REPORT BY THE U.S.

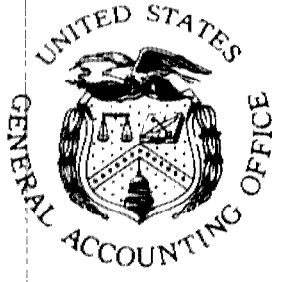
General Accounting Office

Building Energy Analysis Computer Programs Developed By Federal Agencies--Cost, Use, And Need

Six energy analysis computer programs have been developed by Federal agencies at an estimated cost of $8.1 million. A seventh program was also developed, but cost was not available due to the age of the program. Only two of the programs are used with any degree of frequency in the design of buildings and two are not used at all, as far as could be determined.

There are now a sufficient number of acceptable energy analysis computer programs available to meet Federal needs. Therefore, GAO questions the need for further Government development of such programs. Currently, only the Department of Energy is actively involved in development efforts. GAO recommends these efforts be terminated.

This report was requested by Senator Tsongas and Congressman Studds.



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UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

PROCUREMENT, LOGISTICS,
AND READINESS DIVISION

B-206468

The Honorable Paul E. Tsongas
United States Senate

The Honorable Gerry E. Studds
House of Representatives

In response to your March 26, 1981, request, we have examined several issues relating to energy analysis computer programs developed by the Federal Government. Your particular interests were the

--total cost to the Government to develop building energy analysis computer programs,

--uses being made of these programs,

--rationale for selecting a Government-developed program as the Building Energy Performance Standards (BEPS) evaluation technique for calculating energy consumption in buildings, and

--continuing need for the Government to develop these types of computer programs.

You also asked us to examine issues raised by your constituent concerning the need for the parallel development of energy analysis computer programs by the Department of Energy (DOE) and the Department of Defense (DOD).

In summary, we identified seven energy analysis computer programs (see app. I) developed with Federal funds since fiscal year 1965. Since 1967 eight Federal agencies have spent an estimated $8.1 million to develop six of these seven programs. We were unable to obtain an estimated development cost for the oldest of these programs, which began before 1967. Only two of the programs are used, with any degree of frequency, in the design of buildings and two are not used at all, as far as we could determine.

DOE officials did not believe it would be appropriate to use a proprietary program as the BEPS evaluation technique because such a program is not open to public scrutiny.

Regarding the need for the Government to continue developing building energy analysis computer programs, we believe

there is now a sufficient number of acceptable energy analysis computer programs to meet Federal agencies' needs. Further, Federal officials in all agencies contacted, except DOE, told us there was no longer a need for the Government to continue developing such programs.

SCOPE, OBJECTIVES, AND METHODOLOGY

Initially, we contacted your constituent to discuss his concerns in depth. We made an extensive literature search to identify the federally funded energy analysis computer programs to be included in our review. The seven programs we identified were discussed with appropriate officials in those agencies that funded, or were funding, these programs. The agencies funding the programs were DOD (Army Corps of Engineers and the U.S. Air Force), DOE, the Department of Housing and Urban Development, the General Services Administration, the National Aeronautics and Space Administration (NASA), the National Bureau of Standards, the United States Postal Service, and the Veterans Administration. We did not review computer programs designed strictly for solar system simulation and analysis because they are specialized and are usually intended for analysis of specific solar systems.

At each agency, we discussed its program, the purpose of the program, the justification for its development, uses being made of the program, and its development costs. We also contacted contractors who developed the programs for the Postal Service and DOE to obtain data which could not be obtained from the agencies. In evaluating the need for each new program, we considered the time of its development and the availability of suitable programs to meet agency needs at the time the development began. Where possible, we obtained program development justification and development costs. On the older programs, cost information was often not available, and therefore, we estimated the costs using information provided by the applicable agencies. We also obtained user lists from NASA, the National Bureau of Standards, and the Corps of Engineers. The other agencies were unable to provide user lists.

DOE officials advised us that they did not have a list of users because many of their users use the DOE-2 program through commercial service bureaus. However, they were able to provide a list of interested parties which are on their DOE-2 mailing list.

We contacted 29 firms on the three user lists to discuss their use of four of the seven programs. Some of the firms had also used some of the other programs, including DOE's program. We also visited the Army Construction Engineering Research Laboratory, Champaign, Illinois, to discuss its development of the

Army's Buildings Load Analysis and System Thermodynamics (BLAST) program.

BACKGROUND

A building energy analysis computer program is used to (1) simulate the thermal (heating and cooling) loads of buildings and building systems and (2) estimate the annual energy usage for heating, cooling, lighting, and other factors, based on equipment selection and thermal loads. Virtually all available energy analysis programs

--determine peak and hourly loads;

--calculate air-handling requirements;

--simulate heating, ventilating, and air-conditioning systems and equipment; and

--analyze energy consumption.

