SPURR ---- SYSTEM FOR PROJECTING UTILIZATION OF RENEWABLE RESOURCES

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The METREK Division of The MITRE Corporation has developed a computerized System for Projection of the Utilization of Renewable Resources --SPURR. SPURR is an annual simulation model used to study the market penetration of new energy technologies such as distributed and centralized solar energy conversion systems.

This model is intended to fill the gap between the aggregate national energy models[1,2,3] and the uncoordinated analyses of individual applications, e.g., solar hot water heating. The level of detail and modeling structure has been selected to permit analysis of the critical issues involved:

- The dynamic nature of the growth
- The techno-economic description of a wide range of conventional and new systems
- Cost reduction from mass production and accumulated experience
- The interface between the utility and the energy consumer
- Market segmentation and behavior

BACKGROUND

Development of the SPURR model began in 1974 under a contract for the National Science Foundation that was subsequently transferred to the Energy Research and Development Administration (ERDA). This version formed the basis for the SOLARIS model used in a study for the Federal Energy Administration (FEA) on the commercialization of centralized solar energy conversion systems.[4,5] SOLARIS, with the associated data base, simulated regional market competition among conventional fossil- and nuclear-fueled electric generating systems and the centralized solar technologies--wind energy conversion, photovoltaics, solar thermal, ocean thermal, and bioconversion of forest and agricultural residues. The study was completed in January 1976.

The current work on the SPURR model for the Division of Solar Energy at ERDA expands the utility applications to include the production of substitute natural gas (SNG), adds the distributed solar technologies as applied to agricultural and industrial processes (AIP) and solar heating and cooling of buildings (SHACOB), and includes the interactions among the utility and distributed applications. This work is expected to be completed in early 1977. Additional applications of the SPURR model include a cost/benefit analysis for ERDA's Division of Geothermal Energy and a study for FEA on the Wind Energy Commercialization Program.

The Federal government is able to influence the develoment of new energy technologies through research, development, and demonstration programs and through commercialization efforts aimed at manufacturers and buyers. The interactions of these efforts are shown in Figure 1.

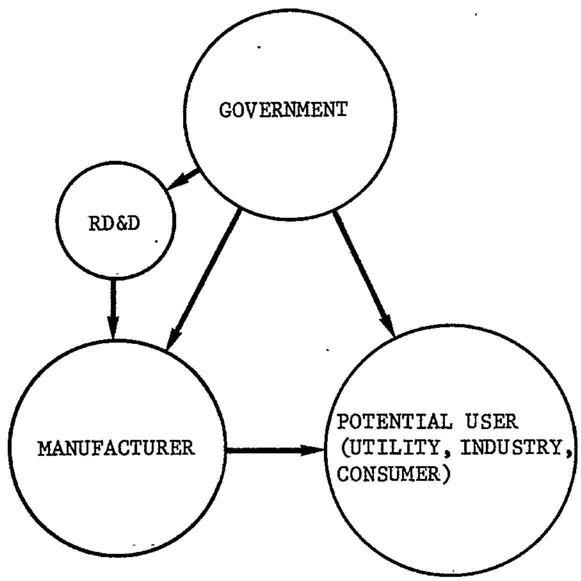
The purpose of the SPURR model is to assist government program directors in planning their RD&D programs. By modeling the dynamic growth characteristics of emerging energy technologies and the interactions among the distributed and utility sectors, the effects of government programs in research, demonstrations, tax incentives, and subsidies can be studied.

OVERVIEW

SPURR is an annual simulation model that includes regional analyses and experience curves to project impacts of centralized and distributed energy systems. Regional analyses allow the model to account for regional variations in

