Title
SYSTEMS SIMULATION AND ECONOMIC ANALYSIS FOR ACTIVE SOLAR COOLING

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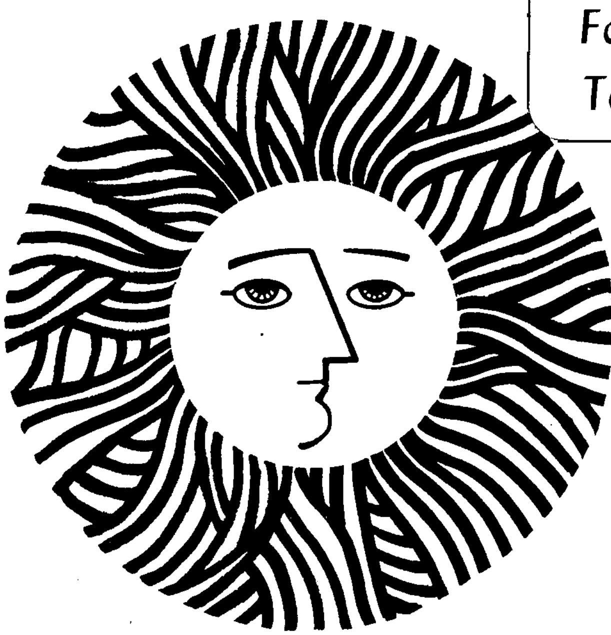

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SYSTEMS SIMULATION AND ECONOMIC ANALYSIS FOR ACTIVE SOLAR COOLING*

LAWRENCE BERKELEY LABORATORY

UNIVERSITY OF CALIFORNIA

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Contract No. W-7405-ENG-48

OBJECTIVES

The LBL system simulation and economic analysis program has four principal objectives:

- To perform economic analysis to establish cost/performance goals for active solar cooling/heating systems.
- To review and to perform analysis using TRNSYS and other simulation codes for evaluation of active solar space cooling and heating systems.
- To provide a library for chiller, storage, and other component models developed for TRNSYS for solar cooling applications.
- To provide limited technical support as part of the Department of Energy solar cooling and heating R & D program. Program support tasks include program planning, preparation and evaluation of solicitations, proposal review, and technical monitoring of system simulation and economic analysis contracts.

DESCRIPTION OF WORK

The attainment of reasonable market penetration of active solar cooling systems, beginning with introduction of commercial units in the late 1980's and continuing through the 1990's, can be related to meeting certain cost goals for these systems. A principal objective of the work at LBL has been to develop a methodology to establish realistic cost goals for active solar cooling/heating systems, and to establish preliminary cost goals for representative solar air conditioning systems.

In general, air conditioning demands are expected to grow significantly over the next 20 years, driven by population shifts to the "sun belt" regions of the country. It is estimated that over 90% of the new construction in this region will have central air conditioning. Energy conservation and passive cooling measures are expected to reduce significantly the sensible cooling and heating loads. However, the substantial latent (i.e., humidity) cooling loads in all buildings and internal heat gains in commercial buildings will remain and will require the use of mechanical cooling systems.

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Economic Performance Goals. Certain cost and economic performance goals must be achieved by the solar industry before market demand will rise to a level that will produce the desired market penetration. Marketing studies[1] indicate that for heating and air conditioning products the relationship between market penetration and payback period is as shown in Figure 1. The payback period, the number of years for the undiscounted fuel cost savings to equal the incremental cost to produce those savings, is related to a real return on investment. Postulating market penetration goals per year necessary to achieve 20% annual penetration by the year 2000, the corresponding payback and return on investment goals as a function of year of purchase have been calculated and are shown in Figure 2.

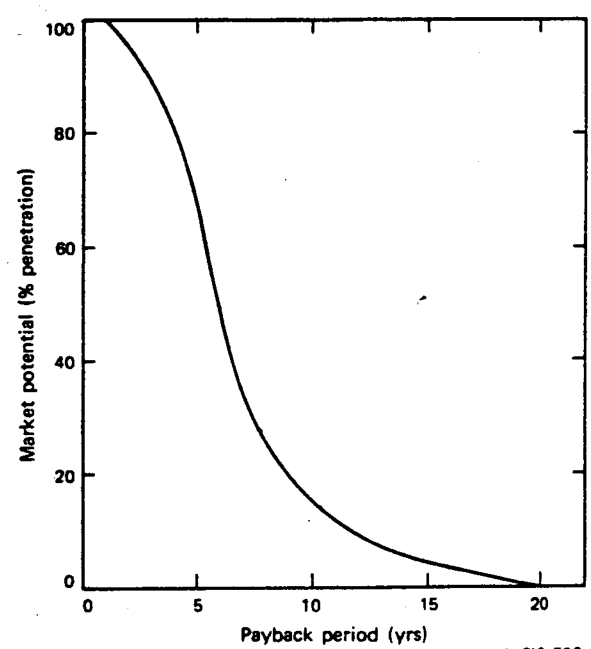

Figure 1. Market potential as a function of payback period.

