 19

OBJECTIVE FUNCTION VALUE

1) 5399247.00

VARIABLE	VALUE	REDUCED COST
HCLH	.000000	16.600000
HCLT	70.000000	.000000
HCLE	210.000000	.000000
HCLI	1588.000000	.000000
HCIH	.000000	16.600000
HCIT	.000000	.000000
HCIE	.000000	16.500000
HCII	4012.000000	.000000
LGLH	3200.000000	.000000
LGLE	6975.000000	.000000
LGLI	2640.000000	.000000
COLH	352.000000	.000000
COLT	2929.000000	.000000
COLE	.000000	73.300000
COLI	.000000	.000000
COIH	.000000	73.399990
COIT	8401.000000	.000000
COIE	.000000	73.300000
COII	8905.000000	.000000
NGIH	6048.000000	.000000
NGIE	5750.000000	.000000
NGII	9255.000000	.000000
HYLE	8750.000000	.000000
HYIE	.000000	.000000
GTLE	15.000000	.000000

RANGES IN WHICH THE BASIS IS UNCHANGED:

OBJ COEFFICIENT RANGES

VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
HCLH	94.400000	INFINITY	16.600000
HCLT	94.400000	.000000	INFINITY
HCLE	107.700000	INFINITY	29.800000
HCLI	94.400000	16.600000	.000000
HCIH	79.400000	INFINITY	16.600000
HCIT	79.400000	INFINITY	.000000
HCIE	79.400000	INFINITY	16.500000
HCII	79.400000	.000000	16.600000
LGLH	71.200000	INFINITY	.100002
LGLE	51.100000	11.800000	INFINITY
LGLI	71.200000	.100002	8.299995
COLH	136.200000	INFINITY	73.399990
COLT	136.200000	.000000	INFINITY
COLE	136.200000	INFINITY	73.300000
COLI	136.200000	INFINITY	.000000
COIH	136.200000	INFINITY	73.399990
COIT	136.200000	INFINITY	.000000
COIE	136.200000	INFINITY	73.300000
COII	136.200000	.000000	73.300000
NGIH	62.800000	.100002	INFINITY
NGIE	62.900000	16.500000	11.800000
NGII	62.900000	8.299995	.100002
HYLE	.200000	.000000	INFINITY
HYIE	.200000	INFINITY	.000000
GTLE	.200000	62.700000	INFINITY

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	.000000	-15.000000
3)	877.000000	.000000
4)	.000000	-16.500000
5)	2190.000000	.000000
6)	.000000	-29.800000
7)	.000000	-79.400000
8)	1960.000000	.000000
9)	.000000	-8.299995
10)	.000000	-.100002
11)	.000000	11.800000
12)	3075.000000	.000000
13)	.000000	.000000
14)	493.000000	.000000
15)	.000000	-73.399990
16)	.000000	-136.200000
17)	.000000	-73.300000
18)	4050.000000	.000000
19)	8445.000000	.000000
20)	2700.000000	.000000
21)	.000000	62.700000
22)	.000000	62.700000
23)	5.000000	.000000
24)	.000000	-62.800000
25)	.000000	.000000
26)	.000000	-62.900000
27)	.000000	-62.900000

NO. ITERATIONS= 19

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	1868.000000	877.000000	1588.000000
3	2745.000000	INFINITY	877.000000
4	5600.000000	8445.000000	4012.000000
5	2400.000000	INFINITY	2190.000000
6	210.000000	1588.000000	210.000000
7	70.000000	.000000	.000000
8	7800.000000	INFINITY	1960.000000
9	5840.000000	1960.000000	2640.000000
10	3200.000000	2640.000000	3200.000000
11	6975.000000	4050.000000	3075.000000
12	3900.000000	3075.000000	INFINITY
13	3281.000000	8401.000000	493.000000
14	2788.000000	493.000000	INFINITY
15	352.000000	2929.000000	352.000000
16	11330.000000	.000000	.000000
17	8905.000000	8445.000000	8905.000000
18	1700.000000	4050.000000	INFINITY
19	810.000000	8445.000000	INFINITY
20	6050.000000	2700.000000	INFINITY
21	8750.000000	4050.000000	2700.000000
22	15.000000	4050.000000	5.000000
23	10.000000	5.000000	INFINITY
24	9600.000000	INFINITY	6048.000000
25	11400.000000	.000000	.000000
26	21700.000000	INFINITY	4050.000000
27	26400.000000	INFINITY	8445.000000