Since 1965 there has been a rapid increase in Federal and private energy analysis computer program development. This increase has been caused, in part, by rapidly escalating fuel and energy costs following the 1973 oil embargo, emphasis on improved building design for energy conservation, and the failure of existing programs to meet Federal needs. From the earliest federally funded programs--the National Bureau of Standards Load Determination program and the Post Office program--have emerged more sophisticated public domain and private proprietary programs to handle more complex building configurations and more complex heating, ventilation, and air-conditioning systems and equipment. Generally, users have access to available energy analysis programs through purchase or lease, or they can obtain access from service bureaus through time-sharing or batch processing services, or they can write their own proprietary programs.

In 1976 the Congress enacted the Energy Conservation Standards for New Buildings Act (title III of Public Law 94-345, Aug. 14, 1976), recognizing the need to conserve energy in building operations and the potential for savings through conservation. The act required building energy performance standards be developed to increase the energy efficiency of new residential and commercial buildings. DOE subsequently developed proposed standards, BEPS, and designated its own DOE-2 computer program as a benchmark energy analysis program to be used to evaluate compliance with the standards.

COST TO DEVELOP PROGRAMS

We identified seven federally funded energy analysis computer programs. We estimated that eight agencies spent

nearly $8.1 million to develop six of these seven programs. Cost data was not available for the National Bureau of Standards program due to its age and because its development was interwoven with other agency objectives and activities.

DOE has spent, by far, the most of any Federal agency on an energy analysis program. Available cost data shows that DOE has spent at least $4.8 million on three versions--CAL-ERDA, DOE-1, and DOE-2--of its program. This represents 60 percent of the total spent to date by all Federal agencies for the six programs for which cost data was available. Furthermore, DOE estimates it will need an additional $1.4 million to complete its planned program development efforts, including documentation and verification. DOE's fiscal year 1982 budget request contains about $910,000 for DOE-2, and DOE anticipates requesting $500,000 for fiscal year 1983 to increase program capabilities, update user manuals, complete reports, and perform experiments and tests. Appendix I shows a recap of the development costs, by program, for the six programs.

USES MADE OF FEDERALLY DEVELOPED PROGRAMS

All seven programs are available to the public, but only two--the Army's BLAST program and the DOE-2 program--are used with any degree of frequency in building design by the Federal or private sector. Users consist of architect/engineer firms, energy consultants, universities, and other Federal agencies. The Veterans Administration Energy Program and NASA's Energy Cost Analysis Program are also used as design tools, but they are used primarily in-house. The National Bureau of Standards Load Determination program was originally developed as a research tool, but some design firms use it for load calculations. Both the NASA and the National Bureau of Standards programs have been used to develop other programs; BLAST and DOE-2 both evolved from these two programs. The Post Office program and the NASA Energy System Optimization program are not being used, as far as we could determine, and both are no longer supported by the agencies and have been abandoned. However, the Post Office program was useful in that most of the existing energy analysis programs evolved directly or indirectly from it. It is considered the grandfather of energy analysis programs.

In some instances, the Air Force has required the use of BLAST on projects, and the Army and the General Services Administration are considering making BLAST mandatory for building energy analyses. We question the advisability of requiring the use of any particular program on all projects because the user of a program should understand (1) how the program functions and (2) how to interpret the program's output. Also, because each program makes certain assumptions and compromises, no one program is best for all types of buildings and building systems. It is doubtful that requiring

the use of a particular program will result in quality design in all cases. We have previously questioned requiring specific energy analysis programs on Federal projects. In our October 15, 1980, report (LCD-81-7), we recommended that agencies require computer capabilities and expertise to be considered and evaluated when selecting architects and engineers for projects on which computer-aided methods, such as energy analyses, can be used. DOD expressed strong concurrence with this recommendation when commenting on this report. We also recommended that during contract negotiations, agencies routinely discuss and evaluate planned uses of computers during the project, including the appropriateness of the energy analysis program the firm plans to use during the design.

In commenting on the draft report, an official in the office of the Deputy Assistant Secretary of Defense, Facilities, Environment and Economic Adjustment, acknowledged that requiring the use of BLAST on all DOD projects could

--in some instances, restrict competition on design contracts;

--increase contract costs; and

--prohibit the use of new and innovative tools which DOD might want used.

He said that DOD was drafting changes to its construction criteria manual, which will probably state that projects "shall be analyzed using BLAST, or one of the other professionally recognized and proven energy conservation design computer programs."

Appendixes II through VIII provide pertinent cost, description, and usage information for the seven programs.

SELECTION OF DOE-2 TO MONITOR BEPS COMPLIANCE

When faced with proposing an evaluation technique to determine compliance with BEPS, DOE chose to use a computer program, rather than to develop some other type of evaluation procedure. DOE eliminated proprietary programs from consideration early in the selection process because they would not be available for public scrutiny. DOE chose its own program over the Army's program, which also was considered technically acceptable. DOE's proposed evaluation technique was widely criticized during public hearings in 1980 on the proposed BEPS regulations.

