ECONOMICS OF THE UTILIZATION OF ELECTRICITY

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Electricity is a highly sophisticated and somewhat abstract form of energy. Once produced, usually from some source of thermal energy, electricity exists but a fraction of a second before being consumed in useful work. About 35 to 40 percent of the original thermal energy reaches the ultimate consumer. Taking competitive advantage of this situation, gas and oil interests are currently promoting the concept of delivery of energy in fossil fuel form to the consumer, with on-site conversion to electrical energy. Judicious use of thermal energy, normally wasted in the conversion process, permits overall theoretical efficiencies approaching 80 percent. The user of energy must therefore decide not only what form of energy to use at the point of utilization, but, if the choice is electricity, whether to purchase it directly or to produce it himself.

The choice of electricity at the point of utilization is mandatory for those devices that depend on the peculiar characteristics of electricity, such as electronic devices and clocks. Electricity may be chosen simply because building a fire is not convenient for such devices as toasters, irons, small motors and interior lights. Economics may dictate the choice of electricity or other energy sources for heating and cooling devices and large rotational loads.

Convenience, as well as economics, dictates that electricity be purchased for users of relatively small quantities of energy such as residences and small commercial establishments. For large users of energy, such as industrial plants and some large buildings, economics is the over-riding criterion for deciding whether to purchase electricity or to generate it locally.

The remainder of this paper is devoted to two presently important areas of energy source competition: first, the economics of local generation instead of purchased electricity for commercial buildings, and second, the utilization of electricity for environment conditioning.

ISOLATED GENERATION ECONOMICS

An isolated generation system currently being promoted for energy supply to commercial buildings consists of gas turbine or natural gas engine generation combined with a means of waste heat recovery. The generation supplies lighting, motor, and other miscellaneous electric equipment. The waste heat recovery equipment supplies various thermal requirements such as hot water,heating and steam absorption refrigeration machines for air conditioning. The economics will favor isolated generation only if the energy cost saving afforded by the isolated generation system, compared to conventional energy supply, more than offsets the additional capital expenditures required for the isolated generating and waste heat recovery equipment. The following economic analysis was performed in order to obtain a rough evaluation of the isolated generation concept.

A 64,000 square foot office building was selected for study to represent an average size office building requiring a typical rating of an isolated generation plant. Twelve major cities scattered throughout the United States were studied in order to represent different climates and relative rates for electricity and gas. The simple gas turbine system was selected because this system is being promoted at the present time as having the greatest long-range potential.

For each of the twelve cities, the two basic methods of energy supply which

are considered are summarized as follows:

Conventional: Electric utility supplying basic electric loads and electric drive refrigeration machines for air conditioning. Gas utility supplying in-building boiler which produces steam for heating, hot water, and other miscellaneous uses.

Isolated Generation: Gas utility supplying gas turbine generator units, which in turn supply electricity for the basic electric loads, and, through a waste heat boiler, supply steam for heating, hot water, steam absorption refrigeration machines for air conditioning, and other miscellaneous uses. All electric loads are supplied at a frequency of 60 c.p.s.

The isolated generation system consists of two normally operating turbine generator sets with a third set used as a spare. Generating frequency is 60 cycles per second. Each turbine generator set is rated at 254 KW with the following conditions: sea level, 70° F. inlet air temperature, two inches of water inlet pressure loss, and eight inches of water exhaust pressure loss.

Energy Cost Analyses

All of the energy cost analyses were made using a special digital computer program developed for that purpose.1 A simplified logic flow diagram of the computer program is shown in Figure 1. The program synthesizes the hourly steam and electrical loads in the building based on hourly schedules of building usages, building physical characteristics, hourly solar angles and radiation intensities and complete hourly weather data for each of the cities. The weather data is available in card or magnetic tape form from the United States Weather Records Center. Once the hourly loads are synthesized, the program simulates the operation of the conventional or on-site energy supply system in order to calculate hourly input energy requirements. The last step in the program is to apply specific utility rate schedules to the input energy requirements in order to determine monthly energy costs. This program is coded for use on an I.B.M. (International Business Machines) 7094 digital computer.

Annual Owning and Operating Costs

Additional equipment required for the isolated energy supply system is listed in Table 1. Two sets of cost figures are included: present prices based on current price estimates, and predicted prices based on the isolated generating concept achieving sufficient acceptance to result in high volume production of the gas turbines.

The annual costs of the capital expenditures required by the isolated generation system are based on a capital recovery factor of 8.7 percent which, in turn, is based on an amortization period of 20 years and a return of six percent on the undepreciated investment. An additional 2.5 percent is included for taxes and insurance. Thus the annual fixed charge rate is 11.2 percent.