Thermal Performance Analysis. Annual system simulations of the thermal performance of active solar Rankine and absorption cooling/heating systems have

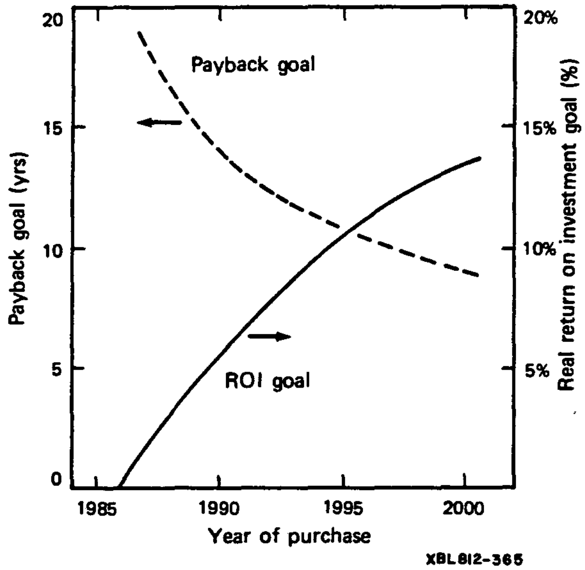

Figure 2. Payback goal and real return on investment (ROI) goal as a function of year of purchase to reach a 20% market penetration in the year 2000.

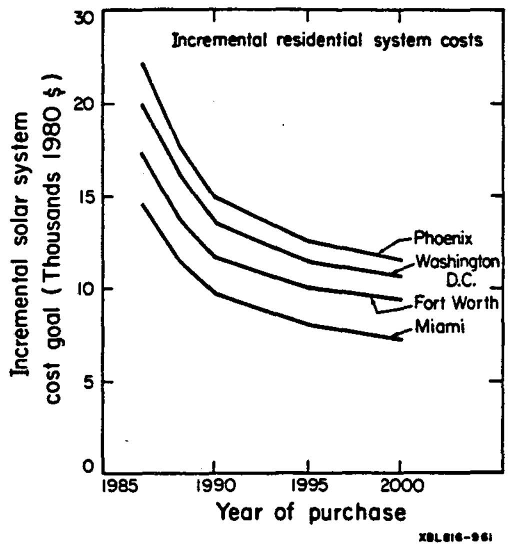

Figure 3. Incremental solar system cost goals (1980$) as a function of year of purchase for a 3 ton residential cooling/heating system without tax credits assuming a 20% market penetration by the year 2000.

been conducted by SAI using TRNSYS.[2,3] These calculations have been carried out for residential solar cooling/heating systems in four cities (Fort Worth, Phoenix, Miami, and Washington, D.C.) and for commercial solar cooling-only systems in three cities (Fort Worth, Phoenix, and Miami) which are representative of the cooling market. Three types of systems were evaluated: residential 3 ton absorption (ARKLA), commercial 25 ton absorption (ARKLA), and commercial 25 ton Rankine (AiResearch).

Incremental Solar System Cost Goals. It is assumed that a solar cooling or cooling/heating system is cost-effective when the incremental solar system cost is equal to (or less than) the present value of the energy savings. The present value over the life of the system (20 years) of the fuel saved by an active solar system has been calculated and is a function of the fuel escalation rates and the expected real return on investment. Details of the analysis are presented elsewhere. [4,5].

Combining these calculations of the incremental solar system cost as a function of real return on investment with the real return on investment goals as a function of year (as contained in Figure 2), incremental system cost goals as a function of year have been generated for residential solar cooling/heating systems and are displayed Figure 3. Similar analysis has been performed for commercial solar cooling systems.

Subsystem Costs. The total solar cooling system cost goals for different locations can, in turn, be subdivided into subsystem cost and performance goals. It is anticipated that the major reductions in subsystem costs will be achieved by technical improvements in subsystem performance (e.g., increased chiller efficiency resulting in reduced collector subsystem array size), by volume production economies, and by improved packaging that will reduce system engineering and installation costs. Preliminary subsystem cost estimates for a residential system are shown in Figure 4. These values are based on estimates of current subsystem costs plus expectations for subsystem cost and performance improvements. Similar analyses have been done for commercial absorption and Rankine systems.