While some alternatives were discussed, current DOE officials were unable to provide us with complete information on the alternatives DOE considered as possible techniques to use

for BEPS compliance evaluations when the decision was actually made. Consequently, we cannot comment on whether DOE adequately considered other available alternatives. The selected technique, public domain computer programs, has weaknesses, such as lack of control over modifications, which could also limit the program's effectiveness as a regulatory tool. DOE officials acknowledged that there are drawbacks with public domain programs, but believe that this was the best available alternative.

Naming specific program freezes state of the art

A basic issue in the controversy over BEPS is whether any specific computer program should have been selected, not whether the selected program should have been DOE-2 or some other program. Naming a specific program in a law, in effect, freezes the state of the art. Once a specific program is named, the lengthy process to make a change is necessary before more advanced programs can be used.

While BEPS legislation does not require the use of any specific evaluation method, the proposed standards developed by DOE did name DOE-2 as the standard evaluation technique to be used for determining compliance to BEPS. DOE officials agreed that naming a specific program or standard in legislation would tend to freeze the state of the art. However, they believed, that under some circumstances, such as in BEPS, it is necessary to be specific in the implementing regulations. In such instances, an established exception process must be set up to permit newer and better programs to be used as they are developed to prevent impeding the advancement of the state of the art.

In the proposed standards, DOE indicated that a procedure would be set up to qualify alternative evaluation techniques for use. Since the proposed standards were not implemented, we cannot comment on how restrictive the proposed procedure might have been. This was a major concern of your constituent. According to DOE officials, the alternative evaluation technique approval procedure was to be clearly defined and require only a minimal amount of time and effort to accomplish.

Computer program results can vary

Another issue raised in comments on the proposed standards was that of the variances in results when different engineers use the same program. Research studies in Canada and at the National Bureau of Standards show that different engineers get different results on the same building model even when using the same computer program. There are two reasons for the variances.

First, the program user's interpretations of the model can change the results significantly. Every energy analysis program must make many assumptions and compromises, and as the state of the art advances, these assumptions and compromises will change.

Second, computer energy analysis is still new to many engineers, consequently, there is still a high input error rate by inexperienced program users. As experience is gained, the incidence of error should decrease. DOE officials indicated that their experience has shown that input errors decrease as users learn how to use the DOE-2 program.

Criteria used for selection of evaluation technique

In the BEPS Technical Support Document for Notice of Proposed Rulemaking - The Standard Evaluation Technique (Nov. 1979), DOE cited the following as the selection criteria for the standard evaluation technique:

--Basic design energy requirements output. Must differentiate between the annual consumption of various fuel types.

--Replicable results. Must be sufficiently objective so that different users, qualified to conduct an analysis of the building design, will produce consistent results independently of each other.

--Flexibility. Should be capable of objectively addressing a wide variety of design options, particularly those normally encountered in common practice.

--Technical sophistication. Should reasonably approximate the known dynamic behavior of a building in calculating its design energy requirements.

--Documentation. Should be documented to the extent that the procedures employed can be investigated.

--Ease and cost of use. Should be as inexpensive and as simple as possible to use, commensurate with the sophistication.

--Complete verification. Should agree closely with the actual, measured performance of real buildings and/or equipment.

--Updating. Should be capable of being updated as the state of the art improves and as innovations in technology are made.

DOE chose its own computer program over the Army's

In its selection of the evaluation standard, DOE only considered those programs available in the public domain. DOE officials believed it would not be appropriate to use a proprietary program for regulatory purposes because the method of problem solution used would not be available for public inspection. DOE selected its own program--DOE-2--over the Army's BLAST program. As for why DOE-2 was selected over BLAST as the BEPS evaluation technique, DOE stated that:

> "From a national perspective, in all likelihood either one could be selected. For a variety of reasons, including direct control over the product, timely delivery, status of code and documentation and verification efforts, the Department of Energy will likely select DOE-2 as a program used by DOE for testing compliance with BEPS."

In the Notice of Proposed Rulemaking on BEPS, DOE acknowledged that DOE-2 did not fully meet the stated selection criteria at that time.

Our survey of firms using federally developed energy analysis programs included some firms which had used both BLAST and DOE-2. Our discussions with these firms suggest that the choice between the two programs really depends on the needs and the experience of the user. One firm stated that DOE-2 was easier to use because its engineers were more familiar with it. Another firm, which had used BLAST on about 15 projects, stated that BLAST had less capabilities but was easier to use than DOE-2. A third firm stated that the choice between the two programs depended on the project's requirements. This firm felt BLAST was useful when radiant components were critical, but DOE-2 was especially useful for heavy structures with heat transfer.

