Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

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AN ANALYSIS OF THE ENERGY IMPACTS OF THE DOE APPROPRIATE ENERGY TECHNOLOGY SMALL GRANTS PROGRAM: METHODS AND RESULTS

Bart Lucarelli, Jeff Kessel, Josh Kay, Janet Linse, Susan Tompson, and Mark Homer

February 1981

Prepared for the U.S. Department of Energy under Contract W-7405-ENG-48

LBL-12253

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This work was supported by the Office of Inventions and Small Scale Technologies within the Appropriate Technology Division, of the U.S. Department of Energy under Contract W-7405-ENG-48.

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ACKNOWLEDGMENTS

Completing this study required the assistance and cooperation of many people. We are especially grateful to DOE's regional program managers, who supplied us proposals and progress reports for the 57 projects. Thanks are due Bob Chase and Herb Sperry (Region I), Jane del Gado and Morrel Thompson (Region II), Tony Pontello (Region III), Mickey Feltus (Region IV), Robbie Dalton and Richard Scharschberger (Region V), Guntis Terauds (Region VI), Jack Stacy and Bob Lewis (Region VII), Tom Stroud (Region VIII), Meg Schachter (Region IX), and Frank Brown (Region X). We are also extremely grateful to the 57 project managers, all of whom diligently responded to our many requests for technical and economic data. Without the active involvement of both the program and project managers, we could not have completed the study.

We also thank Rudy Beran of the U.C. Berkeley Statistics Department for reviewing the statistical analysis in an earlier draft of the report and Don Elmer of Lawrence Berkeley Laboratory for reviewing the report. Finally, we wish to thank Laurie Sampietro and Charlotte Standish of the LBL Solar Group for typing the final report with dispatch and accuracy in the face of a tight deadline. Although these individuals contributed greatly to the report's completion, we, the authors, are responsible for errors, omissions, and the opinions which are presented.

This work was supported by the Office of Inventions and Small Scale Technologies within the Appropriate Technology Division of the U.S. Department of Energy under Contract W-7405-ENG-48.

EXECUTIVE SUMMARY

A. OBJECTIVES

Lawrence Berkeley Laboratory (LBL) has completed this energy impact study for the Department of Energy's (DOE's) Office of Inventions and Small Scale Technologies (OISST). The study presents methods for assessing energy savings from projects funded by DOE's Appropriate Energy Technology Small Grants Program (Small Grants Program) and then applies these methods to a sample of projects from the Small Grants Program to obtain estimates of the energy impacts. Three research objectives evolved over the course of the study. Initially, LBL intended to:

(1) develop a consistent procedure for evaluating energy savings from small energy projects; and

(2) apply the procedure to a large sample and quantify the sample's energy savings.

Later, at DOE's request, LBL expanded the scope of the research to include a third objective, which would:

(3) apply statistical methods to the sample estimates and infer program energy savings.

B. RESEARCH APPROACH

Figure 1 presents schematically the research approach. The study was completed in three phases: (1) sample selection; (2) project evaluation; and (3) statistical estimation.

Sample Selection: Fifty-seven projects were selected from a population of 584 projects. Because we did not plan initially to apply statistical techniques, we did not select the sample randomly. Instead, the sample was selected subjectively. We attempted to select a sample representative of the population, but because random sampling was not used, the estimates of program energy savings may have a systematic bias.

Project Evaluation: For each project, two categories of energy savings, direct and indirect, have been assessed. Direct energy savings are those savings of fossil energy that will result from the successful completion of the project. Indirect energy savings are the lifetime energy savings that will be realized if a project's energy system is replicated because of either demonstration effects or commercialization.

For a project to have indirect savings, it has to meet two criteria:

(1) the energy system applied by the project is cost-effective; and (2) the grantee intends to market or publicly demonstrate the energy system.

Both direct and indirect savings are first estimated at the point of end use in million Btu and then converted into an oil barrel equivalent (OBE), which includes end use energy plus energy lost in generation and transmission. Once converted into OBE, direct and indirect savings are summed to provide an estimate of each project's energy saving potential.

Statistical Estimation: We then applied statistical methods to the sample results and estimated program energy savings. Based on the hypothesis that the sample is unbiased, we computed the sample mean, where the mean measured the average OBE energy savings per $1000 of DOE funding, and the standard error of the mean. From these two estimations, confidence intervals at the 90%, 75%, and 50% levels of probability were constructed. Average program energy savings at each probability level were then estimated.

C. RESULTS AND CONCLUSIONS

The results of the statistical analysis are presented in Table E-1 for three confidence levels: 90%, 75%, and 50%. If the sample mean is the same as the population mean, then the FY 1979 program can attain energy savings of 22.5 million OBE over the lifetimes of the project and replicate energy systems. This estimate is based on the $8 million awarded for grants in FY 1979. On an annual basis, the program energy savings are 1.1 million OBE (not determinable from Table E-1).

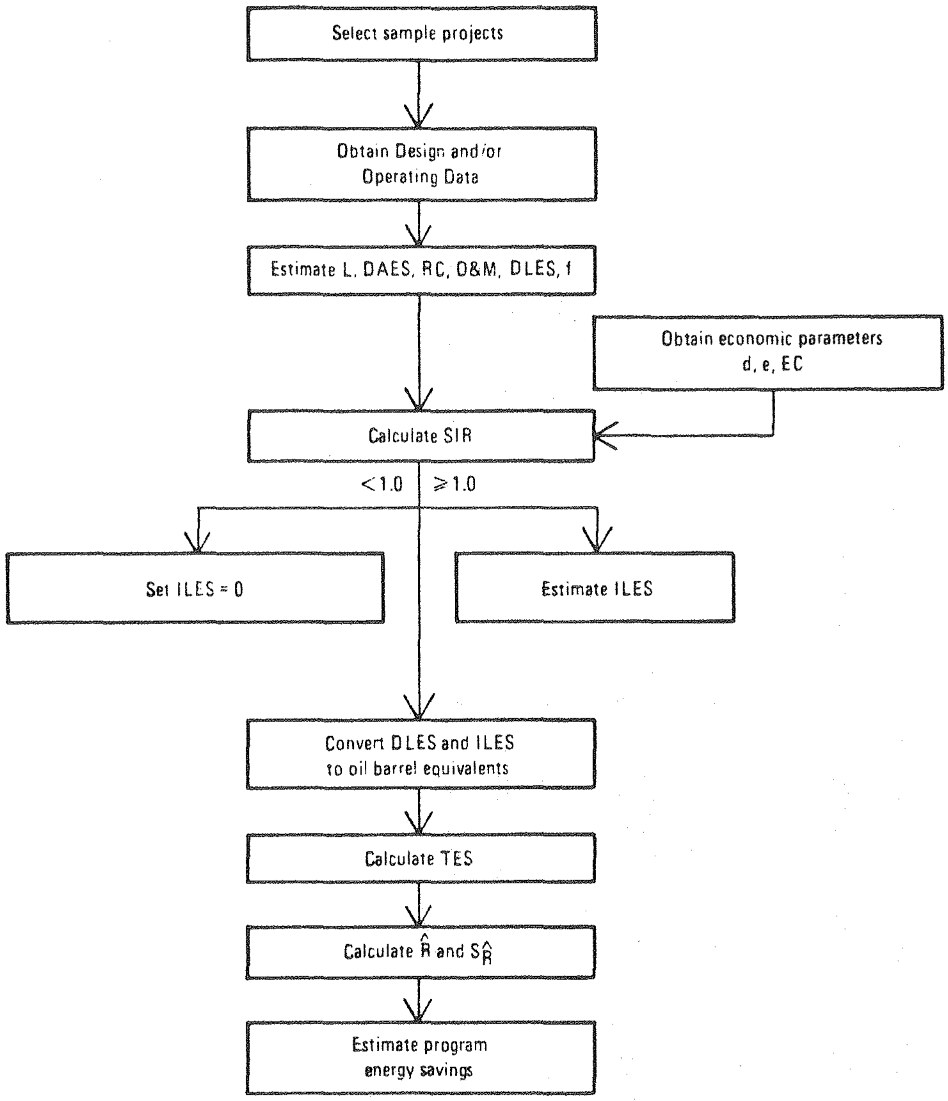
Table E-1 reveals wide ranges in the intervals at the three confidence levels, which reflect the wide variations among the energy saving potentials of the individual projects. For instance, at a 75% confidence level, program energy savings are estimated at 9 to 36 million OBE. Nevertheless, even with this wide interval, the program achieves these energy savings at a very low cost to DOE. At the same 75% confidence level, the program can attain the potential energy savings at a cost ranging from $.20 to $.85 per OBE.

