# STUDYING DYNAMIC EFFECTS OF INDUSTRIAL CAPITAL RETROFIT AND ENERGY PRICE ADJUSTMENT ON ENERGY DEVELOPMENT IN CHINA

Qifan Wang Xiaobo Zhang

System Dynamics Group
Shanghai Institute of Mechanical Engineering
Shanghai, China

May, 1986

Abstract. This paper tries to use System Dynamics as a tool to analyze some existing problems in China's energy system. The paper first points out some most severe energy problems in China and the policies that people suggest toward the solving of these problems, then reveals the dynamics of these policies through simulations on an Energy Dynamic Model that we built. The analyses cover the issues of energy production and supply system, energy price, energy shortage, and industrial capital retrofit toward energy conservation, etc.. Some conclusions are derived from the analyses which are valuable for the solving of China's energy problems. And System Dynamics is believed to be an effective approach in energy price analysis in China.

## I. HEADWORDS

Energy, as the source of power to our modern production and life, is so important that we couldn't live withourt it. However, the supply of energy in China, both for industrial production purpose and for citizen living purpose, has not been being so satisfactory, China has been running severe energy shortage for some years. As China's economy system reformation goes on, the unreasonablness in energy price system and all kinds of problems in energy consumption become more and more apparent. Many economists, socialists in China have suggested some policies and strategies on energy problems solution. In this paper, we examine the results of those policies by applying System Dynamics. First of all, we'll make an introduction to China's current energy problems and suggested policies.

## II. INTROPDUCTION TO CHINA'S CURRENT ENERGY PROBLEMS AND SUGGESTED POLICIES

As we all know, China's economy experienced some unpleasant periods during the past few decads. The bad effects of these periods last up till now. Though the China's economy has been recovering since 10 years ago, there are still many problems existing. Speaking of the energy system, however, are especially concerned on these problems: shortage in energy supply, energy price, industrial capital retrofit and its potential.

## I-1. Existing Problems

A. Severe Shortage in Energy Supply
Energy shortage has long been a troublesome problem to China's economy. Energy shortage causes the under-utilization of industrial production capapcity, therefore causes a great amount of production potential losts. An investigation in 1978 showed that in China about 20% of industrial production lost because of the lack of energy supply. And in 1984, the lost was still as high as about 10%.

The reasons why there is such a shortage could be roughly summerized as the following:

a). The development of the energy consumption sector is over the development of energy production. In the past few years, China had too many industrial constructions which were out of the capacity of energy supply.

b). The energy utilization factor has long been neglected in energy production, transition and consumption process therefore the efficiency is very poor and the energy waste is of very big amount.

c). The tighteness in capital supply prevents the appropriate and necessary investment in energy production capacity and new capital with advanced technology.

d). The unreasonableness in China's energy price system is also accountable to the unfufillness of energy supply to demand. Ww'll discuss this factor further in the following paragraph.

B. Unresonableness In Energy Price System
China's economy is a planning economy, so the prices of those important products, such as energy, steel etc. are determined by goverment, rather than by market. Situations have changed so dramatically in past 30 years, but the energy price system is as it was. As the development of the whole economy, the current fixed energy price appears to be more and more unreasonable. Now in China, profit rate of energy production of energy production system as a whole is abouty 3 times lower than the profit rate of average industrial production profit rate, and coal production even goes to negative profit rate.

The man-made low energy price causes the following impacts on energy production and consumption:

a). The low price of energy causes littel stimulation for energy production enterprises to produce more energy because of the low profit rate in energy production;

b). The low price of energy also causes little stimulation for energy consumption sector to increase the energy utilization rate, to improve energy conservation because the price of energy is low. Therefore these energy consumption secotrs always demand too much energy -- more than they realy need. This is partly accountable to the high energy demand compared to supply.

### II-2. Suggested Policies Toward Energy Problems

In order to cover the energy shortage, Chinese economists have suggested some policies and strategies, here are some typical ones:

A). The fundamental way to solve the energy problem is to enlarge the energy production capacity. This could only be doene by investment. However, becuase of the limitation of funds and the long construction period of energy production projects, we couldn't rely fully on the investment to solve current energy shortage.

