A Study of Energy Supply and Demand System on Village Level

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ABSTRACT

Firstly, the network diagram of energy supply and demand system was drawn then a linear optimized model of integrated energy with economy, the target of which is the least cost of energy supply, was developed to optimized the best energy supply structure. Secondly, according to the above results, an SD model was built up to predict and to study the developmental changes of the system from the long point of view. Finally, the two models combined was applied to a village with a population of 800 people in the North China Plain and results of computer simulation showed on the base year (1990), if energy transformed devices were invested properly, the cost of energy supply system will be lowest on the condition of meeting the energy demand, at the same time it can save energy, and the energy supply is sufficient. But, with the development of economy and the upgrading of people's living level, the energy supply will become an important factor for rural economy development. Several alternative plans designed to simulate the system gave different influences of energy to economy.

Key words: Rural Energy, System Dynamics, Linear Programming

1. INTRODUCTION

China has vast rural area, which feeds large population, who consumes enormous energy while energy supply is in shortage, which results in contradiction of energy supply & demand. In the consumption of rural energy, living accounts 80% of the total and it mainly consumes firewood, cropstraw and other biomass. Statistically, the 137 million peasant families of China has 2-3 months lack of living biomass fuel[1]. As for commercial energy of fuel oil and electricity, the shortage of them is more serious. Taking Beijing as an example, in 1985 the city has 4.36 mil. hp of agricultural mechanical engines, and the supply of oil (0.14 mil tons) can make a engine work only 160 hr/hp.yr, which is 1/3 of the reasonable time (500 hr), that is to say the shortage of oil is 2/3. The rural area of Beijing has a capacity of 2.11 mil kw electric devices, which needs 1.7 bil kw.hr electricity, but the supply is only 1.1 bil kw.hr, the electricity shortage is 35%[2]. On the other hand, energy utilization is in low efficiency and unreasonably. 70% of the biomass consumption is burnt directly, the efficiency is only about 10%[3]. In agricultural production and rural industry, mismatch of devices, outdated devices and unmeasurement use of energy are still existing. The purpose of the study is, starting from the most basic element village, by system methods of linear programming and system dynamics from the static and long point of view to research how to make best & best reasonable use & exploitation of energy resources to raise efficiency, to inquire into how to adjust industrial structure to build up reasonable energy supply & demand system for reduction of energy consumption in order to balance energy supply & demand to make village economy develop continuously and steadily[4].

2. OPTIMIZED MODEL

(1) Rural Energy Supply & Demand System

In order to understand structure of energy supply & demand system, a network diagram (figure 1), which is a depicting model in accordance with actual energy flow describing the system, is drawn. The energy supply system includes mining, collection, processing &