The results of this analysis must be used intelligently to avoid erroneous conclusions. For example, comparing U.S. oil imports in FY1979 to the program's energy savings for that year will show that the program has a relatively small energy savings potential. Such a comparison is not applicable to our analysis as the project estimates are not maximum potentials and are based on a highly conservative estimating procedure. The results are useful figures for evaluating the nearterm potential of the program to save energy and for measuring the energy saving effectiveness of the program, expressed as potential energy savings per dollar of DOE funding.

The results have a second limitation; they only measure program's effectiveness in meeting one of many objectives Congress has set for the program. In particular, the Small Grants Program has to meet economic and social objectives in addition to its primary objective to save energy. Therefore, the program must be judged according to all the objectives set for it by Congress and not merely its energy savings potential.

Nevertheless, opportunities do exist for increasing the program's

Fig. 1-1 **Methodology for Appropriate Energy Technology Project Analysis**



Abbreviations

L : lifetime of energy system (years)

DAES : direct annual energy savings, achieved by project energy system(s) (MBtu)

RC : replicate cost, the cost of energy system when commercialized ($)

O&M : annual system operation & maintenance cost ($)

DLES : lifetime energy savings = L x DAES (MBtu)

f : DOE funding for project (1000 $)

d : discount rate (%)

e : fuel escalation rate (%)

EC : base year fuel cost ($/MBtu)

ILES : indirect lifetime energy savings, the savings achieved by short term commercialization of the project energy system

SIR : savings/investment ratio, the ratio of the present value of net revenues to the present value of investment costs

TES : DLES + ILES

$\hat{R}$: sample mean of total energy savings per 1000 $ of funding, defined to be $\Sigma\ (TES)_i / \Sigma f_i$ (MBtu/1000 $)

$S_{\hat{R}}$: standard error of the sample mean

TABLE E-1

Estimates of Energy Saving Effectiveness and Program Energy Savings

at Three Confidence Levels (90%, 75%, and 50%)

Confidence Level	Range of Values (OBE/$1000 DOE Funding)	DOE Investment per Potential Barrel of Oil Savings	Program Energy Savings (Million OBE)
90%	485 to 5225	$.19 to $2.05	3.9 to 41.8
75%	1195 to 4515	$.20 to $ .85	9.6 to 36.1
50%	1870 to 3840	$.25 to $ .55	15.0 to 30.7

energy impact without changing the program's intent. For example, DOE can require each applicant to include in the proposal a replication plan which clearly describes his/her plan for replicating any system under development. DOE can also improve the quality of projects by increasing the grantee's accountability for completing the project according to the original work plan. Finally, DOE can increase the program's energy impacts by providing additional funding to promising projects at an early stage of development. With these improvements, DOE can increase the program's energy savings potential while meeting the multiple objectives set for the program by Congress.

CHAPTER 1

OVERVIEW OF THE ENERGY IMPACT ANALYSIS

INTRODUCTION

In 1977, Congress directed the Department of Energy (DOE) to create an energy grants program with the object of funding individuals, small businesses, and nonprofit organizations to develop technologies that use renewable energy resources. With this mandate, DOE created the Appropriate Energy Technology Small Grants Program (Small Grants Program). To date, the Small Grants Program has funded over 1300 projects that apply simple, small scale energy technologies which promote renewable energy resources and/or conserve fossil fuels.

This report assesses the energy savings potential of the Small Grants Program. The results of the assessment will help DOE in evaluating the program's overall effectiveness and will identify ways of increasing the energy savings. To estimate the program's energy impacts, we first calculated the energy savings and evaluated the cost-effectiveness of a sample of projects funded in Fiscal Year (FY) 1979 by the Small Grants Program. Then, an estimate of program savings was extrapolated from the sample by statistical inference.

Estimating program energy savings was made difficult by the comprehensive program mandate to encourage the development of all renewable energy resources. The projects develop a diverse array of technologies and resources and have differing objectives. This diversity includes, for example, projects that:

- demonstrate the use of improved wood stoves for space heating;
- develop new types of solar collectors for marketing;
- test the feasibility of using small wind systems to generate electricity for residential use; and
- construct and operate anaerobic digesters.

Diversity is further increased by the fact that the projects address local needs, cater to different markets, and use local resources and expertise whenever feasible.

As a result of this diversity, estimating the program's energy impact requires more extensive project analysis than would be necessary if fewer technologies or resources were developed. Although the program's structure may have made the research more difficult, we do not argue that the program be changed to a simpler format to facilitate its evaluation. On the contrary, the project characteristics are major strengths of the Grants Program. For example, the diverse project mix allows DOE to experiment with many techniques for developing renewable energy resources and conservation technologies. Because the program applies many small scale, simple technologies, it has a relatively low operating cost. Finally, each project's emphasis on meeting local needs and reliance on local resources and labor, increases credibility and the prospect that others may replicate the project in a given locale.

OBJECTIVES OF THE RESEARCH

DOE recognized the need for an assessment of the program's energy impact at an early date and contracted with Lawrence Berkeley Laboratory (LBL) in 1978 to identify methods for evaluating the energy savings of a sample of projects funded by the Program in Federal Region IX. LBL completed the research in October 1979 and published the results (Lucarelli et al., 1979). Because the report evaluated only 20 projects in one federal region, the next step was to evaluate the energy savings of the national grants program.

Initially, we set two objectives for this second energy impact study:

(1) to develop a consistent procedure for evaluating the energy impacts of small energy projects.

(2) to apply the procedure to a large sample and quantify the sample energy savings.

Later, after the sample was selected, we added a third objective at DOE's request:

(3) to infer, using statistical methods, program energy savings from the project sample.

Implementing this last objective after sample selection created problems, which are discussed in detail later in this chapter and in Chapter 5.

DEFINITIONS AND METHODS

The first step in the analysis was to assess the energy savings potential of 57 projects from a national population of 584. Program energy savings were then estimated from project savings using statistical inference. The details of the approach are presented schematically in Figure 1-1 and are discussed below under three headings:

(1) Sample Selection

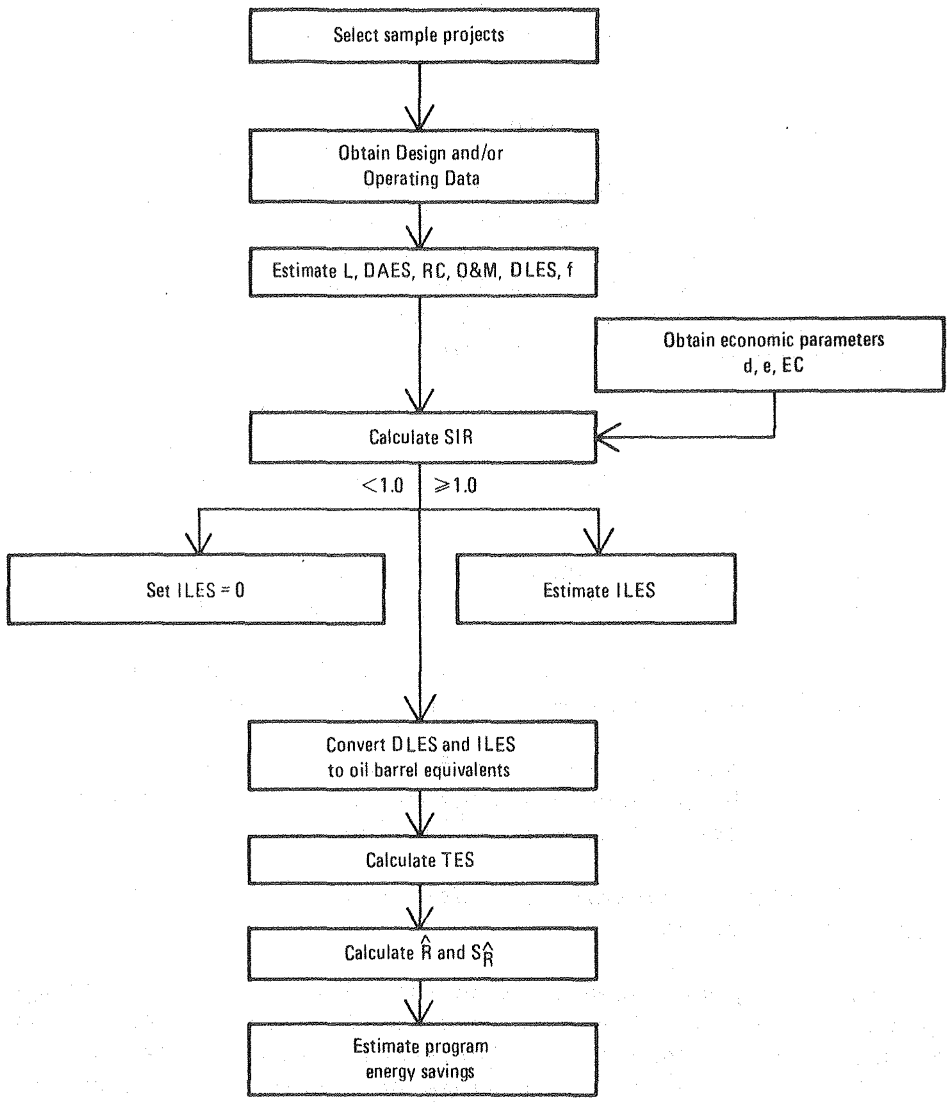
(2) Project Evaluation

(3) Statistical Estimation

Sample Selection

We attempted to select a sample representative of the population of grants funded by DOE in FY 1979. Researchers normally use either simple or stratified random sampling to select objectively a sample from which population estimates can be made. We did not use random sampling.

Fig. 1-1 **Methodology for Appropriate Energy Technology Project Analysis**



Abbreviations

L	: lifetime of energy system (years)
DAES	: direct annual energy savings, achieved by project energy system(s) (MBtu)
RC	: replicate cost, the cost of energy system when commercialized ($)
O&M	: annual system operation & maintenance cost ($)
DLES	: lifetime energy savings = L x DAES (MBtu)
f	: DOE funding for project (1000 $)
d	: discount rate (%)
e	: fuel escalation rate (%)
EC	: base year fuel cost ($/MBtu)
ILES	: indirect lifetime energy savings, the savings achieved by short term commercialization of the project energy system
SIR	: savings/investment ratio, the ratio of the present value of net revenues to the present value of investment costs
TES	: DLES + ILES
$\hat{R}$	: sample mean of total energy savings per 1000 $ of funding, defined to be $\Sigma\ (TES)_i/\Sigma f_i$ (MBtu/1000 $)
$S_{\hat{R}}$	: standard error of the sample mean

Instead, a sample thought to represent the population was subjectively selected.* Although projects were not selected by their apparent energy savings potential, the nonrandom sampling approach may have resulted in a systematic bias in population estimates.

Another problem with the sample is that it was drawn from only 8 of the 10 federal regions. Regions IV and VIII were not represented. Region IV did not award any grants in FY 1979 and thus could not be included in the sampling. Region VIII did award grants but was inadvertantly excluded. When the error was discovered, research was almost complete, and time was inadequate to consider additional projects. As a result of these two features, the sample may be biased, which in turn will affect the reliability of the estimates.

Project Evaluation

For each project, two categories of energy savings, direct and indirect, have been assessed:

> Direct energy savings are those savings of fossil energy that will result from the successful completion of the project.

To obtain direct energy savings, the annual savings are first computed and then multiplied by the economic lifetime of the system.

> Indirect energy savings are the lifetime energy savings that will be realized if the project's energy system is replicated because of demonstation effects or commercialization.

Both direct and indirect savings are estimated at the point of energy use, referred to as end use.

The different methods used in assessing direct energy savings for the projects are not specifically documented in this report because of the large sample size. However, a listing of relevant data is provided in Table 1-1. In general, we obtained necessary information from the grantees on the energy performance of each system and then verified their results by consulting technical literature and experts in the appropriate field. Where differences existed or where performance data did not exist, the opinions of experts and our own best judgments had to suffice.

Our approach to estimating indirect energy savings is a cautious one. First, a project had to be cost-effective before being analyzed for indirect savings.**

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* Initially, we intended to provide DOE with only a case study analysis of representative projects. As DOE's information needs changed, we were requested to expand the focus of our work and to provide an estimate of program energy savings. The sample had already been selected, unfortunately, and our analysis was nearing completion. Thus, our estimates will have to suffice as the best information available at this time, and future studies that use a random sampling approach can provide more precise estimates of program energy savings.

** We exclude four projects from this decision rule. The four projects had already achieved some indirect energy savings despite their lack of cost-effectiveness.

> To be cost-effective, an energy system must generate over its lifetime net revenues equal to or greater than its first cost. Net revenues are the gross revenues generated by the system mainly in the form of energy savings minus any additional operating and maintenance cost compared to an alternative fossil fuel system.

The savings-to-investment ratio (SIR), which is the ratio of net revenues to investment cost, was used to indicate cost-effectiveness.

Cost-effective projects were then studied to determine indirect energy savings potential. We determined a project's indirect potential by examining the grantee's plans for marketing and/or outreach. If the plans were found to be reasonable, and well-formulated, we computed an indirect potential for that project. We then computed and each project's total energy savings which is equal to the sum of direct and indirect savings. This total, expressed in million Btu, was converted first to a primary energy equivalent, which includes both end use energy and losses due to generation and transmission, and then to oil barrel equivalents (OBE).

Statistical Estimation

After calculating direct and indirect energy savings for each project, program energy savings were estimated. Assuming that the sample is unbiased, we computed the sample mean and the standard error of the sample mean, where the mean measured the average energy savings of the sample per $1000 of DOE funding. From the sample mean and standard error, confidence intervals at the 90%, 75%, and 50% levels of probability were constructed. A range for program energy savings at each probability level was then estimated.

LIMITATIONS OF THE STUDY

The first limitation, already mentioned, is that the sample is not random and may not be representative. If the sample is not representative, the population estimates will be inaccurate and the inferences unjustified in probability terms. Second, a large fraction of the total energy savings are indirect and will be achieved only if the assumptions concerning project replication are correct. Each project's cost-effectiveness and the grantee's intent to demonstrate or commercialize the system were carefully evaluated to avoid overstating the indirect savings for each project. Nevertheless, only time will verify whether the estimates are reasonable.

Third, most of the projects serve multiple economic and social objectives and in many cases, act to increase energy awareness and energy self-sufficiency on the community level. Because of the limited scope of the study, these important but somewhat intangible benefits were not considered. For instance, the projects may have important job creation impacts that should be quantified. Moreover, although the energy impacts of certain energy awareness and education projects are difficult to measure, they may have an important influence in shaping public attitude toward energy use. In short, any comprehensive analysis of the value of the program should also consider these less tangible benefits.

ORGANIZATION OF THE REPORT

The next four chapters present the methods and results of the study. Chapter 2 presents estimates of direct energy savings for the 57 projects and discusses direct energy savings. Chapter 3 discusses the methods and results of the economic analysis. Chapter 4 examines the indirect savings. Because of the large size of the sample, neither project descriptions nor specific details of each project analysis are included. Instead, two examples from the analysis are presented in Chapters 2, 3, and 4 to illustrate the methods. The results of the analysis and key project data are summarized in Table 1-1. Chapter 5 presents estimates of program energy savings and the methods used to obtain them. The report concludes with a discussion of how improved project selection can increase program energy savings and presents two approaches for conducting future energy impact studies.