THE TABLEAU

ROW	(BASIS)	HCLH	HCLT	HCLE	HCLI	HCIH
1	ART	16.600	.000	.000	.000	16.600
2	HCLI	1.000	.000	.000	1.000	.000
3	SLK 3	.000	.000	.000	.000	.000
4	HCII	-1.000	.000	.000	.000	.000
5	SLK 5	.000	.000	.000	.000	.000
6	HCLE	.000	.000	1.000	.000	.000
7	HCLT	.000	1.000	.000	.000	.000
8	SLK 8	.000	.000	.000	.000	.000
9	LGLI	.000	.000	.000	.000	.000
10	LGLH	.000	.000	.000	.000	.000
11	LGLE	.000	.000	.000	.000	.000
12	SLK 12	.000	.000	.000	.000	.000
13	COLT	.000	.000	.000	.000	.000
14	SLK 14	.000	.000	.000	.000	.000
15	COLH	.000	.000	.000	.000	.000
16	COIT	.000	.000	.000	.000	.000
17	COII	.000	.000	.000	.000	.000
18	SLK 18	.000	.000	.000	.000	.000
19	SLK 19	.000	.000	.000	.000	.000
20	SLK 20	.000	.000	.000	.000	.000
21	HYLE	.000	.000	.000	.000	.000
22	GTLE	.000	.000	.000	.000	.000
23	SLK 23	.000	.000	.000	.000	.000
24	NGIH	1.000	.000	.000	.000	1.000
25	ART	.000	.000	.000	.000	.000

26	NGIE	.000	.000	.000	.000	.000
27	NGII	.000	.000	.000	.000	.000

ROW	HCIT	HCIE	HCII	LGLH	LGLE	LGLI
1	.000	16.500	.000	.000	.000	.000
2	-1.000	.000	.000	.000	.000	.000
3	.000	.000	.000	.000	.000	.000
4	1.000	.000	1.000	.000	.000	.000
5	.000	1.000	.000	.000	.000	.000
6	.000	.000	.000	.000	.000	.000
7	1.000	.000	.000	.000	.000	.000
8	.000	.000	.000	.000	.000	.000
9	.000	.000	.000	.000	.000	1.000
10	.000	.000	.000	1.000	.000	.000
11	.000	.000	.000	.000	1.000	.000
12	.000	.000	.000	.000	.000	.000
13	.000	.000	.000	.000	.000	.000
14	.000	.000	.000	.000	.000	.000
15	.000	.000	.000	.000	.000	.000
16	.000	.000	.000	.000	.000	.000
17	.000	.000	.000	.000	.000	.000
18	.000	1.000	.000	.000	.000	.000
19	.000	.000	.000	.000	.000	.000
20	.000	.000	.000	.000	.000	.000
21	.000	.000	.000	.000	.000	.000
22	.000	.000	.000	.000	.000	.000
23	.000	.000	.000	.000	.000	.000

24	.000	.000	.000	.000	.000	.000
25	.000	.000	.000	.000	.000	.000
26	.000	1.000	.000	.000	.000	.000
27	.000	.000	.000	.000	.000	.000