The total annual owning and operating cost, excluding fuel, of the isolated system is the sum of the fixed charges and the maintenance costs, as listed in Table 2. This cost is then to be compared with the saving in energy cost associated with the on-site system.

Economic Results

The results of this economic analysis are shown graphically by Figure 2. The bar graphs represent the saving in annual fuel cost of the isolated generation

system compared to the conventional system. The horizontal lines represent the increase in owning and operating costs (excluding fuel) chargeable to the isolated generation system.

The results show that the isolated generation concept is not the economic choice in any of the twelve cities when considering present price estimates. Using predicted future production prices, the isolated generation concept would be the economic choice for this building in Chicago and Atlanta and would be marginal in Minneapolis, St. Louis and Jacksonville.

ELECTRICITY FOR ENVIRONMENT CONDITIONING

Electricity may be utilized for environment conditioning in two basic manners. Electrical energy may simply be converted back to thermal energy and directly used for space heating. Even though this energy reconversion is accomplished at 100 percent efficiency, the overall efficiency from the thermal energy at the power plant to the utilization point remains at 35 to 40 percent. Thus it is difficult for electricity to compete on a strictly energy cost basis with a fossil fuel system having an overall efficiency of about 65 percent. This situation is demonstrated by Figure 3A which shows the number of cities, out of a selected sample of 26, that have the indicated ratios of gas heating costs to electric heating costs for residences. The cost ratios apply to energy only and assume an overall gas system efficiency of 65 percent, and that a 10 percent savings can be realized with the electric heating system through the use of diversified temperature control.

One must be aware, of course, that the total economic picture includes first costs of the systems, differential structure costs and maintenance costs, all of which tend to favor electric resistance heating over a fossil fuel system. This is substantiated by the fact that electric resistance heating is quite commonly utilized in certain areas of mild climates, where, regardless of the competitive rate situation, total heating energy bills are relatively low.

Electricity is a uniquely convenient means of supplying rotational loads over a complete spectrum of magnitudes. Consequently the second means of utilizing electricity for environment conditioning is through the use of electric motor-driven refrigeration compressors. These devices may be either refrigeration units just for cooling, or heat pumps for both heating and cooling.

Electric motor-driven refrigeration units compete quite favorably with any other type of cooling on the basis of first costs and operating costs. Consider, for example, the 300-ton steam absorption and electric drive centrifugal refrigeration machines studied in conjunction with the isolated generation system reported previously in this paper. The steam absorption machine, compared to the electric-drive machine, required 7.25 times as much energy to the machine itself, 25 percent more auxiliary power, and cost over 15 dollars per ton more in first cost. Economically justifying the steam absorption machine would be difficult unless the steam or fossil fuel were very inexpensive by-products of another process, or the electrical energy were unusually expensive.

The heat pump improves, to a considerable extent, the ability of electricity to compete with fossil fuels on the basis of heating energy cost. This reverse-cycle refrigeration unit permits the utilization of free heat available from such mediums as the outside air. A typical performance factor for a residential air-source heat pump is two. This may be considered to be an annual efficiency of 200 percent, considering electricity as the only chargeable input energy source. The relative significance of the heating energy cost for a residential heat pump may be seen by Figure 3B. Since the heat pump is a central system, no savings is assumed for diversified temperature control. Note that the heat pump is

competitive on the basis of energy costs in about one-third of the cities. Because of first cost considerations, the heat pump is used primarily in areas where air conditioning is desired in addition to heating.

CONCLUSIONS

The isolated generation analysis presented in this paper is but one of many performed by the author on buildings ranging in size from under 100,000 square feet to over 500,000 square feet.1 Isolated generation has not proved to be the present-day economic choice in any of these studies. For isolated generation to have been economical would have required a higher than usual thermal load factor, and either none or relatively low financial return required on the additional capital expenditure.

Electric resistance heating is not generally the economic choice of space heating energy source in areas with an adequate supply of fossil fuels. In spite of the economics, however, electric heating is growing in use, seemingly because of the combined effects of general desirability and at least acceptable costs. Electricity is the economic choice in many areas over fossil fuels for environment heating and cooling through the use of a heat pump.

REFERENCES

1. "Building Loads and Energy Supply Simulation," R. F. Lawrence, R. F. Cook, A. D. Patton, IEEE Proceedings T-151, 1963, pp. 304-325. To be published in the IEEE Transactions.

2. "Economics of On-Site Generation," R. F. Lawrence, R. F. Cook, Proceedings of the 1963 American Power Conference.