SUMMARY TABLE OF APPROPRIATE ENERGY TECHNOLOGY PROJECT ANALYSIS

TABLE 1-1

Project Number	Region	Technology	End Use	Sector of Application	Fuel Displaced	Funding Level ($1000)	Project Lifetime (years)	Project Type	Direct Energy Savings (MBtu)	Savings/ Investment Ratio (SIR)	Indirect Energy Savings (MBtu)	Oil Barrel Equivalent (bbls)	Notes
1	2	3	4	5	6	7	8	9	10	11	12	13	14
NJ-861	II	SOL	FP	COM	FO	4.6	20	PSD	2,100	0.9	0	398	
IA-94	VII	SOL	PH	AGR	EL	0.9	20	PSD	412	2.4	0	234	
MO-201	VII	SOL	PH	AGR	LP	5.5	20	PSD	51	NA	0	10	
NJ-255	II	SOL	SH/PH	COM	NA	14.0	NA	PSD	0	NA	NA	0	
OH-1221	V	SOL	WH	COM	NG	24.5	20	CSTM	10,000	0.9	NA	1,897	
IN-701	V	SOL	NA	RES	EL	10.0	20	LR	0	NA	0	0	
PA-6	III	SOL	PH	IND	FO	28.2	20	CSTM	16,500	>1	16,500	6,259	
VA-180	III	SOL	PH	RES	NG	8.1	15	PSD	630	1.1	22,050	4,301	
OH-478	V	SOL	WH	RES	NG	1.9	25	ED	0	NA	12,603	2,390	
AR-1372	VI	SOL	PH	COM	NG	6.3	20	PTM	332	72.7	6,648	1,323	
NM-626	VI	SOL	PH	COM	NG	10.8	20	PSD	134	12.2	2,013	407	
OH-418	V	SOL	WH	RES	NG	16.4	20	ED	40	0.1	800	159	
MO-198	VII	SOL	SH	RES	NG	7.3	1	FS	0	NA	0	0	
IA-6	VII	BIO	SH	AGR	NG	14.4	10	CSTM	36,000	22.9	2,700,000	518,897	
IL-397	V	BIO	SH	PUB	NG	50.0	20	CSD	730,000	2.9	0	138,448	

1: Number contains state abbreviation

3: Solar = SOL, Biomass = BIO, Wind = WIN, Hydropower = HYD, Energy Storage/Transfer = EST, Conservation = CON, Education = ED, Geothermal = GEO

4: Space Heating = SH, Space Cooling = SC, Water Heating = WH, Lighting = LT, Cooking = CK, Clothes Washing = CW, Clothes Drying = CD, Dish Washing = DW, Transportation = TR, Process Heat = PH, Food Production = FP, Waste Treatment = WT

5: Residential = RES, Commercial = COM, Industrial = IND, Public = PUB, Agricultural = AGR

6: Electricity = EL, Natural Gas = NG, Fuel Oil = FO, Liquified Propane = LP

9: Feasibility Study = FS, Lab Research = LR, Prototype Component Development = PCD, Prototype System Development = PSD, Prototype Testing and Monitoring = PTM, Commercial System Testing and Monitoring = CSTM, Commercial System Demonstration = CSD, Commercialization = COM, Educational/Workshop = ED

13: Col. 13 sums columns 10 and 12. To convert given MBtu to oil bbls, first convert to primary energy by multiplying by 1.1 for projects that displace gas or oil, or by 3.3 for projects that displace electricity. Then divide by 5.8 to convert from primary MBtu to barrels of oil.

SUMMARY TABLE OF APPROPRIATE ENERGY TECHNOLOGY PROJECT ANALYSIS

TABLE 1-1 (cont.)

Project Number	Region	Technology	End Use	Sector of Application	Fuel Displaced	Funding Level ($1000)	Project Lifetime (years)	Project Type	Direct Energy Savings (MBtu)	Savings/ Investment Ratio (SIR)	Indirect Energy Savings (MBtu)	Oil Barrel Equivalent (bbls)	Notes
1	2	3	4	5	6	7	8	9	10	11	12	13	14
MD-53	III	BIO	SH	RES	FO	42.5	30	CSD	66,000	2.5	0	12,517	
AK-043	X	BIO	SH	RES	LP	9.0	15	PTM	528	-.2	0	100	
MA-642	I	BIO	SH	RES	FO	20.0	1	COM	3,300	43.2	0	569	
NY-00	II	BIO	FP	IND	EL	25.0	20	PSD	459	.5	0	261	
VT-1	I	BIO	SH	RES	FO	24.6	NA	PTM	0	NA	NA	0	
OK-1271	VI	BIO	PH	IND	NG	10.0	NA	LR	0	NA	0	0	
OH-1089	V	BIO	TR	AGR	GS	19.8	NA	FS	0	NA	0	0	
WV-134	III	BIO	TR	RES	GS	36.9	NA	PCD	0	NA	0	0	
CT-409	I	BIO	WT	COM	NG	4.8	NA	PSD	0	NA	0	0	
MD-159	III	BIO	WT	IND	EL	25.0	20	CSD	0	1.9	0	0	
VT-559	I	BIO	SH	COM	LP	9.3	30	CSTM	0	7.5	0	0	
RI-859	I	BIO	SH	RES	FO	19.4	NA	FS	0	NA	0	0	
KS-71	VII	BIO	SH	RES	NG	6.7	NA	PTM	0	NA	0	0	
WA-289	X	BIO	WT	PUB	EL	9.0	NA	FS	0	NA	0	0	
MI-113	V	WIN	FP	AGR	EL	6.7	30	CSD	1,536	0.8	0	874	

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SUMMARY TABLE OF APPROPRIATE ENERGY TECHNOLOGY PROJECT ANALYSIS TABLE 1-1 (cont.)

Project Number	Region	Technology	End Use	Sector of Application	Fuel Displaced	Funding Level ($1000)	Project Lifetime (years)	Project Type	Direct Energy Savings (MBtu)	Savings/ Investment Ratio (SIR)	Indirect Energy Savings (MBtu)	Oil Barrel Equivalent (bbls)	Notes
1	2	3	4	5	6	7	8	9	10	11	12	13	14
TX-522	VI	WIN	NA	NA	NA	9.8	NA	LR	0	NA	0	0	
NH-539	I	WIN	NA	COM	EL	41.0	20	CSD	9,102	0.9	0	5,179	
NY-539	II	WIN	WT	PUB	EL	48.7	20	CSD	3,512	0.7	0	1,998	
OH-673	V	WIN	NA	RES	EL	9.9	20	CSD	610	0.2	0	347	
VI-7	II	WIN	NA	RES	EL	9.3	20	CSD	356	1.0	4,276	2,635	
IL-849	V	WIN	NA	PUB	EL	27.0	20	ED	543	0.1	0	310	
MI-122	V	WIN	SH	RES	NG	22.5	20	PSD	1,024	0.1	0	195	
OK-152	VI	WIN	FP	AGR	EL	3.4	30	CSD	33	0.1	0	2	
MN-382	V	WIN	NA	AGR	EL	19.6	20	CSD	1,146	0.6	0	652	
TX-1296	VI	GEO	SH	COM	EL	11.4	20	PSD	655	1.5	4,586	2,982	
TX-1267	VI	GEO	SH	PUB	NG	8.0	NA	FS	0	NA	0	0	
ME-903	I	HYD	NA	PUB	EL	27.0	20	PSD	107,851	18.8	35,495	81,559	
NE-3	VII	EST	SH	RES	EL	9.8	20	PSD	3,079	1.4	0	1,752	
IL-50	V	EST	SC	RES	NG	23.8	1	PTM	0	NA	0	0	
MN-296	V	EST	SC	RES	EL	12.0	NA	PCD	0	NA	0	0	

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Project Number	Region	Technology	End Use	Sector of Application	Fuel Displaced	Funding Level ($1000)	Project Lifetime (years)	Project Type	Direct Energy Savings (MBtu)	Savings/ Investment Ratio (SIR)	Indirect Energy Savings (MBtu)	Oil Barrel Equivalent (bbls)	Notes
1	2	3	4	5	6	7	8	9	10	11	12	13	14
PA-645	III	CON	WT	PUB	NG	6.9	1	PSD	64	-4.6	0	12	
IN-904	V	CON	SH	COM	NG	16.9	1	PCD	0	NA	0	0	
LA-132	VI	CON	CW	IND	NG	31.6	25	COM	7,884	53.0	5,802,755	1,102,018	
CA-390	IX	CON	WH	COM	NG	8.0	25	CSD	6,000	4.9	4,416,100	838,674	
NM-766	VI	CON	SH	RES	NG	10.2	20	PSD	0	NA	0	0	
NM-126	IX	CON	SH	RES	NG	1.9	30	CSTM	0	NA	0	0	
OH-580	V	CON	SH	RES	EL	33.3	13	CSTM	2,106	4.8	0	1,198	
IL-206	V	CON	SH	COM	NG	48.2	20	PSD	0	4.0	22,500	4,267	
IA-23	VII	CON	SC	RES	EL	2.7	20	PTM	55	0.8	55	31	
NY-278	II	CON	SH	RES	NA	12.1	12	PSD	0	0.6	0	0	
VT-102	I	CON	SH	RES	FO	8.0	12	PSD	95	0.2	284	18	
ME-914	I	CON	WH	COM	LP	20.0	10	CSD	576	0.6	0	109	