DOE officials believe that adequate documentation is a key issue in selecting the DOE-2 program. They contend that DOE-2 has been documented in an unprecedented manner. We did not review the documentation and therefore, cannot comment on its adequacy. The amount of documentation, while useful for research purposes, may present problems for the average design firm. For example, in testimony at public hearings on BEPS in 1980, the head of the mechanical engineering division of a large engineering firm stated in response to a question about his firm's use of DOE-2 that:

> "We have not put this particular program up on our computer, mostly because I have all the documentation that is publicly available on DOE-2,

> and at this moment [1980] it scares me half to death. It is about an eighteen inch high pile of papers, as you well know. I've tried to read much of the documentation and frankly I do not feel qualified right now to say whether we could accommodate it or not. * * *"

Standard evaluation technique criticized in BEPS hearings

In responding to the Notice of Proposed Rulemaking on BEPS in 1980, many organizations criticized the selection of DOE-2 as the standard evaluation technique. The Massachusetts State Building Code Commission challenged the selection, stating "DOE-2 does not represent any form of consensus towards the methodologies and algorithms contained in the program." A regulatory analysis review group concluded that the evaluation technique (DOE-2) "appears inadequate and costly." The National Institute of Building Sciences (NIBS) concluded that the evaluation technique did not satisfy the basic requirements for a viable performance standard. Problems with DOE-2 were pointed out by NIBS, including

> --"DOE-2 computer program does not currently [April 1980] have the capability to simulate most of the heating and air conditioning systems in common use today. While it is capable for simulating central systems, it cannot handle the unitary commercial and residential systems which make up the bulk of the units sold in today's market. Nor can it handle room-by-room controlled electric baseboard heating."
>
> --"* * * potential with DOE-2 for user 'errors' or differences of up to 25-30 percent in the calculation of design energy consumption."

NIBS further stated that

> "DOE has acknowledged these and other problems and shortcomings with DOE-2 and indicates that new capabilities are being worked on and refinements and corrections are being made to existing programs, all of which are planned to be ready and available by the August 1980 rule publishing date. However, the size and complexity of DOE-2 and the magnitude of changes needed, combined with the fact that the model has been evolving since the mid 1960's, does not lend much credence to the claimed August completion date."

Similar criticism probably could have been leveled against all of the energy analysis programs available in 1980. While the above comments were directed specifically at DOE-2, had some

other program been selected, we believe the criticism would have been directed at that program. As indicated previously, the underlying issue was whether a computer program should have been used as the evaluation technique.

Weaknesses in public domain programs can also limit their effectiveness as a regulatory tool

DOE did not select a proprietary program as the standard evaluation technique, in spite of the criticism, because it wanted a program which would be available for public inspection. While there is some validity for selecting public domain programs, such programs have weaknesses which could limit their usefulness as a regulatory tool. Some of these are:

--Public domain programs, such as the Post Office program and the Integrated Civil Engineering System (public domain version), are often not properly maintained, documented, or supported, and fall into disuse. DOE officials stated that they will discontinue supporting DOE-2 after fiscal year 1983. An exception will be the Army's BLAST program because the Corps of Engineers plans to continue supporting BLAST for use by its own personnel in the military construction program.

--Administrative and enforcement problems are created because public domain programs can be easily revised or modified, without restriction, by any users.

--Knowledge of how a program works, how to apply and interpret the results, and where to find help when needed are important. This kind of support is often lacking in public domain programs. The adequacy of support may be more important than the fact that a program is proprietary or public domain.

--Even if a computer program's method of problem solving is open for inspection, it will still require a skilled reviewer to interpret the results and evaluate the application.

Many of the problems resulting from these weaknesses are no longer relevant. BEPS was originally a mandatory requirement. However, DOE now intends to ask for only voluntary compliance, thereby greatly diminishing the significance of the weaknesses noted relative to the enforcement of BEPS.

CONTINUING NEED FOR GOVERNMENT PROGRAM DEVELOPMENT

All programs we identified were initially developed because agency officials believed that existing programs failed to satisfy Federal needs. We did not attempt to go back and verify these conclusions. Our observations of factors concerning the need for further Government development of energy analysis programs, particularly in the current fiscal environment, lead us to believe that such development is questionable. Some of the factors we considered were:

--Availability of, and access to, acceptable commercial programs to fulfill energy analysis needs.

--Actions taken by the private sector to improve existing programs.

--Current market conditions.

Justification for past development

When agencies undertook the development of the identified programs, each agency reportedly believed that available programs, both commercial and public domain, did not respond to its needs. For example, Army officials at the Construction Engineering Research Laboratory gave us the following information regarding their analysis of available energy analysis programs at the time they undertook the development of the BLAST program in 1973.