TABLE 1 - ISOLATED GENERATION EQUIPMENT COSTS

	Quantity	TOTAL COSTS FOR QUANTITY REQUIRED Present	Production
Turbine-generator set complete with mounting arrangement, protection, inlet air cooler (evaporative) and controls. 254 KW output.	3	$ 179,800	$ 96,300
Gas booster, battery charger, gas compressor and storage tank for start-up	1	9,200	9,200
Boiler (differential cost)	1	8,000	8,000
Absorption refrigeration machine (differential cost)	1	4,700	4,700
Floor space (300 square feet)	1	6,000	6,000
Installation	1	25,000	25,000
Sub-Total		$ 232,700	$ 149,200
Engineering (7.5 percent)		17,400	11,200
TOTAL		$ 250,100	$ 160,400

TABLE 2 - ANNUAL OWNING AND OPERATING COST OF ISOLATED GENERATION SYSTEM EXCLUDING FUEL

Item	Present Cost	Production Cost
Capital Recovery[1]	$ 21,800	$ 14,000
Taxes and Insurance[2]	6,200	4,000
TOTAL FIXED COST	$ 28,000	$ 18,000
Turbine Maintenance[3]	1,800	1,200
TOTAL ANNUAL COST EXCLUDING FUEL	$ 29,800	$ 19,200

1. Six percent return, 20-year depreciation: 8.7%
2. 2.5%
3. $.15/turbine hour - present cost
   $.1/turbine hour - production cost

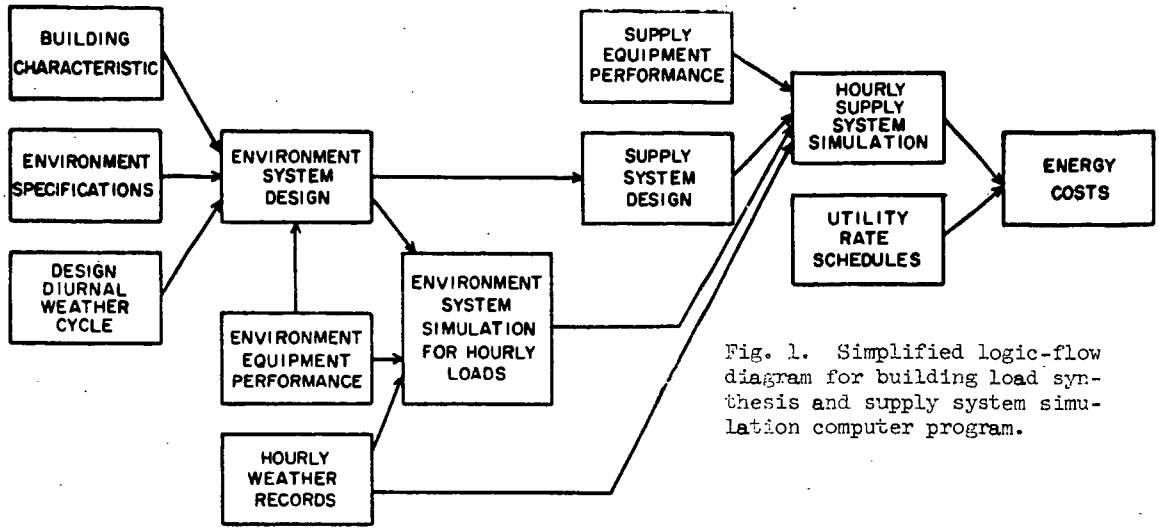
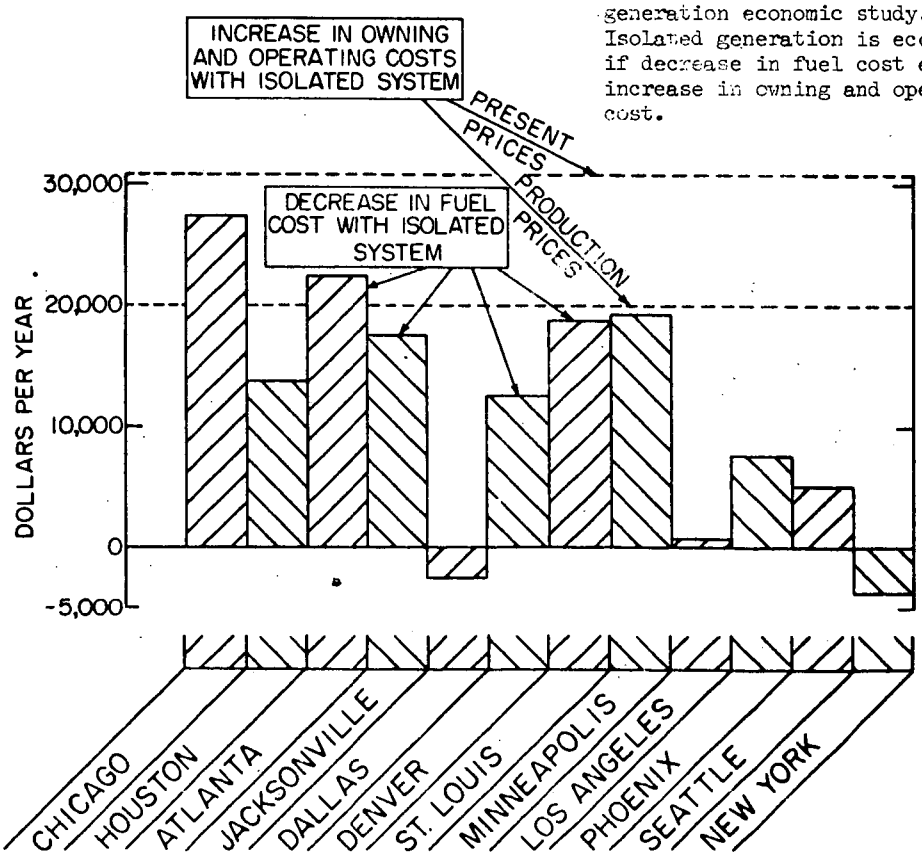