1: Number contains state abbreviation

3: Solar = SOL, Biomass = BIO, Wind = WIN, Hydropower = HYD, Energy Storage/Transfer = EST, Conservation = CON, Education = ED, Geothermal = GEO

4: Space Heating = SH, Space Cooling = SC, Water Heating = WH, Lighting = LT, Cooking = CK, Clothes Washing = CW, Clothes Drying = CD, Dish Washing = DW, Transportation = TR, Process Heat = PH, Food Production = FP, Waste Treatment = WT

5: Residential = RES, Commercial = COM, Industrial = IND, Public = PUB, Agricultural = AGR

6: Electricity = EL, Natural Gas = NG, Fuel Oil = FO, Liquified Propane = LP

9: Feasibility Study = FS, Lab Research = LR, Prototype Component Development = PCD, Prototype System Development = PSD, Prototype Testing and Monitoring = PTM, Commercial System Testing and Monitoring = CSTM, Commercial System Demonstration = CSD, Commercialization = COM, Educational/Workshop = ED

13: Col. 13 sums columns 10 and 12. To convert given MBtu to oil bbls, first convert to primary energy by multiplying by 1.1 for projects that displace gas or oil, or by 3.3 for projects that displace electricity. Then divide by 5.8 to convert from primary MBtu to barrels of oil.

CHAPTER 2

ASSESSMENT OF DIRECT ENERGY SAVINGS

INTRODUCTION

This chapter discusses the direct energy savings of the 57 projects and the methods used to determine those savings. Direct savings are both a portion of total energy savings and one of the parameters used to calculate cost-effectiveness. Moreover, direct savings provide the basis for estimating indirect energy savings once the extent of system replication has been estimated.

Direct energy savings are the amount of energy saved over the lifetime of the system(s) implemented by a project. Not all projects have direct savings. Some projects, such as feasibility studies or laboratory research efforts, do not use a system to meet an end use and thus cannot attain direct savings. Others had no savings because they failed to meet their objectives.

We separate this chapter into three sections. The first defines direct energy savings and discusses methods used to calculate them. The second presents two projects to illustrate these methods. The third section presents the results of the analysis and discusses project characteristics that indicate a potential for direct energy savings.

DEFINITIONS AND METHODS

A project has direct savings if it meets two criteria:

(1) the project must be successfully completed or show signs of nearing successful completion.

(2) the project must install an energy system that produces or conserves energy to meet an end use, meaning the production of an economic good or the supply of a service.

By these criteria, worthwhile projects that produce energy only for the purposes of system development and testing do not have direct savings. Most projects attain direct savings by displacing an amount of fossil energy that would otherwise be used for an existing end use such as space heating. Other projects do not displace conventional energy in such a straightforward manner. As a case in point, a new building that incorporates a solar technology does not have a prior energy use. For such projects, the amount of fossil energy that would be needed to operate that building without the solar technology is computed and this figure is used as the estimate of direct savings.

The specific fuel displaced by a project, e.g., natural gas, electricity, or fuel oil, was usually determined from past use at the project site. When fuel information was not available, as in the case of a new building, the fuel that would have been used in that region, based on the end use addressed by the project, was selected.

The amount of energy saved by each project was determined from a variety of sources:

- o operating and monitoring data on the installed energy system.
- o utility bills before and after the system was installed.
- o calculations based on design parameters of the system and on comparisons with similar systems.

From these data, energy savings were estimated on an annual basis. The direct energy savings were calculated by multiplying annual savings by the projected lifetime of the system. In other words, direct energy savings are the amounts of fossil energy saved by the projects over the lifetime of the implemented energy systems.

Ideally, every project that deploys an energy system should have several years of operating data upon which to base an estimate of direct energy savings. At the time of this study, most projects were just being completed. In the absence of sufficient operating data, we relied on the operating data available, on discussions with the grantee and consultants, and on comparisons of the project system with similar systems for which operating data were available.

EXAMPLE PROJECTS

To illustrate the methods for calculating direct energy savings, two projects are presented below.

Example 1

The first project, located in Marlin, Texas, uses hot water from an existing geothermal well to heat the nearby office of the Marlin Chamber of Commerce. DOE awarded the Chamber of Commerce $11,400 to design and install a heat exchanger at the well, associated piping, and a heating coil in the existing, forced-air heating system, which remains in place as backup for the geothermal system (Marlin, 1979). In addition to the DOE Grant, the Chamber of Commerce contributed $3,500 to the project. The Chamber will use the project to promote inexpensive heat to attract industry (Johnson, 1980).

The most accurate estimate of the project's direct energy savings would have been provided by comparing utility bills before and after installation of the system (with corrections made for differences in weather). Because these records are not yet available, direct energy savings are estimated from design operating parameters made available by the engineering firm hired to design the system.

When in operation, the system raises 1500 cfm of air by $30^{o}F$ (Johnson, 1980). This warm air flow is equivalent to 49,250 Btu/hr or 14.4

kw. An electric heating system with an efficiency of 0.9 requires an input of 16.0 kw to supply this heat to an occupied space (14.4/0.9 = 16.0).

In order to estimate annual energy savings we assume a 120 day heating season (which excludes weekends and holidays during the heating months) and a daily system use of 5 hours per day. The annual energy savings (AES) are found by multiplying the number of days in the heating season by the daily use by the power displacement.

AES = (120 days/yr)x(5 hr/day)x(16kw) = 9600 kwh/yr.

The project engineer estimated the system lifetime to be 20 years. Therefore, the direct energy savings (DES) are:

DES = (20yrs)x(9600 kwh/yr) = 192,000 kwh = 655.2 MBtu*

Example 2

The second example, a project that develops a solar kiln for drying lumber, illustrates a different technology and another method for estimating direct energy savings. DOE awarded John Vincent of New Mexico $10,000 to develop the kiln and demonstrate it to local woodworkers. The project has a special importance for northern New Mexico's craftsmen who use cabinet grade pine to build a Spanish-style furniture. Although New Mexico grows sufficient pine for this trade, no kilns exist in New Mexico that can dry pine to cabinet grade quality. Therefore, dried pine must be imported from Oregon at a cost of $1.75 per board foot, compared to $.30 per board foot for undried pine produced in New Mexico (Vincent, 1979). The high cost of imported pine, which threatens the existence of these marginal, small-scale furniture makers, is directly related to the use of natural gas for drying the lumber and of diesel for transporting wood from Oregon to New Mexico.

The kiln consists of a wood-framed shed with walls of corrugated metal. A solar collector adjoins the shed. It uses halved beer cans to provide the heat exchange surface for heating air. The south and west walls of the kiln are painted black to maximize solar gain. The kiln operates without fans; air flow is totally by natural convection through vents in the top and bottom of the shed. The kiln has a capacity to produce 10,000 board feet of dried lumber per year given the level of solar insolation in northern New Mexico (Vincent, 1979). However, a typical woodworker in the area requires only 4000 board feet annually. This requirement is used as the estimate of the kiln's annual production.

* The electrical energy is converted to MBtu by using the thermodynamic equivalence of 1 kwh = 3412.4 Btu = 0.0034124 MBtu. Note that the nation's primary energy savings are larger than this figure because 3.3 units of primary energy are needed to deliver 1.0 unit of electrical energy, due to generation and transmission losses. Thus the direct primary energy savings by this project are (3.3)x(655.2 MBtu) = 2,165 MBtu. This conversion to primary energy units is later expressed in oil barrel equivalent units in Chapter 5.

The kiln saves energy by displacing natural gas used for drying lumber and diesel fuel used for transporting the lumber round trip between Oregon and New Mexico. A typical gas kiln will consume 1.8 MBtu of natural gas per 1000 board feet of 2 inch ponderosa pine (Argonbright, 1980). According to one lumber wholesaler, a typical lumber truck has a hauling factor of .01 gallons per board foot mile (gal/BF-mi)(Gerry, 1980).

Natural gas savings are estimated to be:

(4000 BF/yr)x(.0018 MBtu/BF) = 7.2 MBtu/yr.