Faults with handbook energy design methods

1. Too conservative--high first cost, low efficiency.

2. Too simplistic--could not adequately analyze energy conservation options, most architectural variations, solar energy systems, and total energy systems.

Faults of early computer-aided design methods

1. Proprietary programs--not available to users, costly, only slight improvement in accuracy over handbook methods, and poor documentation.

2. Accurate research programs--not available in general use, not complete, very complex, and very costly (time and computer costs).

Army officials said they wanted a program which was user oriented, had easy data input procedures, had low computer run times, was well documented, and was well supported. They believe they have achieved this with BLAST.

Comments of officials at other agencies were similar. Private sector programs were often proprietary, and outside users did not have access to assumptions, limitations, and source codes. As a result, the user was denied the flexibility to modify programs to meet special needs. Public domain programs available at the time, which could be easily modified to meet special needs, had not been validated or documented, lacked technical flexibility and sophistication, or were too complex, too slow, or too costly to be used.

Parallel development questioned

In line with your constituent's concern, we questioned why both DOE and the Army needed to simultaneously develop energy analysis programs which are similar, evolving from the same base programs--the National Bureau of Standards Load Determination program and NASA's Energy Cost Analysis Program. BLAST development began in 1973 and DOE-2 in 1975. A knowledgeable DOE official said that there was no concrete reason why DOE-2, then called CAL-ERDA, and BLAST were developed at the same time. DOE's facility management officials expressed a need for an energy analysis program they could use for energy surveys on DOE's large inventory of existing buildings. This was the initial reason for developing the DOE program. Subsequently, when BEPS appeared, the primary objective of the project became the development of a regulatory tool. Currently, DOE officials consider their program as a research tool, which they hope will lead to an industry-selected voluntary national standard, or benchmark for energy analysis.

Corps of Engineers officials said they could not risk the possibility that the DOE efforts might fail. They needed an energy analysis program for their military construction program. Therefore, they decided not to suspend their ongoing work on BLAST, but to go forward with the project in parallel with DOE's efforts.

At our closeout conference, DOE officials suggested that there were justifiable reasons for going ahead with the planned DOE-2 development once the primary objective of the effort shifted to developing a standard evaluation technique for BEPS. They stated that the law established a tight deadline on the development of the BEPS. To comply as closely as possible to the congressionally mandated deadline, DOE officials felt that the program's schedule and content had to be dictated by DOE's needs. They said that since the Army had its own schedule and priorities, direct control over research and development of the program was, in their opinion, the most appropriate management decision.

Furthermore, DOE officials told us that the researchers and engineers involved in the projects claim that, since the

programs use different solution methods, the programs are not a duplication. However, they agreed that some overlap exists. DOE officials believe the DOE-2 and BLAST programs should be merged to develop an even better program than either of the existing programs by employing the best engineering models of both.

Availability of adequate programs

Increased energy analysis requirements in design have provided the private sector needed incentive for funding energy analysis program development. In addition, the private sector has been encouraged to upgrade both federally funded and private sector programs. As a result, there are over 70 computer programs available for simulating various building configurations and heating, ventilating, and air-conditioning systems. Although these programs differ in their overall purposes and capabilities and can yield different predictions of system performance and economics, they can fulfill diverse Federal requirements and should provide an adequate basis for effective decisionmaking in the design of buildings. This conclusion is based on information we obtained during our literature search and from the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., and the Electric Power Research Institute, both of which have issued reports on the availability of energy analysis computer programs during the last 2 years.

Government competition with the private sector

Both BLAST and DOE-2 programs are available to Federal and private users through computer service bureaus. Consequently, the two programs are competing on the open market with proprietary programs which are also available to Federal and private users. Because all development and all but minor acquisition costs are eliminated, we believe that the service bureaus marketing these Government-funded programs have an unfair advantage over proprietary program developers. BLAST and DOE-2, for example, may be obtained from at least three service bureaus. According to Army and DOE officials, one of these bureaus has already refined both programs and now has proprietary versions of the programs which it also markets. Both the public domain and proprietary versions, however, have a competitive edge over non-Government funded programs because the vendor has greater flexibility in setting the service charges.

Questionable need for further government involvement

Your constituent was concerned about Federal competition through its development efforts. There has clearly been competition, especially from the DOE-2 and BLAST programs. We

believe these program efforts provided healthy competition for the private sector. They stimulated the private sector to enhance existing programs to remain competitive from a state-of-the-art standpoint. However, from a marketing standpoint, the Government programs now provide a competitive advantage in the commercial marketplace as discussed above.

The private sector is capable of carrying on the advancement of the state of the art without Government stimulation and competition. Federal officials in all of the agencies we contacted, except DOE, told us there was no longer a need for their efforts in the development of energy analysis programs. DOE, however, continues to fund efforts to develop energy analysis capabilities; all other agencies have completed their efforts and told us that they plan no further work in this area. DOE officials feel strongly that they need to complete the efforts which have already begun, especially the documentation and verification efforts. They feel that the programs' usefulness, especially as a research tool, would be limited if these efforts were not completed.