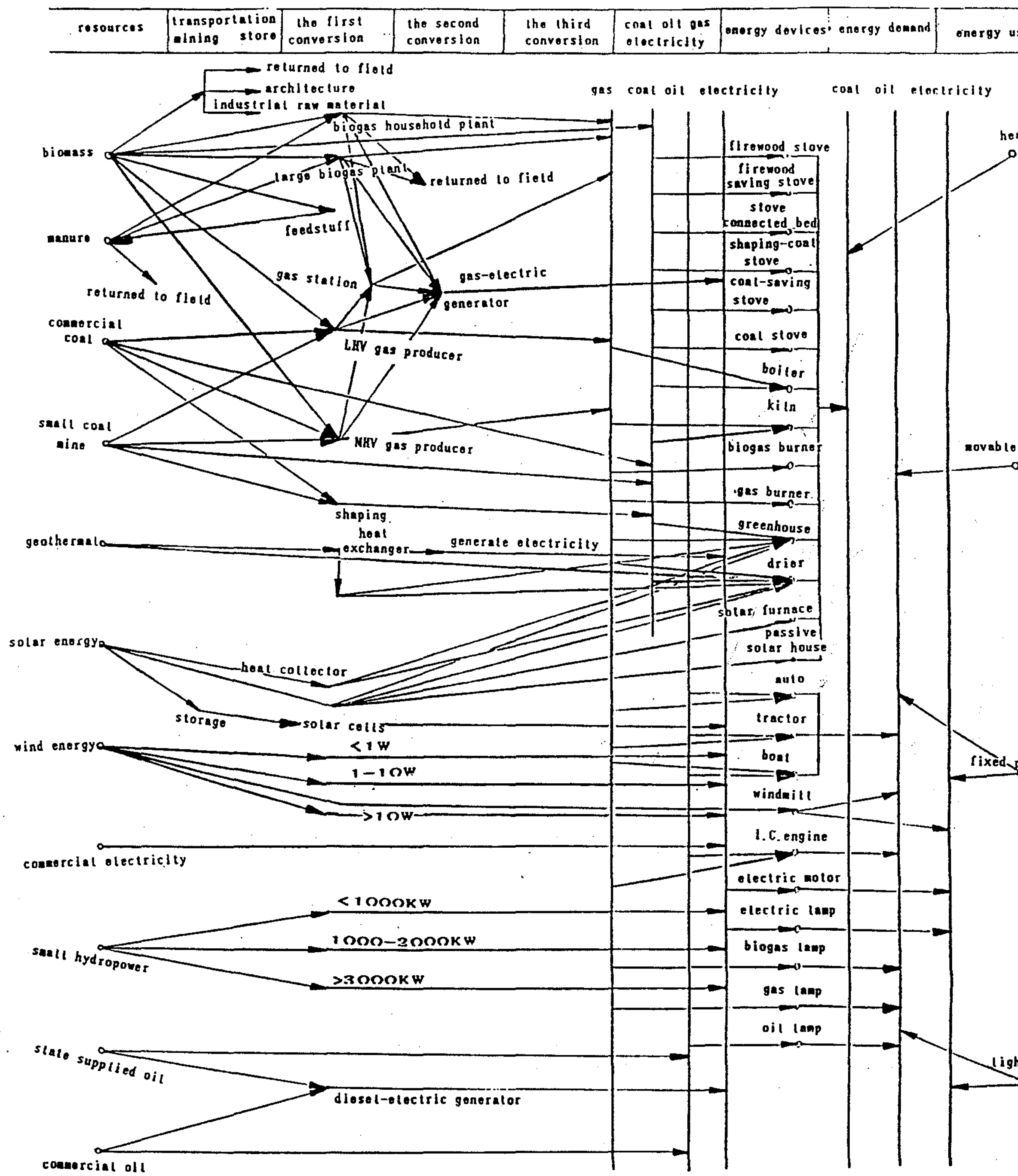

Figure 1 Network Diagram of Rural Energy Supply and Demand

conversion, transportation and distribution of preliminary energy resources. It connects with demand system through end energy using devices. The demand system, which is on the right of the diagram, consists of heat, fixed mechanical power, movable mechanical power and electricity demand.

(2)Optimized Model

A static, linear programming model is introduced. The optimized contents are optimization of energy conversion and its distributed paths, introduction of techniques of energy substitution and investment direction to energy construction. The target function is the least cost of energy supply. With the help of figure 1, the model is described as following[5]:

target function $\quad \min C = \sum_i c_i x_i$

resources restraint $\quad \sum_i x_i + \sum_j (x_j/\eta_i) <= Er_i$

demand restraint $\quad \sum_i x_i >= H_i$

other restraint $\quad \sum_i x_i <=$ or $>= W_i$

C--total cost x_i--energy consumption quantity in i device c_i--unit cost correspondent to x_i η_i--conversion efficiency of i to j energy Er_i--i usable energy resource H_i--i energy demand
restraint (4) contains technique requirements, capacity of energy conversion devices and max or min of x_i

3.SD MODEL

In order to predict and study the developmental changes of rural energy supply & demand system from the long point of view, a system dynamics model with 4 level variables and 78 equations is developed. The model integrated energy with economy considers the factors of energy resources, energy supply out of village, energy construction, energy consumption and output value. Figure 2 is the cause-effect relations diagram, which consists of 3 positive feedback (main loop) and 3 negative feedback loops. According to figure 2, a flow diagram is drawn then equations are established, and model can be simulated on computer[6].