Diesel fuel savings are estimated to be:

(7800mi/round trip)x(4000 BF/yr)x(.01 gal/BF-mi)x(.14 MBtu /gal) = 10.1 MBtu/yr.

The estimate of AES is 17.3 MBtu per year, which is the sum of natural gas and diesel fuel savings. Assuming a lifetime of 20 years results in a DES of 345 MBtu.

RESULTS

Table 1-1, Column 10 lists the DES for all 57 projects, Tables 2-1 and 2-2 summarize the results by technology and project type, respectively. Although other classifications are possible, we believe technology and project type are the two characteristics most likely to be related to project energy savings.

By technology, most solar, wind, and conservation projects had direct energy savings. However, the more direct relation is between project <u>type</u> and direct energy savings. Projects with direct energy savings tended to demonstrate, develop, or market a commercial device or prototype. Projects without direct energy savings were mainly feasibility and laboratory research projects that tested an energy system without using the energy saved. Although these latter projects have no direct energy savings, they may have a large energy savings potential through their indirect impacts. For example, if a project shows an energy system to be economically and technically feasible, other people might implement similar systems. These "spin-off" energy savings are considered in Chapter 4 and referred to as indirect energy savings. However, a determination of cost-effectiveness precedes the estimation of indirect savings. The following chapter considers project cost-effectiveness and presents the methods and results of the economic analysis.

Table 2-1

Technology Applied by Projects With and Without Direct Energy Savings

Technology	With Direct Savings	Without Direct Savings	Total
Solar	9	4	13
Conservation	7	5	12
Biomass	6	10	16
Hydro	1	0	1
Geothermal	1	1	2
Wind	9	1	10
Energy Storage	1	2	3
Total	34	23	57

Table 2-2

Project Type and Direct Energy Savings

Type of Project*	With Direct Savings	Without Direct Savings	Total
FS	0	5	5
LR	0	3	3
PCD	0	3	3
PSD	12	5	17
PTM	3	4	7
CSD	11	0	11
CSTM	4	2	6
COM	2	0	2
ED	2	1	3
Total	34	23	57

*See Table 1-1, Key 9, for full description.

CHAPTER 3

ECONOMIC ANALYSIS

INTRODUCTION

In this chapter, the cost-effectiveness of each project is assessed on a life-cycle cost basis. The results of the economic analysis are used in the next chapter to select projects that can have indirect energy savings. Except in cases where indirect energy savings have already been achieved, only cost-effective projects are assumed to have indirect energy savings. The economic analysis serves a second purpose by indicating to DOE projects that have an exceptional potential for achieving indirect energy savings with relatively small amounts of government assistance.

In general, a project is cost-effective if it applies an energy system that generates on a life-cycle basis net revenues equal to or greater than its first costs. To make our analysis consistent with others done for DOE, we followed guidelines established by DOE for conducting a life-cycle cost analysis of energy projects (Ruegg et al., 1978)(Federal Register, 1980). Each project was analyzed on a before-tax basis, and the ramifications of income tax credits and deductions which might affect a systems cost-effectiveness are not considered. The next sections of this chapter cover in detail the methods, key assumptions, and findings of the analysis.

DEFINITIONS AND METHODS

Life-cycle costing (LCC) is used to evaluate the cost-effectiveness of each project. LCC is the method for evaluating all relevant costs and revenues for an energy system over its economic life. The LCC method is applied in four steps:

(1) Estimation of first costs

First costs include the costs of purchasing and installing a small-scale energy system less any capital savings from not using a fossil fuel system. Whenever possible, we base a system´s first cost on the actual cost or expected cost of the system in the commercial market. The first costs are either those claimed by the grantee or in the case of marketing projects, the price charged for the system if commercially marketed. In cases where the project is developing a prototype system first costs are estimated either from the grantee´s best estimate of what his system will cost when commercially available or from comparisons to similar systems already being marketed. The cost of a commercial system is usually less than a project´s grant, which in many cases includes cost of design, development, and testing.

(2) Estimation of annual net revenues

Net revenues are the dollar value of energy or other output produced or saved over a system´s life-cycle minus operating, maintenance, and replacement costs. Similar to first costs, these revenues are computed on a net basis, taking into account any additional savings and/or costs incurred by the prospective user from not using a fossil fuel alternative.

(3) Conversion of costs and revenues to present values

The costs and revenues estimated in (1) and (2) occur at different times. To convert these values into time-equivalent amounts, future costs are discounted by a real rate of interest that reflects the real time value of money. In other words, future benefits resulting from an investment are worth less to an investor today because he could have invested his funds in an alternative investment and generated a monetary return.

In estimating life-cycle costs for each project, assumptions were made about future energy and nonenergy costs. To maintain consistency between our analysis and other DOE studies, the following DOE guidelines for conducting an LCC analysis were observed:

- All future costs and revenues are expressed in real 1980 dollars: that is, they are net of inflation (Ruegg et al., 1978).
- Nonenergy costs and revenues are assumed to increase annually at the rate of inflation, i.e., at a 0% real rate of increase.
- The real discount rate is 10% (Federal Register, 1980).
- Base year energy prices are either the actual price per unit paid by the grantee or regional DOE estimates of energy prices for 1980 (Federal Register, 1980).*
- Energy prices escalate at a real annual rate of 3% to 5%, depending on the region in which the project is located, the fuel displaced, and the sector of application (Federal Register, 1980).

(4) Determination of cost-effectiveness

After computing life-cycle costs, a system's cost-effectiveness was determined. A system is deemed cost-effective if, on a life-cycle basis, the net present value of before-tax revenues equals or exceeds first costs. As an indicator of cost-effectiveness, the savings to investment ratio (SIR), which is the ratio of the net present value of before-tax revenues to first costs, was used to indicate cost-effectiveness. By definition, energy systems with a SIR equal to or greater than 1.0 are cost-effective.

The before-tax SIR roughly indicates whether a specific energy

* The DOE energy prices are average prices paid for each fuel in a specific region by economic sector. The prices underrate the actual value of the energy savings from each project as they do not measure the marginal cost of imported oil to the economy, which, in the final analysis, is what each project displaces and hide tax and other subsidies fossil fuels have enjoyed which keep their price artificially low.

system that relies on renewable energy resources can compete against a fossil fuel alternative without government subsidies. It does not indicate whether a private firm or individual will invest in a particular energy system. To determine whether a firm or individual will invest in an energy system would require a detailed analysis of the economic sectors in which the system can be used and of the applicable investment criteria and tax laws. Because many of the projects develop systems that can be applied in more than one sector, economic analysis on an after-tax basis is unduly cumbersome and beyond the scope of this report. Thus, we opted for the simpler, before-tax approach.

THE TWO EXAMPLES

To illustrate how the cost-effectiveness of each project was computed, we return to the two examples introduced in Chapter 2. The computations are described in a paragraph followed by data showing the basic computations.

Example 1

The Marlin Chamber of Commerce heats its building for only 600 hours each year (Johnson, 1980). The geothermal system is not economically feasible based on such limited use. However, this limited use in not typical of many users. For instance, most factories operate for two or three shifts per day. Shopping malls and hotels have daily heating demands of 18 to 24 hours. For the economic analysis, we assume that a firm with a heating demand of 16 hours per day during a typical heating season or 2000 hours per year locates at the site and installs a system similar in design and cost to the one installed in the Chamber's building. The project engineer estimates the system's cost at $9000 installed, which is the first cost of the system in the Chamber's building excluding design costs. Operating and maintenance costs are $100 per year. Annual energy savings (AES) are estimated to be:

AES = (2000 hrs/600hrs)x(32.8 MBtu/yr) = 109.2 MBtu/yr.