FIGURE 1

GOVERNMENT ROLE IN THE DEVELOPMENT OF NEW ENERGY TECHNOLOGIES

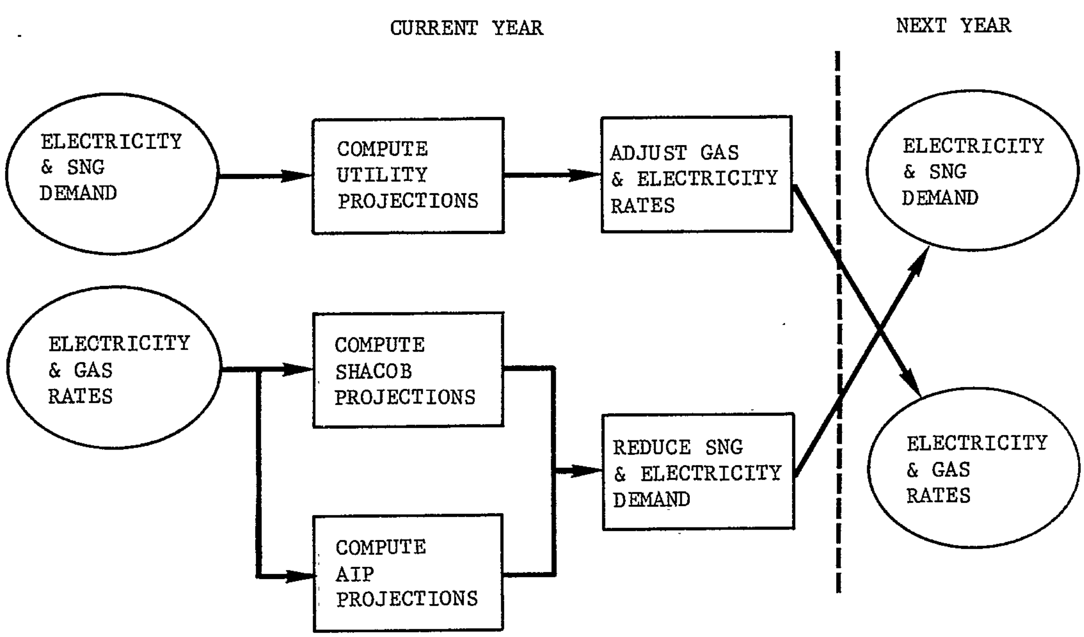


insolation and wind and for differences in the costs of fossil fuels, construction, and operation and maintenance. Experience curves reflect reductions on selected components of new systems as a function of cumulated experience. That is, projections of the utilization of solar components, such as solar flat plate collectors and photovoltaic cells, result in price reductions on these components in subsequent years as manufacturers gain experience. Hence, utilization of a system in regions with favorable climatic conditions can cause price reductions that will make the system competitive in other regions in later years.

The utility component of the SPURR model projects conventional and solar generation of electricity and SNG. Similarly, in the two distributed components, AIP and SHACOB, the use of solar energy in these applications is projected. At the end of each simulated year, the results of the utility component are used to update the regional cost of electricity and gas used by the distributed components to project solar market penetration; and the projected use of solar energy by the distributed applications is used to reduce future demand for electricity and gas to be supplied by the utilities. This interaction is shown in Figure 2.

FIGURE 2

INTERACTION BETWEEN UTILITY & DISTRIBUTED APPLICATIONS



Market allocation is simulated separately within each major component--utility, AIP, and SHACOB--for each year as shown in Figure 3. First the market is divided into segments with similar characteristics and the competitive system costs computed for each segment based on

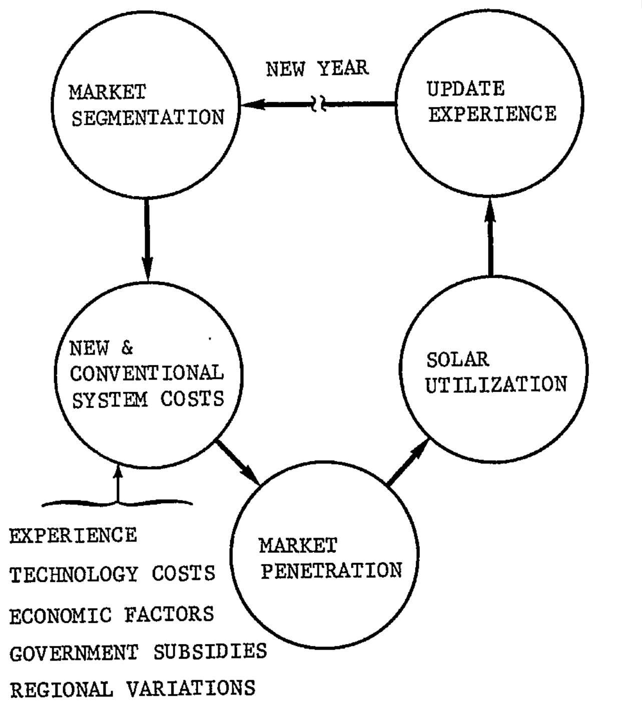
- Technology costs including experience
- Regional variations in climate and fuel costs
- Inflation, cost of capital, and taxes
- Government subsidies

Different market penetration algorithms are used for each major component to compute the market shares within each segment. Finally the projected utilization is reflected back into the experience curve.