B). Some economists say that a good way to solve current energy shortage problem is by "Retrofit and Energy Conservation". This is obviouly a way, nevertheless, how much that the energy supply situation could be improved through energy conservation? Are there some other factors that are more effective than energy conservation to relieve energy shortage currently?

C). Another policy is to reform the economy structure and products structure, therefore to adjust the proportion of high energy consuming production sectors to low energy consuming production sectors.

D). Energy price problem has been paid attention to by more and more economists and by Chinese government. It is inevitable that energy price system should be reformed. But the question is how energy price system should be reformed? Some people suggest that energy price should be adusted very seriouly and slowly in order to prevent the side-effects on prices of other industrial products and living material. Some one hold more radical idea, they argue that energy price should be determined fully by market situation of demand and supply, that is to say the energy price system should be reformed from current planning system to a market system.

Later in this paper, we'll try to evaluate these suggestions. In the following section, we'll discuss our Energy Dynamic Model which is built to analyze the energy problems we discussed previouly.

## III. MODEL STRUCTURE DESCRIPTION

Focusing on the energy problems that we discussed in last section, we build in 3 sectors in our System Dynamics model: Capital and Energy Demand Sector, Energy Price Sector and Energy Supply Sector.

## III-1. Capital and Energy Demand Sector

This sector deals with the relationship of energy demand with industrial capital. 4 mechanisms are intended to be revealed:

a). Energy demand increase and decrease through capital formation and discard;
b). Energy conservation through retrofit;
c). Energy demand increase and decrease affected by energy price;
d). Energy demand variation through industrial production structure changes.

There are four Level varaiables in this sector: ED (Energy Demand), EDOC (Energy Demand of Old Capital), K (Capital) and IO (Industrial Output). ED and EDOC differs in that ED takes capital retrofit into account while EDOC not. The structure could be showed roughly by the Fig.1.

## III-2. Energy Price Sector

In energy price sector of the model, we have two level variables: EP (Energy Price) and IPP (Industrial Product Price). The structure is designed to reflect the co-effects of energy price and industrial product price (typically the price of industrial materials).

Furthermore, EP is determined by two Rate variables:

L EP.K=EP.J+(DT)(EPCRP.JK+EPCRS.JK)

EP : Energy Price
EPCRP : Energy Price Change Rate from Price factor
EPCRS : Energy Price Change Rate from Shortage factor

By considering EPCRP, we are applying the policy that Energy Price is adjusted up in order to increase energy production profit to a desiered level during a certain time period:

R EPERP.KL=(EC.K*DEPPR.K+EC.K-EP.K)/EPAT

EC : Energy Cost
DEPPR : Desired Energy Production Profit Rate
EPAT : Energy Prices Adjustment Time (years)

Note that in our model all variables except time variable are treated as dimensionless variables.

Later in Section IV we'll show that variation of EPAT could represent different energy price adjustment strategies.

And EPCRS reflect the mechanism that energy price is adjusted by energy market situation:

R EPCRS.KL=EESEP.K*EP.K

EESEP : Effect of Energy Shortage on Energy Price

EESEP is a Table function of ESR (Energy Shortage Rate). EP and IPP (Industrial Product Price) affect mutually on EC (Energy Cost) and IPC (Industrial Product Cost).

The structure of this sector could be described by Fig. 2 -- Flow Diagram of Energy Price Sector.

### III-3. Energy Supply Sector

In Energy Sypply sector, there is only one Level variable: EPC (Energy Production Capacity) which is integrated by EPCI (Energy Production Capacity Increase) and EPCO (Energy Production Capacity Discard).

L EPC.K=EPC.J+(DT)(EPCI.JK-EPCD.JK)

EPCI is fully determined by investment of capital.