4.CASE

A village with a output value ¥1.56 mil and a population of 800 people (1990) in the North China plain is taken as a case example. Table 1 is energy resources, demand and conversional capability of devices of the village in 1990[7].

Table 1 Energy Resources, Demand and Devices of the Village (1990)

resources (tce)	biomass	cropstraw	manure	coal	electricity	oil	oil state supplied	total
total	418.4	402.4	474.4	294	34.6	60.1	46	1281.5
per capital	0.523	0.503	0.593	0.593	0.043	0.075	0.058	1.6

demand (tce)	heat	oil	oil for movable	electricity	total
total	554	100	90	46.7	700.7
per capital	0.693	0.125	0.113	0.058	0.8759

devices	household biogas plant	diesel-electricity generator
conversional capability (tce)	1.477	14.1

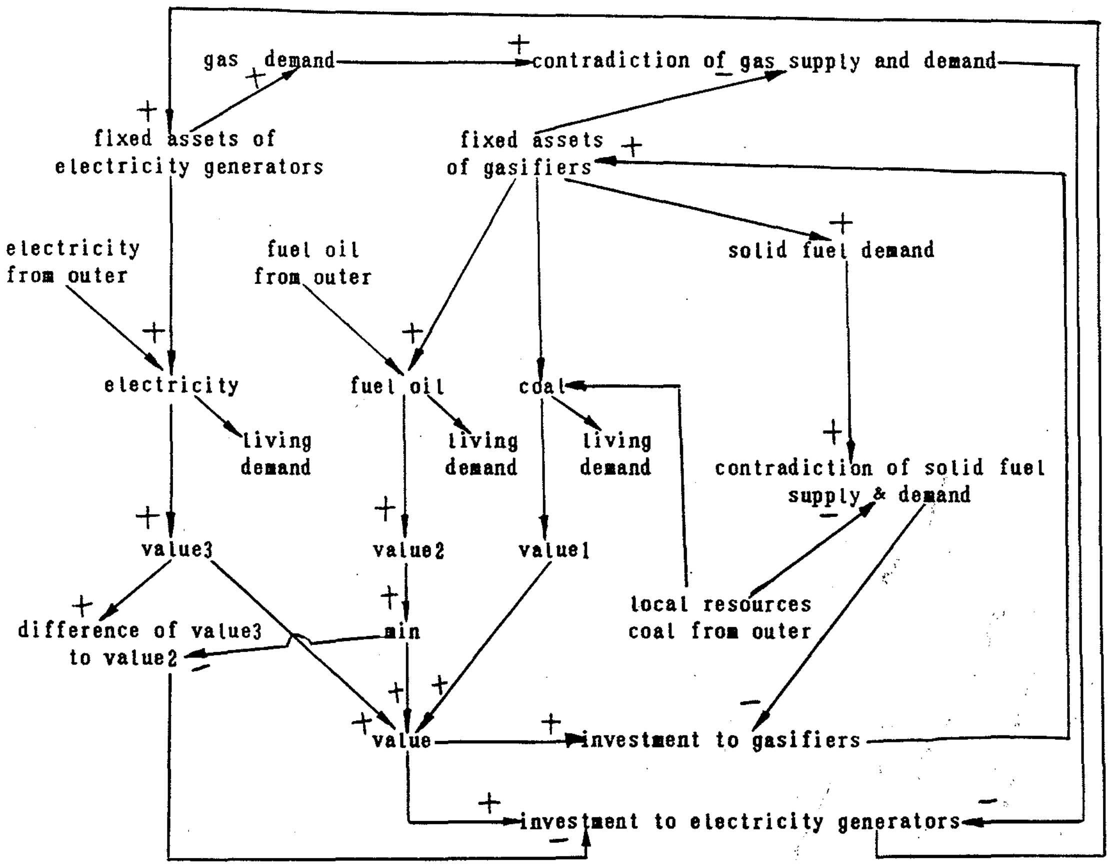

Figure 2 The Cause-Effect Relations Diagram of SD Model

The optimized model above developed with the data is put into computer and give the results, There exist optimum solution, value of target function i.e. cost of energy supply C=108,421 ¥, which accounts 6.93% of output value (1.56 mil ¥) of the village. The objective can be reached at by investment of ¥ 37,856 to energy conversional devices, accounting 2.4% of the output value. Of the investment, ¥ 8,166 to MHV gas producer with a capacity of generating 19,700 nm^3gas, ¥ 19,490 gas producer and system of duel-fuel engine & electricity generator with producing 114,600 kw.hr, no investment to biogas plant and diesel-electricity generator because of high cost of the plant and shortage of diesel. At the same time, it can save coal 147 tce, fuel oil 26.7 and electricity 2 tce. Computer also gives duel problem solution, objective row ranges and right hand side ranges, which can help analyze influence of demand to cost, cost to the system and resources & demand to the system.

The optimized structure is put into SD model this developed, which simulates on computer for 4 alternative plans and with the results that if commercial fuel oil and electricity supply doesn't increase while the quota of coal supply increases at the same rate as that of a few years ago (before 1990) (7%, Plan A), then, in the period of 1990-2030, only 0.71% of the output invested to energy conversional devices is required to keep the economic growth rate at about 6.8%, and by the year of 2030, the village would have conversional capabilities of producing 1.28 mil nm^3 MHV gas, 93,639 nm^3 biogas, 16.8 mil