DOE officials said that once they complete their planned efforts, they will not support DOE-2. They believe that once a program is developed, the private sector should provide the necessary training and program support. We believe that, in order for a computer program to survive, it must receive continuous support. If it does not, it will die as a design tool. Designers use programs which are supported and for which they can obtain technical assistance when needed. There are no assurances that the private sector will support the public domain version of DOE-2.

In contrast to DOE's position on support, the Corps of Engineers plans to support the BLAST program. It is undertaking an extensive program to train DOD engineers how to use BLAST and is establishing a BLAST support group to provide continuing program maintenance and to handle user problems. The Corps recognizes the importance of program support to encourage its own engineers to use the program on military construction design work.

CONCLUSIONS

In view of the current state of the art and private development efforts and the cost cutting efforts of the current administration, continuing Government investment in the development of new energy analysis programs is questionable. Since private firms are investing in energy analysis program development, Government funds could be directed toward activities and projects in which private firms are not sufficiently investing to meet national needs. We believe that in the foreseeable future, Federal agencies should seek commercially available computer programs to satisfy their needs and use strengthened design

requirements and other means to provide incentives for the private sector to continue to move the state of the art forward. The administration's stated philosophy in this area is that Government research and development should be redirected to focus primarily on long-term, high risk, potentially high-payoff research and development which private industry cannot reasonably be expected to undertake.

If it is determined that there is a real need to develop and maintain a national standard for energy analysis methodology, we believe that others, such as the National Bureau of Standards and the private sector standards organizations, are more appropriate activities for carrying out such efforts.

RECOMMENDATION

We recommend that the Secretary of Energy discontinue planned program development efforts to improve energy analysis capabilities of the DOE-2 program.

AGENCY COMMENTS

DOE was unable to provide us comments on the draft report within the allowed time frame. However, we discussed the draft with agency program officials and their comments have been considered in the report.

DOD concurred with our conclusions and recommendations. Revisions to the report were made to reflect revised design criteria being developed by DOD. Each of the agencies whose energy analysis computer program is discussed in appendixes II through VIII reviewed and concurred with the synopsis of its own program.

Donald J. Horan
Director

APPENDIX I

ENERGY ANALYSIS COMPUTER PROGRAMS

DEVELOPED WITH FEDERAL FUNDING

	Program name	Funding agency	Cost	Time frame
1.	NBS Load Determination program	National Bureau of Standards	Not available	FY 1965-70
2.	Post Office program	U.S. Postal Service	$ 800,000	FY 1967-70
3.	Energy System Optimization Program	NASA and Dept. of Housing and Urban Development	$ 627,000	FY 1972-75
4.	BLAST (3 versions)	Corps of Engineers, U.S. Air Force, General Services, and DOE	$1,382,000	FY 1974-80
5.	NASA's Energy Cost Analysis Program	NASA	$ 314,000	FY 1974-80
6.	VA Energy Program	Veterans Administration	$ 246,000	FY 1975-81
7.	DOE (3 versions)	DOE	$4,810,000 $1,410,000 (projected budget)	FY 1977-81 FY 1982-83

APPENDIX II

NATIONAL BUREAU OF STANDARDS HEATING AND COOLING LOAD DETERMINATION PROGRAM

Sponsoring agency: National Bureau of Standards, Department of Commerce.

Developer : Dr. Tamami Kusuda, National Bureau of Standards.

Time frame : 1965-70.

Cost : Not available.

Need filled : This program was originally developed as a research tool to analyze building designs normally used, as well as nonconventional or innovative ideas on structures and/or their heating and cooling systems.

Description : This program calculates the hour-by-hour heating and/or cooling load in buildings. It utilizes the thermal response factor technique for calculating transient heat conduction through walls and roofs. In lieu of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., weighting factor method, however, detailed heat balance calculation among the room surfaces is performed to arrive at accurate heating and cooling loads. It is intended for use in the design of equipment and air-conditioning systems and for estimating building energy requirements.

Usage : This program has been an indispensable tool for studies of numerous housing systems and constructions where nonconventional design conditions had to be evaluated. Several copies of the program have been distributed to universities, research centers, scientific laboratories, energy consultants, and architect/engineer firms. It has served as a basis for numerous second and third generation federally and commercially developed energy analysis computer programs and as a reference program in verifying the accuracy of DOE-2 and BLAST.

PROGRAM FOR ANALYSIS OF ENERGY UTILIZATION IN POSTAL FACILITIES

Sponsoring agency: Post Office Department (now the United States Postal Service).

Developer : General American Research Division, General American Transportation Corporation.

Time frame : 1967-70.