And there is another important variable ES (Energy Supply) which is EPC multiplied by EEPES (Effect of Energy Profit on Energy Supply). The closere the energy production profit rate to its desired level, the closer the energy supply to its production capacity. Fig.3 shows the flow diagram for the structure of this sector.

## IV. POLICY SIMULATIONS AND RESULTS ANALYSES

In this sector, we'll use our model to simulate the dynamic consequences of above-mentioned energy policies and so that to make our comments on these policies. Our analyses are designed into four steps: 1).Energy development under exact the same condition as now,i.e., with no price reformation and no retrofit; 2).Energy development with single effect of industrial capital retrofit; 3).Energy development with single effect of energy price adjustment; 4).Energy development with both industrial capital retrofit and energy price adjustment.

Before we begin our discussion, we'll list some important variables here used as indicators in our model:

ESR : Energy Shortage Rate
(Energy Demand - Energy Supply)/Energy Supply
EPPR : Energy Production Profit Rate
(Energy Price - Energy Cost)/Energy Cost
IPPR : Industrial Production Profit Rate
(Ind.Prod.Price - Ind.Prod.Cost)/Ind.Prod.Cost
EIPR : Energy Industry Price Ratio
(Energy Price)/(Industrial product Price)
RF : Retrofit Rate
Percent of margin between Energy Intensity of New Capital and Energy Intensity of existing Capital

that could be improved through retrofit.

EINCIP: Energy Intensity of New Capital Changing Portion every year.

IV-1. Energy Development Under The Current Condition

By "Current Condition", we are assuming:

a).No price adjustment. Energy price is not related to the market situation of energy demand and supply and is not adjusted toward a resonable level.

b).Energy Intensity of Capital EIC is improved only through capital turnover with average capital life of 10 years with 1.5% improvement in EIC every year. There is no effect from capital retrofit.

Fig.4 shows the simulation result under this case.

The definitions about the variables shown in Fig.4 would be helpful for readers to understand:

ED(1) : Energy Demand
ES(2) : Energy Supply ((ED-ES)/ES)
ESR(3) : Energy Shortage Rate
EPPR(4) : Energy Production Profit Rate
IPPR(5) : Industrial Production Profit Rate
EIPR(6) : Energy/Industry Price Ratio
IEDR(7) : Omcrease of Energy Demand from Capital Retrofit

From Fig.4, we can get the following information:

a).Energy Shortage Rate keeps in high level through out the simulation level from 1985 to 2015.

b).All price, profit indicators keeps exactly the same through out the simulation period.

c).Effect of capital retrofit on energy demand is zero (IEDR equals zero)

Then to see the effects of retrofit and energy price adjustment on energy supply and demand, we go to the next paragraphs.

IV-2. Energy Development With Capiatl Retrofit

By capital retrofit, normally we are assuming that:

a).EINC (Energy Intersity of New Capital) is 1.5% lower than EIC (Energy Intesity of Existing Capital) every year (EINCIP=-0.015)

b).Retrofit Rate (RF) equals 50%.

Fig.5 shows almost the same developing pattern as in Fig.4.

The only difference is that ESR in Fig.5 is reduced somewhat comparing to Fig.4, but is in a very limited range.

However, if we change the values of paprameter EICCIP, the ESR will change significantly, as Table 1 shows;

| ESR / YEAR | EINCIP | | |
|---|---|---|---|
| | -0.015 | -0.02 | -0.03 |
| 1985 | .175 | .185 | .185 |
| 1990 | .168 | .165 | .160 |
| 1995 | .168 | .161 | .145 |
| 2000 | .159 | .145 | .118 |
| 2005 | .144 | .124 | .083 |
| 2010 | .127 | .100 | .044 |
| 2015 | .108 | .074 | .003 |

Table 1. Energy Shortage Rate (ESR) Simulation Results with Different EINCIP Values

The conclusion from Table 1 is obvious that the improvement in technology level in China's industrial production, which is represented by decreasing EINCIP values, has a very significant influence on Energy Shortage. If we double the normal EINCIP (from 1.5% to 3%), then by the year of 2015, ESR will approach to zero.