One of the most challenging areas in the development of the SPURR model has been how to allocate the demand among the competing technologies. There is a substantial body of literature on the penetration of a single new technology into an existing market. However, this theory is not adequate to cover the utility market where several new technologies compete with several conventional systems, or the SHACOB and AIP market where the solar energy systems must compete with conventional systems using different fuels of varying costs (all of which seem to get a share of the market regardless of the economic implications). A brief description will be given of the market segmentation, technology costing methodology, and market allocation algorithm for each of the three major components.

FIGURE 3

METHODOLOGY FOR PROJECTING UTILIZATION WITHIN EACH COMPONENT



UTILITY COMPONENT

In the utility component the market is segmented by region and demand type. SPURR currently uses the nine census regions; however, other regional breakdowns can easily be incorporated. The demand types used are SNG and base, intermediate, and peak electric. The subdivision of electric demand is required to compensate for the daily and seasonal variations in demand. The utility system must be configured to satisfy the annual energy requirements as well as provide sufficient capactiy to meet the maximum power requirement. This variation in demand is depicted by a load duration curve for a typical utility, as shown in Figure 4. With today's technology, three generic systems are used in combination to satisfy this demand. Expensive, highly efficient coal and nuclear plants satisfy the base load; older base load plants and oil plants satisfy the intermediate load; and cheap, but less efficient, gas turbines satisfy the peak load.*

Systems supplying peak and intermediate energy demand have capacity factors of approximately 0.23 or 0.45 respectively, representing the portion of the time they are used. Baseload systems have a capacity factor of around 0.7, which is determined by the availability of the system rather than the demand. Solar electric systems, if they are to fit into this framework, must be available when needed (rather than when the sun shines or the wind blows). This means they must be configured with sufficient storage or as a hybrid solar/conventional system having an availability equivalent to the standard conventional units. Solar electric systems operating alone without storage, known as fuel savers, are given special treatment by the SPURR model and are discussed later.

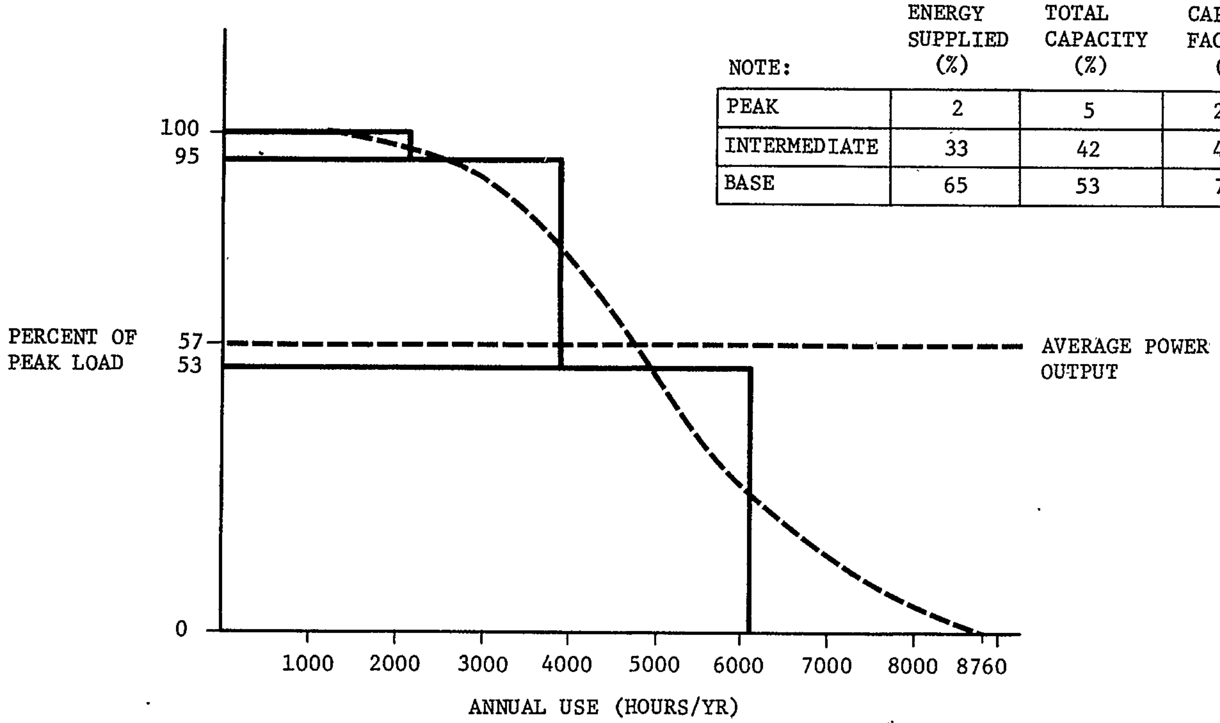
For each market segment, a financial analysis based on the life-cycle cost and annual energy production is performed to determine a levelized energy cost (mills/kWh on $/MBtu) for each conventional and solar technology.[5] A probability distribution of energy cost is constructed using estimates on the variability of capital, operations and maintenance, and fuel costs. The probability distributions are assumed to be triangular as shown in Figure 5 and are used to assign a probability of least cost to each technology.[7]