ROW	COLH	COLT	COLE	COLI	COIH	COIT
1	.000	.000	73.300	.000	73.400	.000
2	.000	.000	.000	.000	.000	.000
3	.000	.000	.000	.000	.000	.000
4	.000	.000	.000	.000	.000	.000
5	.000	.000	.000	.000	.000	.000
6	.000	.000	.000	.000	.000	.000
7	.000	.000	.000	.000	.000	.000
8	.000	.000	.000	.000	.000	.000
9	.000	.000	.000	.000	.000	.000
10	.000	.000	.000	.000	.000	.000
11	.000	.000	.000	.000	.000	.000
12	.000	.000	.000	.000	.000	.000
13	.000	1.000	1.000	1.000	.000	.000
14	.000	.000	.000	.000	.000	.000
15	1.000	.000	.000	.000	.000	.000
16	.000	.000	-1.000	-1.000	.000	1.000
17	.000	.000	.000	1.000	.000	.000
18	.000	.000	1.000	.000	.000	.000
19	.000	.000	.000	.000	.000	.000
20	.000	.000	.000	.000	.000	.000
21	.000	.000	.000	.000	.000	.000

22	.000	.000	.000	.000	.000	.000
23	.000	.000	.000	.000	.000	.000
24	.000	.000	.000	.000	1.000	.000
25	.000	.000	.000	.000	.000	.000
26	.000	.000	1.000	.000	.000	.000
27	.000	.000	.000	.000	.000	.000

ROW	COIE	COII	NGIH	NGIE	NGII	HYLE
1	73.300	.000	.000	.000	.000	.000
2	.000	.000	.000	.000	.000	.000
3	.000	.000	.000	.000	.000	.000
4	.000	.000	.000	.000	.000	.000
5	.000	.000	.000	.000	.000	.000
6	.000	.000	.000	.000	.000	.000
7	.000	.000	.000	.000	.000	.000
8	.000	.000	.000	.000	.000	.000
9	.000	.000	.000	.000	.000	.000
10	.000	.000	.000	.000	.000	.000
11	.000	.000	.000	.000	.000	.000
12	.000	.000	.000	.000	.000	.000
13	.000	.000	.000	.000	.000	.000
14	.000	.000	.000	.000	.000	.000
15	.000	.000	.000	.000	.000	.000
16	.000	.000	.000	.000	.000	.000
17	.000	1.000	.000	.000	.000	.000
18	1.000	.000	.000	.000	.000	.000
19	.000	.000	.000	.000	.000	.000

20	.000	.000	.000	.000	.000	.000
21	.000	.000	.000	.000	.000	1.000
22	.000	.000	.000	.000	.000	.000
23	.000	.000	.000	.000	.000	.000
24	.000	.000	1.000	.000	.000	.000
25	.000	.000	.000	.000	.000	.000
26	1.000	.000	.000	1.000	.000	.000
27	.000	.000	.000	.000	1.000	.000

ROW	HYIE	GTLE	SLK 2	SLK 3	SLK 5	SLK 6
1	.000	.000	15.000	.000	.000	29.800
2	.000	.000	-1.000	.000	.000	1.000
3	.000	.000	1.000	1.000	.000	.000
4	.000	.000	1.000	.000	.000	-1.000
5	.000	.000	.000	.000	1.000	1.000
6	.000	.000	.000	.000	.000	-1.000
7	.000	.000	.000	.000	.000	.000
8	.000	.000	.000	.000	.000	.000
9	.000	.000	.000	.000	.000	.000
10	.000	.000	.000	.000	.000	.000
11	.000	.000	.000	.000	.000	.000
12	.000	.000	.000	.000	.000	.000
13	.000	.000	.000	.000	.000	.000
14	.000	.000	.000	.000	.000	.000
15	.000	.000	.000	.000	.000	.000
16	.000	.000	.000	.000	.000	.000
17	.000	.000	.000	.000	.000	.000

18	.000	.000	.000	.000	.000	1.000
19	.000	.000	.000	.000	.000	.000
20	1.000	.000	.000	.000	.000	.000
21	1.000	.000	.000	.000	.000	.000
22	.000	1.000	.000	.000	.000	.000
23	.000	.000	.000	.000	.000	.000
24	.000	.000	.000	.000	.000	.000
25	.000	.000	.000	.000	.000	.000
26	.000	.000	.000	.000	.000	1.000
27	.000	.000	.000	.000	.000	.000