However, even we double EINCIP, the energy shortage problem could not be fully solved before year 1995. As we'll see in the following situation, Energy Price is a more important factor than capital retrofit and technology in the near future, speaking particularly of the impacts on energy shortage.

### IV-3. Energy Development With Energy Price Adjustment

In this sector, we'll discuss how energy price adjustment would change China's energy situation. The policy control variable is EPAT (Energy Price Adjustment Time) which controls the speed of energy adjustment, and ESRP (Effect of Energy Shortage Rate on Profit) which links energy price to market situation.

b).Retrofit is pull off temporarily in order to see the single effect of energy price adjustment.

Simulations are done by changing EPAT to 1 year, 2.5 years and 5 years separately. We'll analyze the simulation results one by one.

A. EPAT euqals 1 year.
Under this policy, the unreasonableness of low energy production profit rate is to be solved within 1 year, and energy price is related to the market situation of energy

demand and supply.

Fig.6 shows the result. Comparing to the Fig.4, we find that under this policy, ESR could be quickly reduced. However the problem arose from this case is the severe fluctutaion of energy profit, industrial production profit rate and energy/industry price ratio. Such a rough adjustment could not be accepted by Chinese Goverment, therefore this policy has little favorability.

B. EPAT equals 2.5 years
Under this policy, energy price is adjusted more smoothly than policy A. Fig.7 shows the result.

We could see from Fig.7 that by this policy there is no severe fluctuation in prices. However, there is a not-very significant overshoot in energy profit rate, that is EPPR is somewhat over the desired level for a long time period which might cause new problems.

C. EPAT equals 5 years.
The simulation result is shown in Fig.8.

By this policy, the price adjustment is smoothy enough, but there is a more significant enrgy price overshoot. So comparing to policy B, this policy may be less preferable.

## IV-4. Effect of Energy Price Adjustment on Energy Supply

If we compare the simulation results of price adjustment of 2.5 years with the reslults of no price adjustment, we could see the
influence of energy price adjustment on energy supply, see Table 2.

| ES / Year | Price Adjustment of 2.5 Years | No Price Adjustment | Difference | % |
|---|---|---|---|---|
| 1985 | 81.51 | 81.51 | 0 | 0 |
| 1990 | 105.34 | 94.78 | 10.56 | 12.46 |
| 1995 | 128.63 | 115.05 | 13.61 | 11.83 |
| 2000 | 170.81 | 152.14 | 18.67 | 12.27 |
| 2005 | 236.19 | 210.73 | 25.46 | 12.08 |
| 2010 | 332.83 | 298.00 | 34.83 | 11.69 |
| 2015 | 473.18 | 425.14 | 48.04 | 11.31 |

Table 2. Figures of Energy Supply With and Without Energy Price Adjustment

Then under the policy of price adjustment the enrgy supply could increase more than 10% than without price adjustment.

## V. CONCLUSIONS

To summarize the above analyses, we have the following conclusions:

a).The improvement of industrial capital technology level has a good impact on the solving of China's energy shortage problem in the long run. Nevertheless, the effect of capital retrofit on energy shortage is limited.

b).The adjustment of energy price toward a reasonable level is more important than technology progress and capital retrofit in the near future.

And further work could be done on this subject by disaggregating energy prices into coal, oil and electricity prices etc. so as to better reveal the price dynamics, and also the price of industrial product could further disaggregated. This in fact implies that we could disaggregate Level variable "Energy" into Levels of Coal, Oil, Electricity etc..

## REFERENCES

China Energy Research Society (1986). The Reality and Prospection of China's Energy.