Cost : Estimated by GAO at $800,000. Research and development contract was $601,703 for writing the computer program, user's manual, and a final report and giving on-the-job training to engineers. No cost data was available for in-house overhead. Agency officials speculated that these costs would have equalled about 25 percent of contract costs, considering salaries, travel, supervision, contract administration, and managerial support.

Need filled : Because of steadily increasing operating costs for postal facilities, it became necessary to develop a procedure for selecting equipment and utility systems that provided the most economical combination of equipment and energy source.

Description : The program, often known as the Post Office Program, evaluates (1) total building design and effects of size, shape, orientation, wall and roof construction, and window designs on heating and cooling demands, (2) system selection and effects of equipment capacity, schedule of operation, and choice of components on ability to maintain design equipment in every space of the building for each hour of the year, and (3) owning and operating costs, effects of equipment types, energy source type, and maintenance and overhaul costs on maximizing return on investment.

The program was intended to be used during the predesign selection of basic system and energy source; during the design stage to evaluate proposals or deviations from construction plans and specifications; or after completion of construction to evaluate maintenance and

APPENDIX III

operation of the facility and the utility systems.

Usage : The program is the "grandfather" of several energy analysis computer program efforts. Since its release in 1970, over 800 copies of the user's manual have been distributed to consultants, utilities, manufacturers, engineering schools, and Government agencies. By 1971 the Postal Service was using the program in the design of systems in several new facilities. Presently, the program is no longer supported.

APPENDIX IV

ENERGY SYSTEM OPTIMIZATION PROGRAM

Sponsoring agency: National Aeronautics and Space Administration (NASA) and Department of Housing and Urban Development.

Developer : Lockheed Electronics Corporation and NASA-Johnson Space Center in cooperation with the HUD Modular Integrated Utility System program.

Time frame : 1972-75.

Cost : $637,000 (1980 dollars), including $433,000 contributed by NASA and $204,000 by the Department of Housing and Urban Development for salaries, computer time, and maintenance.

Need filled : The program was specifically developed to support Modular Integrated Utility System program evaluation on modular systems performance and comparison of these and conventional systems.

Description : The program addressed portable water requirements, waste water management, solid waste disposal, heating and cooling needs, energy usage, and economics of modular system installations. It calculates facility load and energy requirements, equipment sizes, and life-cycle costs of alternative methods of meeting utility needs and evaluates yearly operational characteristics of modular integrated utility systems. Modular systems provided communities of limited size with the required utility services of energy, water, and waste disposal from a single package which balances the requirements for environmental quality and conservation of resources.

Usage : NASA stopped using and supporting this program in 1976. About 50 copies of the program were distributed. In addition, several outside organizations, such as other Federal agencies, several foreign countries, architect-engineer firms, universities, and many private research firms, made inquiries about the program. However, NASA knows of no one actually using the program for its intended purpose.

APPENDIX V

NASA ENERGY COST ANALYSIS PROGRAM

Sponsoring agency: National Aeronautics and Space Administration.

Developer : General American Research Division under contract at Langley Research Center.

Time frame : 1974-80.

Cost : $314,000 (1980 dollars), including original development and modification, salaries, computer time, and publication costs.

Need filled : This program was developed to determine and minimize building energy consumption in both new and existing buildings.

Description : This program is a highly sophisticated and powerful computerized simulation system. It provides users with data for selection of the most economical system, system size, fuels, window area, and thermal barriers during the design phase. After installation, users can optimize operating schedules, determine the most economical temperature setting components, and obtain other valuable information.

Usage : Many programs and design approaches are a "spin-off" of this program. Currently, this program is used in-house for evaluating the design and operation of facilities in regard to building energy consumption. It is available to outside consultants, but is not a requirement.

BUILDING LOADS ANALYSIS AND SYSTEM THERMODYNAMICS

Sponsoring agenies: Departments of the Army and Air Force and DOE.

Developer : U.S. Army Construction Engineering Research Laboratory.

Time frame : 1974-80.

Cost : $1,382,207, including development, testing, training, maintenance, and support. See chart below for agency funding details.

Sponsoring agencies

Version	Army	Air Force	GSA	DOE	Total
BLAST-1	$135,000	$260,000	$ -	$ -	$ 395,000
BLAST-2	180,000	144,800	138,407	-	463,207
BLAST-3	336,000	123,000	-	65,000	524,000
	$651,000	$527,800	$138,407	$65,000	$1,382,207

Need filled : Army, Air Force, and GSA needs for a user-oriented, easily used, low run time, well-documented program, which was also well supported. Enhancements have been added to make program more suitable for passive solar studies.