ROW	SLK 8	SLK 9	SLK 10	SLK 11	SLK 12	SLK 13
1	.000	8.300	.100	11.800	.000	.000
2	.000	.000	.000	.000	.000	.000
3	.000	.000	.000	.000	.000	.000
4	.000	.000	.000	.000	.000	.000
5	.000	.000	.000	.000	.000	.000
6	.000	.000	.000	.000	.000	.000
7	.000	.000	.000	.000	.000	.000
8	1.000	1.000	.000	.000	.000	.000
9	.000	-1.000	1.000	.000	.000	.000
10	.000	.000	-1.000	.000	.000	.000
11	.000	.000	.000	1.000	.000	.000
12	.000	.000	.000	1.000	1.000	.000
13	.000	.000	.000	.000	.000	1.000
14	.000	.000	.000	.000	.000	1.000
15	.000	.000	.000	.000	.000	.000

16	.000	.000	.000	.000	.000	-1.000
17	.000	.000	.000	.000	.000	.000
18	.000	.000	.000	-1.000	.000	.000
19	.000	1.000	-1.000	.000	.000	.000
20	.000	.000	.000	.000	.000	.000
21	.000	.000	.000	.000	.000	.000
22	.000	.000	.000	.000	.000	.000
23	.000	.000	.000	.000	.000	.000
24	.000	.000	1.000	.000	.000	.000
25	.000	.000	.000	.000	.000	.000
26	.000	.000	.000	-1.000	.000	.000
27	.000	1.000	-1.000	.000	.000	.000

ROW	SLK 14	SLK 15	SLK 17	SLK 18	SLK 19	SLK 20
1	.000	73.400	73.300	.000	.000	.000
2	.000	.000	.000	.000	.000	.000
3	.000	.000	.000	.000	.000	.000
4	.000	.000	.000	.000	.000	.000
5	.000	.000	.000	.000	.000	.000
6	.000	.000	.000	.000	.000	.000
7	.000	.000	.000	.000	.000	.000
8	.000	.000	.000	.000	.000	.000
9	.000	.000	.000	.000	.000	.000
10	.000	.000	.000	.000	.000	.000
11	.000	.000	.000	.000	.000	.000
12	.000	.000	.000	.000	.000	.000
13	.000	1.000	.000	.000	.000	.000

14	1.000	.000	.000	.000	.000	.000
15	.000	-1.000	.000	.000	.000	.000
16	.000	-1.000	.000	.000	.000	.000
17	.000	.000	-1.000	.000	.000	.000
18	.000	.000	.000	1.000	.000	.000
19	.000	.000	1.000	.000	1.000	.000
20	.000	.000	.000	.000	.000	1.000
21	.000	.000	.000	.000	.000	.000
22	.000	.000	.000	.000	.000	.000
23	.000	.000	.000	.000	.000	.000
24	.000	1.000	.000	.000	.000	.000
25	.000	.000	.000	.000	.000	.000
26	.000	.000	.000	.000	.000	.000
27	.000	.000	1.000	.000	.000	.000

ROW	SLK 21	SLK 22	SLK 23	
1	63.	63.	.00	-.54E+07
2	.000	.000	.000	1588.000
3	.000	.000	.000	877.000
4	.000	.000	.000	4012.000
5	.000	.000	.000	2190.000
6	.000	.000	.000	210.000
7	.000	.000	.000	70.000
8	.000	.000	.000	1960.000
9	.000	.000	.000	2640.000
10	.000	.000	.000	3200.000
11	.000	.000	.000	6975.000
12	.000	.000	.000	3075.000
13	.000	.000	.000	2929.000
14	.000	.000	.000	493.000
15	.000	.000	.000	352.000
16	.000	.000	.000	8401.000
17	.000	.000	.000	8905.000
18	-1.000	-1.000	.000	4050.000
19	.000	.000	.000	8445.000
20	1.000	.000	.000	2700.000
21	1.000	.000	.000	8750.000
22	.000	1.000	.000	15.000
23	.000	1.000	1.000	5.000

24	.000	.000	.000	6048.000
25	.000	.000	.000	.000
26	-1.000	-1.000	.000	5750.000
27	.000	.000	.000	9255.000