The existing demand in each market segment is then allocated to the technologies based on an algorithm using the probability of least cost, S-curve constraints, and capacity constraints. Probabilistic least cost allows for uncertainty in technology costs, which includes a certain

*For a more extensive discussion of utility load management see reference 6.

FIGURE 4

LOAD DURATION CURVE AND DEFINITION OF BASE, INTERMEDIATE & PEAK LOADS



NOTE:

	ENERGY SUPPLIED (%)	TOTAL CAPACITY (%)	CAPACITY FACTOR (%)
PEAK	2	5	25
INTERMEDIATE	33	42	45
BASE	65	53	70

element of risk. The S-curve constraints limit the early entry of new systems into the market. The capacity constraints are used primarily to limit the government subsidy programs but can also be used to constrain expansion because of limits on manufacturing capacity.

SHACOB COMPONENT

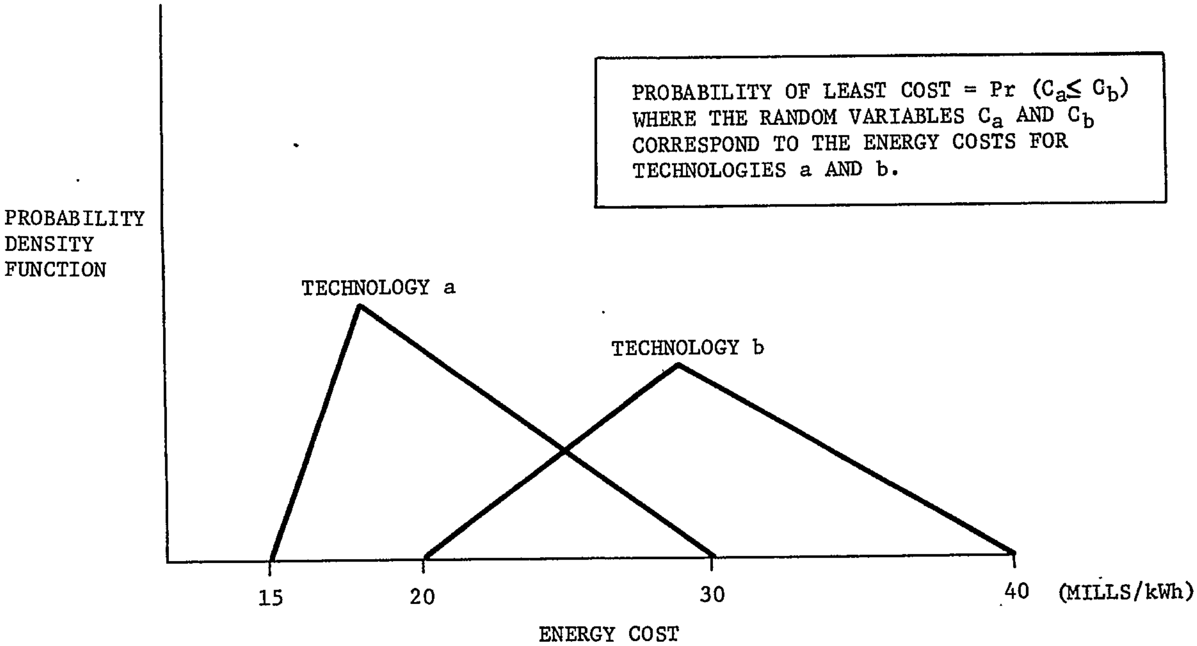
In the SHACOB component the market segmentation is by 9 building types, new and retrofit systems, 15 climatic regions, and 3 applications (hot water; hot water and heating; and hot water, heating, and cooling). For each market segment, the market shares for 3 to 5 conventional systems are included in the model inputs to incorporate the regional availability of fuels and the emergence of other new technologies such as the heat pump.