Description : BLAST is a comprehensive set of subprograms which use extremely rigorous and detailed algorithms to compute loads, simulate fan systems and boiler and chiller plants, and compute building operation energy life-cycle cost. The program has its own user-oriented input language and is accompanied by a library which contains the properties of all materials, wall, roof, and floor sections listed in the American Society of Heating, Refrigerating, and Air-Conditioning Engineers Handbook of Fundamentals. It has three major subprograms which compute hourly space loads in a building; calculate hot water, steam, gas, chilled water, and electric demands

APPENDIX VI

on the building and air-handling system; and compute monthly and annual fuel and electrical power consumption.

Usage : BLAST users are Government agencies, universities, and architect/engineer firms. BLAST is available from various service bureaus.

VETERANS ADMINISTRATION ENERGY PROGRAM

Sponsoring agency: Veterans Administration.

Developer : University of Pittsburgh.

Time frame : 1975-81.

Cost : $246,096, including original development, additions and modifications, salaries, travel, computer rental, consultants' fees, training ($8,000), supplies, publications, support, and indirect costs.

Need filled : The program fulfills the Veterans Administration's requirement for a computer-oriented procedure with the capability to systematically analyze and evaluate both current and planned facilities through program data tailored to agency standards, specifications, locations, operations, and experiences.

Description : This program is an hour-by-hour energy system used to make the basic energy analysis for facilities. It calculates the heating and cooling loads of a building; simulates the various heating, ventilation, and air-conditioning systems and building operations; predicts the annual and monthly energy requirements; and uses the energy requirements to predict utility costs of the building and to determine comparative life-cycle costs of each alterative.

Usage : Study of existing Veterans Administration hospitals and other facilities. This program is also used for monitoring energy use, reviewing designs, and developing energy budgets for new projects. Currently, it is used in-house and has not been made available to the private sector. When all documentation is received at headquarters from the developer, the program will be made available to the public.

APPENDIX VIII

THE DEPARTMENT OF ENERGY COMPUTER PROGRAM FOR BUILDING ENERGY ANALYSIS

Sponsoring agency: Department of Energy (formerly the Energy Research and Development Administration). 1/

Developer : Lawrence Berkeley Laboratory in cooperation with Argonne National and Los Alamos Scientific Laboratories.

Time frame : 1975-present.

Cost : $4,810,000 plus a projected budget of $1.4 million for fiscal years 1982-83. Costs include research, development, validation, modifications, computer time, consultant fees, travel, training, and manuals.

Need filled : The DOE program was developed to provide an easy to use, fast-running, completely documented, public domain computer program that could be used on DOE facilities. Subsequent to the start of the project, it had a goal of ultimately becoming the evaluation standard for BEPS. This goal has not been achieved to date.

Description : DOE-2 calculates the hour-by-hour energy use of a building and the building's life-cycle cost of operation given information on the building's location, construction, operation, and HVAC equipment. The program has a new building design language which simplifies data input and verification. It also has four main calculation sections which calculates the constant inside temperature hourly heating and cooling loads for each user-designated space; simulates the operation of the secondary HVAC distribution system and primary energy conversion equipment; and calculates the present value of the life-cycle cost of a building, including cost of fuel, equipment, operation, and maintenance. It can also be used to compare the cost of

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1/Initial development was also supported by the State of California Energy Commission.

APPENDIX VIII

different building designs or to calculate savings to investment statistics for retrofits to an existing building.

Usage : The program is being used by architect/engineer firms and universities. It is available through several computer service bureaus.

PAUL TSONGAS
MASSACHUSETTS

United States Senate
WASHINGTON, D.C. 20510

March 26, 1981

Honorable Milton J. Socolar
Acting Comptroller General
U.S. General Accounting Office
441 G Street, N.W.
Room 7000
Washington, D.C. 20548

Dear Mr. Comptroller General:

Enclosed is a letter from a Massachusetts constituent raising questions about the efficient use of the taxpayers' dollars on the development of computer programs used in the design of buildings to determine energy consumption. Mr. Ferreira feels that our Government is competing with the private sector by developing computer programs to estimate energy consumption and then forcing the use of one of these programs under the provisions of the proposed Building Energy Performance Standards (BEPS) regulations.

It is our understanding that GAO has issued reports on the use of computer-aided building design methods, including energy analyses, and therefore would be a logical source of assistance. We would greatly appreciate it if the GAO would look into the issues raised in the enclosed letter. Our particular interests are:

1. How much money the Government has spent on building energy analyses computer programs development;

2. Whether these programs are being used and by whom;

3. Whether there is a continuing need for Government development of these types of computer programs; and

4. The rationale for singling out one Government-developed program as the standard to be cited in BEPS regulations for calculating energy consumption in buildings.

Our staff is available to discuss any aspect of this request with members of your staff prior to or during the course of an audit. Thank you for your assistance in this matter.

Sincerely,

GERRY E. STUDDS
U.S. Representative

PAUL E. TSONGAS
U.S. Senator

PET/mgz
enclosure

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