nm^3 LHV gas and 2.88 mil kw.hr electricity; in case the rate of coal supply rises to 10% (Plan B), the investment needed increases to be 0.8% of the gross production value to keep a economic growth rate exceeding 9.2%, by the time of 2030, the village would have conversional capabilities of producing 6.99 mil nm^3 MHV gas, 241,570 nm^3 biogas, 36.6 mil nm^3 LHV gas and 6.59 mil kw.hr electricity. If the rate of commercial energy supply increases at the same pace as that of a few years ago (10% for fuel oil and electricity, 7% for coal, Plan D), an investment of 0.71% of the gross production value is required to keep the economic growth at the level of 10.7%, and by the time of 2030, the village would have conversional capabilities of producing 1.67 mil nm^3 MHV gas, 46,108 nm^3 biogas, 15.23 mil nm^3 LHV gas and 0.54 mil kw.hr electricity. Therefore, if commercial energy supply is sufficient, even in the form of coal alone, the economy would develop continuously at the same pace, with the prerequisite that investment for energy transformed devices is allocated accordingly and gas gasifiers be adapt to other kind of biomass and coal as well.

5. CONCLUSION

The SD model with additional optimized model is successfully operated on computer and gives results, which shows the rural energy system's developmental directions of the village.

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REFERENCES

1. Fang Zhen, "A Study on Biomass Pyrolysis gasifier and Its Application in Rural Energy Supply System", Phd Dissertation, Beijing Agricultural Engineering University (Aug. 1990) (in Chinese)
2. Fang Zhen et al., "Rural Energy Construction Developmental Planning in Beijing", the Academy of Sciences of China (1987) (in Chinese)
3. Fang Zhen et al., "Approach and Development of Technology of Utilization of Bioenergy", Energy of China, 1991 No. 11, pp.9-12 (in Chinese)
4. Fang Zhen, "An SD Model Applicable to the Study of Rural Energy Development Strategy in Beijing", Energy System and Policy, 1990 Vol. 14, pp.213-226
5. Qinhua University, Energy Planning and System Model, Qinhua Press (1983) (in Chinese)
6. Fang Zhen, "Rural Energy Development of Strategic Research in Beijing Area", Proceedings of the 1991 International System Dynamics Conference, pp.718-727
7. The Rural Energy Office of Tongxian County, "Rural Energy Planning Report in Tongxian", (1987) (in Chinese)