The steps and details of our analysis are shown below:

(1) First costs: $9000

(2) Operating and maintenance (O&M) costs: $100

(3) Annual energy savings 109.2 MBtu

(4) Cost of energy in 1980: $12.16/MBtu

(5) Present value of O&M cost: (10% discount rate, 0% real rate of increase) = $850

(6) Present value of energy savings (10% discount rate, 5% real rate of increase): $14,365

(7) Present value of net revenues = (6)-(5) = $13,515

(8) SIR = (7)/(1) = 1.5

Example 2

The second example, the solar kiln, requires a different approach in estimating cost-effectiveness. Estimating the cost of building a second unit excluding design cost is the first step. The grantee thought that a second unit could be built for $1400 or less based on short cuts he learned by building the first kiln (Vincent, 1980). The second step was to compute net revenues from the solar kiln. In contrast to the geothermal example, net revenues for the solar kiln do not directly include energy revenues. Instead, the dollar value of energy savings are accounted for indirectly by computing the annual cost savings that will accrue to woodworkers from buying green rather than cabinet grade pine. Net revenues are estimated by subtracting operating, maintenance, and replacement costs of the kiln from the dollar savings of buying green versus kiln dried pine. The savings are substantial, $5800 per year for a woodworker using 4000 board feet of lumber each year. The data below are used to compute SIR.

(1) First Cost: $1400

(2) Gross revenues: $5800

(3) Operating and maintenance cost: $3200

(4) Net revenues = (2)-(3) = $2600

(5) Life of project: 20 years

(6) Present value of net revenues (10% discount rate, 20 year life): $22,125

(7) SIR = (4)/(1) = 15.8

RESULTS

Table 1-1, Column 11 presents the SIRs for the 57 projects. Tables 3-1 and 3-2 present the findings of our economic analysis by technology and project type, respectively. Of the 57 projects, 20 were not evaluated. These projects either developed an energy system that proved technically infeasible or failed for other reasons. They had no direct or indirect energy savings and could not be evaluated for cost-effectiveness. Although these projects failed to accomplish their objectives, they still may have been worthwhile investments of DOE funds. For instance, some of these projects attempted to improve the efficiency or reduce the cost of existing energy systems. If successful, some of these projects could have achieved technological breakthroughs that later might have led to the system's cost-effectiveness. Other projects attempted to prove or disprove whether an energy saving system or concept could work. By investing relatively small amounts of funds in these projects, DOE determined that future investments are not

Table 3-1

Number of Projects by Technology and Cost-Effectiveness

Technology	Cost-Effective	Not Cost-Effective	Total
Solar	5	8	13
Conservation	5	7	12
Biomass	5	11	16
Hydro	1	0	1
Geothermal	1	1	2
Wind	1	9	10
Energy Storage	1	2	3
Total	19	38	57

Table 3-2

Number of Projects by Type and Cost-Effectiveness

Type of Project*	Cost-Effective	Not Cost-Effective	Total
FS	0	5	5
LR	0	3	3
PCD	0	3	3
PSD	6	11	17
PTM	1	6	7
CSD	5	6	11
CSTM	4	2	6
COM	2	0	2
ED	0	3	3
Total	18	39	57

*See Table 1-1, Key 9, for full description.

justified.

Of the 37 projects evaluated, 19 were found to be cost-effective. Moreover, a correlation was found between a project's characteristics, such as technology applied and project type, and a project's cost-effectiveness. For example, many of the solar and conservation projects were found to be cost-effective. Of the 25 solar and conservation projects, 10 had a SIR greater than 1 (See Table 3-1). SIRs ranged from -4.6 to 53. (Projects with O&M costs greater than net revenues had a negative SIR.)

Wind projects, on the other hand, were poor cost competitors. Ten wind projects were evaluated and only 1 was cost-effective. The 1 cost-effective project was a wind-electric project located on the Virgin Islands, where electricity rates are very high. (See Table 1-1, VI-7.) The project was located at an apartment complex, and the site had an excellent annual wind regime. The wind generator was small (1.5kw), and the full output was used on site (Graham, 1980).

The uneconomical wind projects were either too small to achieve economies of scale or faced inadequate demand at the site for the energy produced. For instance, wind electric systems that supply a home with electricity require costly investments in batteries, inverters, voltage control devices and wiring, in addition to the substantial first cost of the wind generator and tower. Zoning restrictions on tower height and structural requirements for anchoring the tower increase significantly the first cost of a residential wind electric system (Benjamin, 1980). In the case of agricultural water pumping, windmills are needed only part of the year because of the seasonal nature of a farm's demand for irrigation water (Goulden, 1980). As a result, the windmill is underused during the year, reducing its economic value to the farmer.

Cost-effective projects tended to demonstrate or test an existing commercial system. Except for one promising project that is developing an improved method of harvesting firewood (Tate, 1980), none of the projects made major advances in design or operation or moved a system from the laboratory testing place to commercial demonstration during the grant period. Each followed a more gradual path of development. Frequently, small but significant improvements were made in understanding the technical requirements of a specific energy system and in developing ways to improve its operation.

To summarize, the economic analysis identified 19 projects that either developed or demonstrated cost-effective systems. The 19 projects will be examined in greater detail in Chapter 4 to determine whether they have indirect energy savings.

CHAPTER 4

ASSESSMENT OF INDIRECT ENERGY SAVINGS

INTRODUCTION

Indirect energy savings occur as a consequence of either demonstrating a particular energy system or encouraging its commercial development. This chapter assesses the indirect energy savings of the 57 projects and discusses project characteristics that impact indirect indirect savings.

Not all projects can induce indirect savings. Two important factors that determine whether a project can have indirect savings are:

(1) the cost-effectiveness of the energy system applied by the project; and

(2) the intent of the grantee to demonstrate the system or to market it.

These two factors are threshold criteria. In other words, if a project's energy system was judged cost-effective and if the grantee intends to replicate the project system, then the project was evaluated for indirect potential and a value calculated from information supplied by the grantee. The details of the analysis are presented in the remainder of this chapter. First, the methods of analysis are discussed followed by the two examples illustrating how these methods are applied. The chapter concludes with a presentation of the results of the analysis and an interpretion of their significance for the Small Grants Program.

DEFINITIONS AND METHODS

A project's indirect energy savings are the lifetime energy savings from energy systems installed as a consequence of that project. The additional systems, referred to as replicate systems, result from a project's demonstration effects that induce others to replicate the system or from direct marketing of the system. Ideally, we would have preferred to estimate the actual indirect savings from a project. In most cases, the projects were still being completed, and indirect savings had not yet been attained. Therefore, we could estimate only indirect potentials, based on information supplied by the grantee.

For a project to have the potential for indirect savings, it has to meet two criteria:

(1) the project must apply a cost-effective energy system.

(2) the grantee must have a specific intent to market or demonstrate to the public his energy system.

Indirect energy savings were estimated for 11 projects that met these criteria and 4 projects that were not cost-effective but still had achieved indirect savings.

Determining the indirect potentials of those projects was a difficult task for a number of reasons. First, the projects had differing objectives ranging from publicly demonstrating a commercial system to proving the economic and engineering feasiblity of a prototype system. Second, the grantees differed with respect to entrepreneurial spirit, marketing expertise, and capital resources; qualities that can greatly affect a project's indirect impact. Third, the projects addressed different markets, audiences, and economic sectors and were located in different areas. Finally, projects had different time frames for achieving their indirect impacts. For instance, a solar workshop project was found to tap its indirect potential during the course of the workshop program but a project to develop and market an improved wood stove could achieve its indirect impacts over a far longer time horizon. Because of these factors, the potential market for each project was considered before an estimation of the indirect energy savings was made. To maintain a consistent approach in dealing with diverse conditions, the following procedures were established:

- o The time period over which a project can have an indirect impact was limited to five years. Effects that might accrue beyond five years were treated as unpredictable. Thus, a project with commercial potential is credited with energy savings over only the first five years.

- o The grantee's estimates of indirect savings were relied on if the grantee had a clear idea of the project's overall potential and the fraction of the total he could achieve over a five year period.

- o In cases where the grantee had a clear idea of a project's indirect potential but no idea what fraction he could achieve, our own judgment was used in an attempt to assign a number based on information obtained during the project's analysis. In cases where this seemed unduly speculative, we assumed that the project achieved 1% of the overall potential each year over a maximum of five years.

Although sufficient information existed for an estimation of indirect savings for all projects, we had to rely on the last procedure more often than not. To guard against overly optimistic estimates, the lower bound of any range of possible values was selected as the estimate of indirect savings for a project. To illustrate how indirect savings were calculated, the geothermal and solar kiln projects already discussed in Chapters 2 and 3, are presented below.