Mao, Yushi (1984). Price Problem of Energy Products. Collection of Papers on China's Energy-economic Problems, Energy Press, pp. 24-29

Raghavendran, P. and Wang, Q. (1984). Energy Development and Economic Growth in India. Proceedings of 1984 International System Dynamics Conference, pp. 362-377

Statistics Press (1985). Statistics Almanac of China

Wang, Q., Mckeller, B. et al. (1984). A Simple Model of Energy Dynamics. Proceedings of 1984 International System Dynamics Conference, pp. 297-307

Yan, Reixiang (1984). Analyses on China's Energy Price Problem. Collections of Papers on China's Energy-economic Problems, Energy Press, pp. 24-29

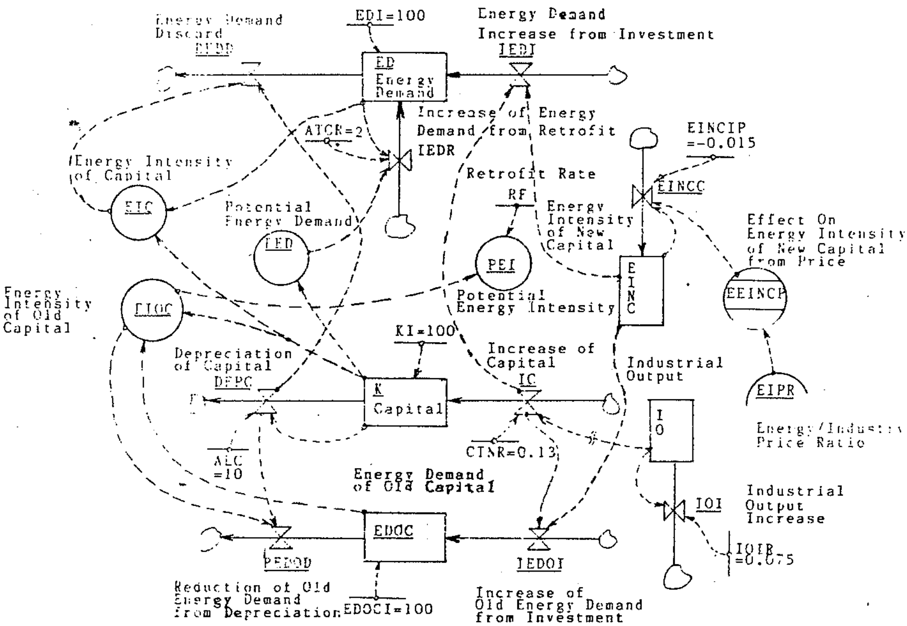


Fig.1 Flow Diagram of Energy Demand and Capital Sector

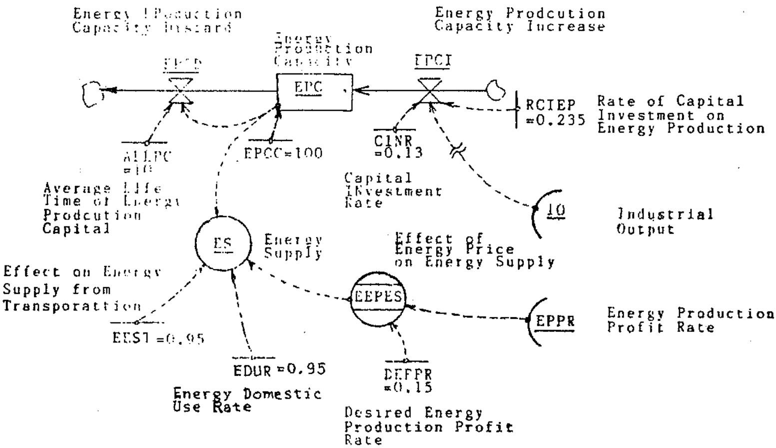


Fig.3 Flow Diagram of Energy Supply Sector

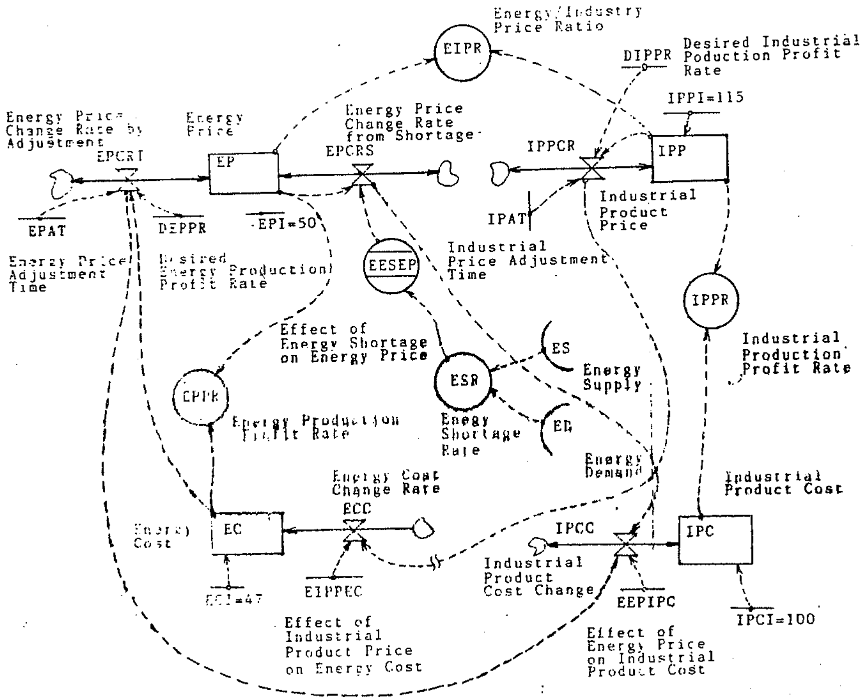


Fig.2 Flow Diagram of Energy Price Sector

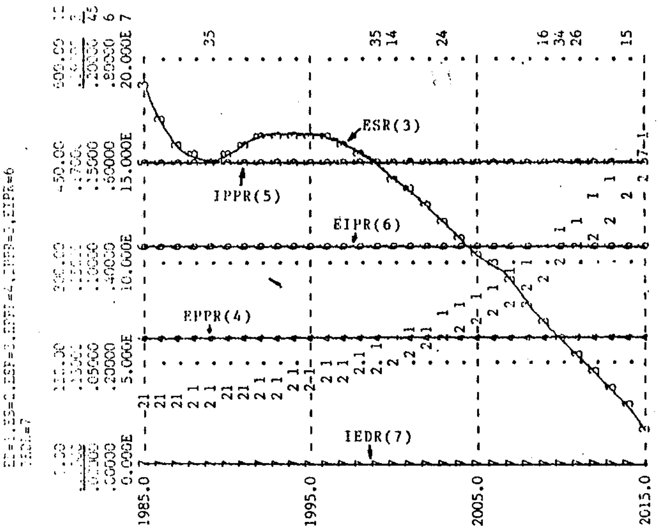