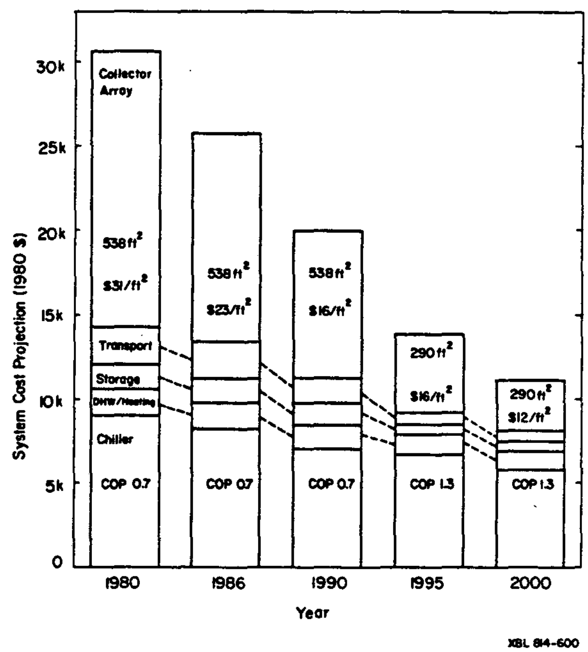

Figure 4. Preliminary solar system cost projections for a 3 ton residential absorption cooling, heating, and hot water system, showing breakdown into subsystem costs.

Collector Array Costs. The collector array is one of the major cost items of any active solar cooling system. The key to cost effective cooling systems is reducing the collector array costs. For residential systems with less that about 50 m^2 (500 ft^2) of collector, the collectors are mounted directly on the roof, and no support structure is usually needed. For commercial systems a support structure is needed.

For the high temperature, high COP future scenario, either evacuated tubes with reflectors or cylindrical trough collectors will likely be used. Collector manufacturing costs of $14/$ft^2$ have been projected[6] for evacuated tube concentrating collectors. A key to low cost collectors is the use of light weight and inexpensive materials. The Low

Cost Collector Program has recently projected[7] the manufacturing cost of a linear trough collector with a light-weight reflector and iron pipe absorber at $6-8/ft^2.

It may be possible to achieve system and subsystem cost goals using current chiller technology, with a COP of 0.7 and operating temperatures below 200^{o}F, if very low cost, (about $6/ft^2) good performance collectors can be developed. "Good performance" in this context means an efficiency of about 40% to 50% at a typical absorption chiller driving temperature of about 185^{o}F. Work underway at Brookhaven National Laboratory[8] is directed toward the development of solar collectors that may meet these cost and performance requirements. A recent evaluation of the potential for cost reduction indicates that with automation and a production volume of greater than 200,000 panels per year in a single facility, the cost of evacuated tube collectors can be reduced to $6.50/ft^2.[9]

Summary

A consistent methodology has been developed by which general solar cooling market capture goals have been translated into specific cost and performance goals for solar cooling systems and subsystems. Preliminary results indicate that realistic cost/performance goals can be established for active solar cooling systems and that, with aggressive development, these goals can be reached by the year 2000. As the technology develops, tax incentives will be required to bridge the gap between the actual costs and the cost goals, so that the scenario of an ever increasing share of market penetration can be maintained over the 1986 to 2000 time period.

It must be emphasized that the actual numbers used so far -- although the best numbers available at this time -- are nonetheless still preliminary. Efforts are currently underway to acquire better estimates of the market penetration vs. payback relationship, better estimates of cost and performance projections, and more realistic systems analysis models of the thermal performance of the cooling systems.

Finally, this methodology for establishing cost goals and developing cost and performance improvement pathways to reach those goals is not limited to active solar cooling applications. It could equally well be used for other technologies such as passive cooling and heating.

TECHNICAL ACCOMPLISHMENTS

- Developed preliminary cost/ performance goals for active solar cooling/heating systems.
- Produced a background report describing methodology for developing cost/performance goals.
- Worked with other contractors performing systems analysis work to characterize realistic buildings and active solar cooling systems for simulation.

FUTURE ACTIVITIES

Continue to work with other systems analysis contractors in developing realistic models of active solar cooling systems.

Continue to develop inhouse capabilities for systems simulation and economic analysis for active solar cooling.

Develop a library of chiller, storage, and other component models developed for TRNSYS for solar cooling applications.

Refine the calculation of cost goals and cost projections for active solar cooling systems, using better estimates of market penetration curves and better estimates of subsystem cost and performance improvements.

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CONTRACT INFORMATION

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Total of contract: $100k.

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