A figure of merit for each conventional system within a market share is calculated and compared to a figure of merit for an optimal solar heating and cooling system. The figure of merit is a weighted sum of the initial cost, life-cycle cost, and a risk factor that includes the number of systems installed in the region and the nation. Market shares are then estimated based on an assumed functional relationship between the relative figure-of-merits.

The optimal solar system with backup and auxiliary storage is determined through the use of design charts by selecting a collector area that minimizes life-cycle costs. The design charts were developed through extensive simulations[8,9] and incorporate regional climatic data, collector performance, and building energy demands.

FIGURE 5

PROBABILITY DISTRIBUTIONS FOR COMPETING TECHNOLOGIES



AIP DEMAND

The market penetration analysis was considerably simplified for the AIP component because of a lack of reliable data. The market is first segmented according to application (such as crop drying, cement curing, etc.), region, and competing fuel type. The installed cost per square foot of collector (with no backup) is then compared against the fuel cost. The solar market share is then determined as a function of the ratio of solar cost to fuel cost and years since market entry of the new system.

FUEL SAVER

In the utility component the fuel saver systems are treated separately since they are assumed to provide no credit toward system capacity. A fuel saver must be justified by the fuel savings of systems that are not used when the "fuel saver" is available. The value of the fuel savings will depend on whether it occurs during the peak, intermediate, or base demand. The fuel savings are computed from the load duration curve and the availability of the fuel saver. This method is illustrated for a wind fuel saver which is assumed to be randomly available 50 percent of the time (based on wind statistics). From the load duration curve shown in Figure 4 it can be seen that the utility is using only base load systems 53 percent of the time, base and intermediate 42 percent, and all three systems 5 percent. Combining this with the fuel saver availability, the annual savings for a 1 kW fuel saver system are

Base	2321 kWh
Intermediate	1840 kWh
Peak	219 kWh

In many utility systems, the baseload plants are not suitable for intermittent operation; e.g., nuclear plants take days to stabilize. Thus we do not assume any savings during the baseload hours, but will assume that the intermediate and peak plants can be cycled without any loss of efficiency.

Next the value of the fuel saved is computed. Using the expected fuel use rate of systems being displaced by the fuel saver (this fuel use rate is generally higher than for the new conventional systems since older, less efficient plants are shut down first) and the corresponding fuel costs, the annual savings is computed. From this a breakeven capital cost for the fuel saver is determined.

Since both the fuel savings and wind system capital costs have a range of values to represent uncertainty, a probabilistic least cost analysis is applied to determine the level of market penetration. Two additional factors are used to limit the size of the potential market. One is a limit based on the assumption that most utilities would not have more than 5 to 10 percent of their total installed capacity coupled with fuel savers. The other is a decrease in the fuel use rate as more fuel savers are added and the newer systems are being cycled more.

REPORTS

The results of each simulation are summarized and a transaction file generated for further detailed analysis. The summary reports contain national impacts, the amount of solar equipment in operation, solar energy utilized, and the private and Federal expenditures. The transaction file records the simulated technology utilization and can be sorted based on keywords to provide a variety of reports. This feature has been employed because of the extreme detail of the simulation and the large range of potential data aggregation and output formats.

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