Fig. 1. Simplified logic-flow diagram for building load synthesis and supply system simulation computer program.

Fig. 2. Results of isolated generation economic study. Isolated generation is economical if decrease in fuel cost exceeds increase in owning and operating cost.



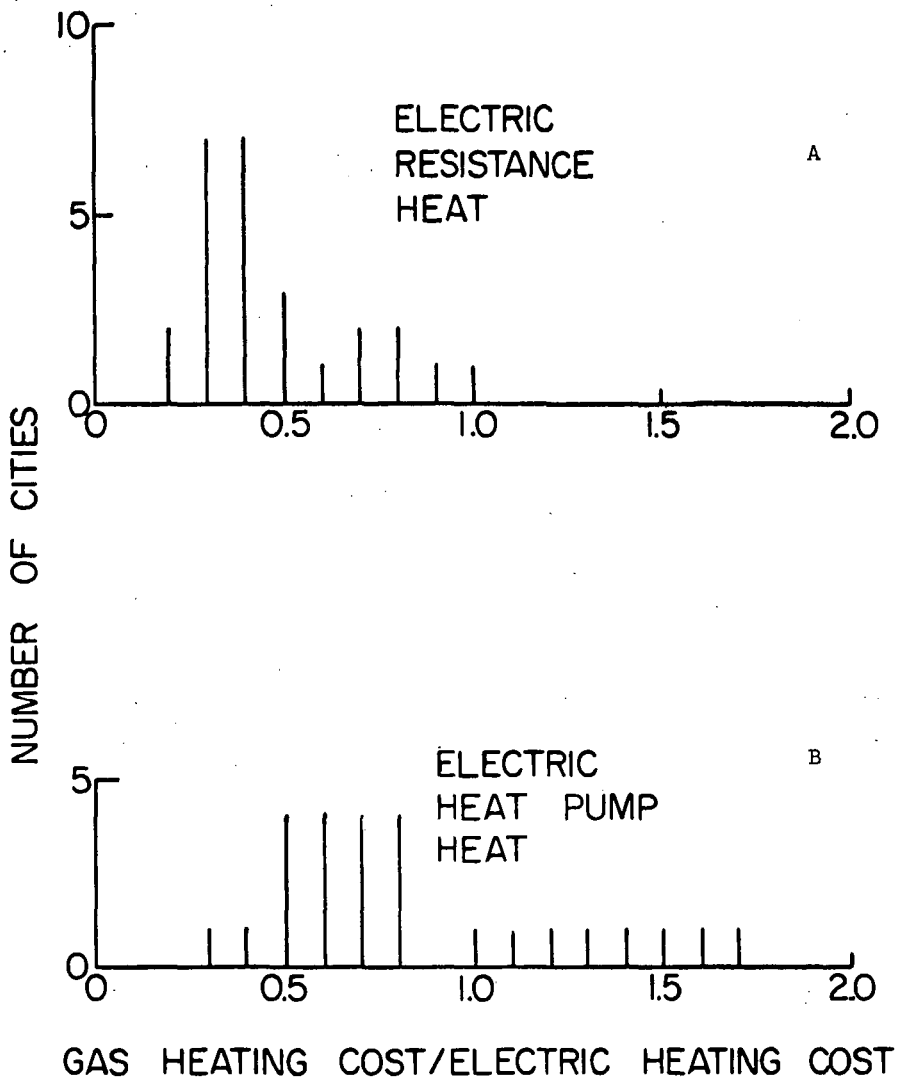


Fig. 3. Ratio of gas heating cost to electric heating cost for 26 U.S. cities. A - Resistance heat. B - Heat pump heat.