Fig.4 Energy Development With No Energy Price Adjustment and No Capital Retrofit

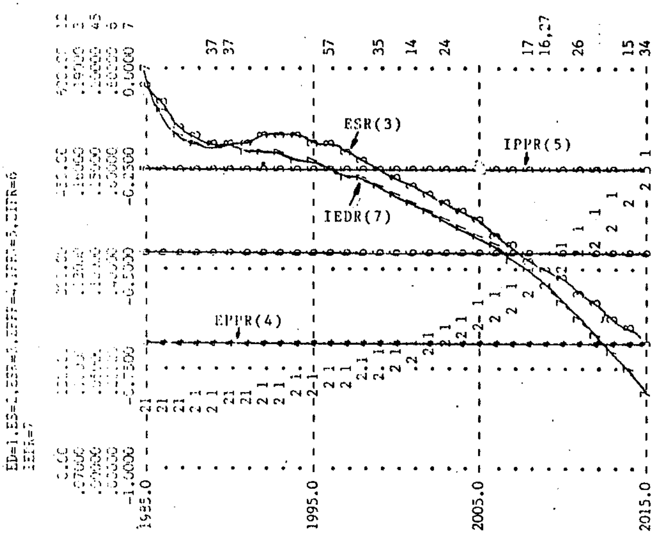


Fig.5 Energy Development With Capital Retrofit

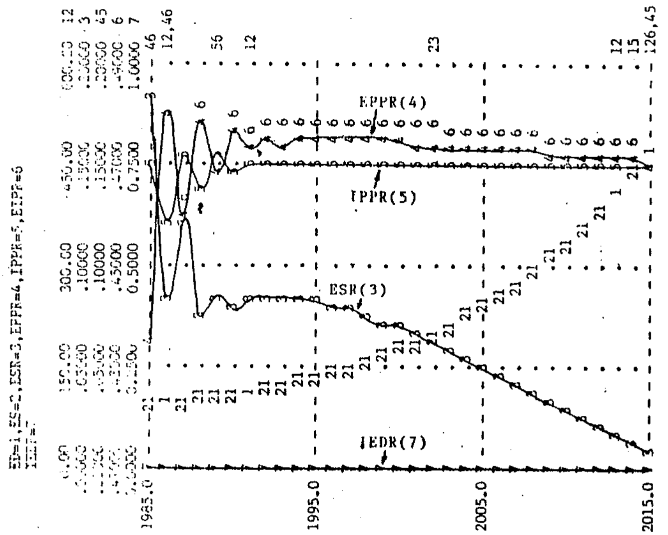


Fig.6 Energy Development With 1 Year of Energy Price Adjustment

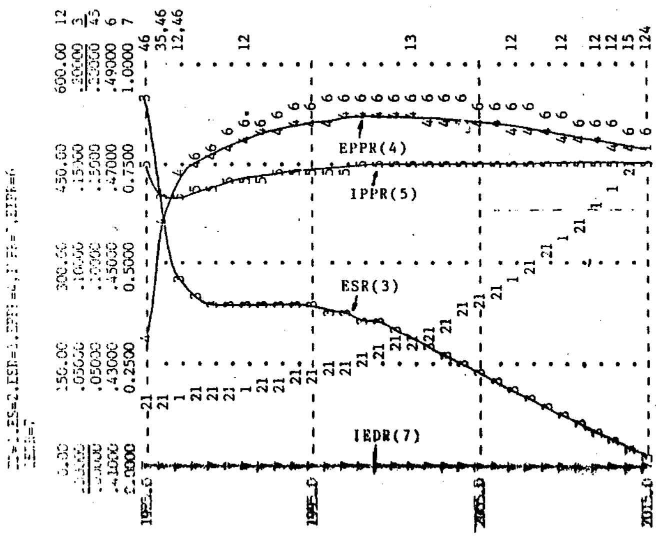


Fig.7 Energy Development With 2.5 Years of Energy Price Adjustment

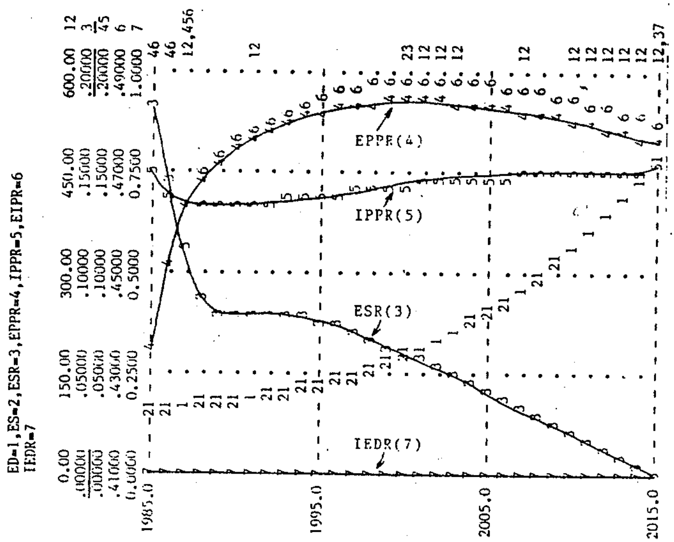


Fig.8 Energy Development With 5 Years of Energy Price Adjustment