THE TWO EXAMPLES

Example 1

The Marlin Chamber of Commerce will promote the geothermal well as a source of inexpensive space heat for new businesses. The project tapped only 1/8th of the well's flow, and the remaining flow is available for development (Johnson, 1980). The Chamber hopes the well will encourage new businesses to locate in the town. The economic analysis showed the geothermal heating system to be cost-effective if used for 2000 hours per year or greater. To estimate indirect savings, we assume that:

(1) the Chamber of Commerce is successful in attracting new industry to Marlin.

(2) some of the businesses locate near the geothermal well and tap its remaining capacity.

(3) the new businesses heat their buildings for at least 2000 hours per year.

We estimated in Chapter 3 that 1/8th of the available well flow used 2000 hours per year could displace 109.2 MBtu of electricity annually. With a 20 year life, the system will save 2184 MBtu of electricity (7 x 2184). If the remaining 7/8ths of the well capacity is used for space heating, then the project wil have an indirect savings of 15,288 MBtu of electricity.

Whether new businesses will actually locate in Marlin is unpredictable. Nevertheless, the Chamber is attempting to attract them and using the geothermal project as a key sales point (Johnson, 1980). Thus, the indirect savings are reasonably certain of being achieved. Furthermore, the estimates do not account for any demonstration effect that the project may have on nearby communities that might also have a geothermal resource.

Example 2

The solar kiln is highly cost-effective, and the grantee intends to have an open house for local woodworkers to show them how the kiln was constructed, how it operates, and samples of the dried lumber (Vincent, 1980). The grantee estimates that northern New Mexico has at least 300 small woodworkers who could profitably operate a solar kiln. He has developed a mailing list of those woodworkers and will send invitations to them to attend the open house.

Whether these woodworkers construct a kiln will depend on their available capital and their willingness to invest time in constructing and operating the kiln. The grantee has no idea how many will actually build a kiln. Thus, the assumption is that 15 kilns are built over the next five years, which is equal to 1% of the 300 woodworkers per year for five years. This number may be overly conservative as the kiln has a very short payback and is simple to build and operate. Moreover, it does not consider the kiln's use in other areas of the country if plans and operating manuals are disseminated to interested people.

These two examples indicate the approach in estimating indirect savings. Restricting estimates to those savings likely to occur in a locale over a maximum period of five years, offers estimates at the low end of the range of possibilities.

RESULTS

Table 1-1, Column 12 presents estimates of indirect energy savings for the 57 projects. Comparing projects with and without indirect savings reveals some interesting correlations (See Tables 4-1 and 4-2). First, projects with indirect savings mainly developed or demonstrated solar, conservation, and biomass projects. All wind projects except one have very low SIRs and thus did not have indirect savings. Second, most projects that had indirect savings either developed or demonstrated an energy system. Almost all projects that conducted feasibility studies or laboratory research did not have indirect savings. This is in line with expectations for a project at an early stage of development.

A surprising finding is that only 15 of 57 projects were judged to have the potential to achieve indirect savings. Further, 8 of the 15 projects accounted for almost all of the sample's total energy savings:* that is, the sum of direct and indirect energy savings for the 57 projects.

A superficial reading of this finding would suggest that DOE could have maximized the program's energy savings potential by investing all the program's monies in these 9 projects. Such a conclusion would be wrong. First, DOE funded some projects at an early stage of development. As they move toward commercialization, they may develop into major energy saving projects. DOE, by providing early support for these projects, may induce large energy savings in the future. We do not know whether these savings will occur nor their magnitude and have avoided speculating about them.

Second, DOE is not omniscient in selecting grants with large energy savings. It receives over 10,000 proposals each fiscal year and funds over 500. In most cases, DOE can state only after the project is completed whether the project has a large energy savings potential. Thus, the program should not be judged by the fact that only a small number of projects have large energy savings. One should look instead at the overall performance of the program in terms of the energy saved per dollar of DOE funding. This figure gives a better indication of whether DOE pooled its selection of projects in a manner which gave the country a high return on its tax dollars. In Chapter 5, the next chapter, we turn to the issue of program energy savings and the cost-effectiveness of the Grants Program.

* The 9 projects are CA-390, LA-132, IL-206, PA-6, VA-180, OH-478, IA-6, and ME-903.

Table 4-1

Number of Projects by Technology With and Without Indirect Savings

Technology	With Indirect Savings	Without Indirect Savings	Total
Solar	6	7	13
Conservation	5	7	12
Biomass	2	14	16
Hydro	1	0	1
Geothermal	1	1	2
Wind	1	9	10
Energy Storage	0	3	3
Total	16	41	57

Table 4-2

Number of Projects by Type With and Without Indirect Savings

Type of Project*	With Indirect Savings	Without Indirect Savings	Total
FS	0	5	5
LR	0	3	3
PCD	0	3	3
PSD	5	12	17
PTM	4	3	7
CSD	2	9	11
CSTM	2	4	6
COM	1	1	2
ED	2	1	3
Total	16	41	57

*See Table 1-1, Key 9, for full description.

CHAPTER 5

ESTIMATING PROGRAM ENERGY SAVINGS

INTRODUCTION

From the analysis of the 57 projects, we infer the energy savings potential of all projects funded by the small grants program in fiscal year (FY) 1979. We label these savings "program energy savings." The information presented in this chapter can serve two purposes. First, savings data can help DOE evaluate and improve the program. Second, DOE can apply the methods of analysis in future studies of the program's energy impacts.

The chapter is divided into 3 sections. Section 1 describes the methods and limitations of the methods used to estimate program energy savings. Section 2 presents the estimates of program energy savings for FY 1979. Section 3 suggests ways to increase program energy savings and provides direction for future analyses.

METHODS OF ESTIMATION

Estimates of program energy savings have been statistically inferred from the energy savings potential of the 57 project sample. Compared to project savings, program savings are a more difficult and speculative calculation. The approach is separated into 3 steps:

(1) sample selection

(2) statistical inference

(3) estimation of program energy savings

Sample Selection

The first task was to select an unbiased sample representative of the population of funded projects. Ideally, either simple or stratified random sampling should have been used to select an unbiased sample (Cochran, 1977, p. 11).*

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*When a population is homogeneous, simple random sampling should be used to select an unbiased sample from a population. Random selection is usually accomplished by reference to a random numbers table. If a population is not homogeneous, stratified random sampling may help to reduce variation between strata and produce large gains in the precision of population estimates. A stratified sample contains a certain number of randomly selected items from each population stratum, based on that stratum's proportion of the total population. Before constructing a stratified sample, one must first know what strata of the population affect the outcome of interest and second, collect population data that allows one to stratify a sample.

As mentioned earlier, neither of these two approaches was used. Instead, the sample was selected nonrandomly, which was an adequate sampling procedure for the case study analysis originally planned. By the time the task of estimating program energy savings was added, the detailed analysis of the 57 projects had begun, and selecting a new sample at such a late date was infeasible.

Thus, we opted for a nonrandom sampling approach known as judgment sampling. Judgment sampling refers to the selection of projects based on someone's judgment that those chosen are representative of the population. We chose the sample from project summary booklets prepared by each regional program office. From the summary booklets, which provide a short description of each project, between 10 and 15 projects were selected from each region except IV, VIII, and IX.

The initial sample was 86 projects from which 57 were evaluated for the study. Twenty-nine projects were dropped from the study because of the deadline for finishing the study and not because of high or low energy savings potential. Because the project summaries were brief and contained no information concerning energy saving potential, we are confident that the sample has not been intentionally biased.

However, the sample may contain unintentional selection bias because of nonrandom sample selection. As a result, the use of probability theory is unjustified, and formal statistcal inferences cannot be made about the population (Freedman, et.al., 1978, p. 350). The estimates do provide the basis for an educated guess about program energy savings and being the best data presently available, are used for this purpose.

Computing Point Estimates and Confidence Intervals

Chapters 2 and 4 presented estimates of direct and indirect energy savings for each project in the sample. To provide a measure of the sample's energy savings effectiveness, the sum of these direct and indirect savings was converted into oil barrel equivalents (OBE) and divided by DOE funding (in $1000s) for the sample. To convert direct and indirect energy savings to OBE estimates, energy losses in generating and transmitting energy to the user were accounted for and the figure divided by 5.8 MBtu, which is the Btu equivalent of a barrel of oil. Projects displacing electricity are multiplied by the factor 3.3 which accounts for the amount of energy lost in generating and transmitting electricity from a fossil fuel power plant. For projects which displace natural gas and liquid fuels, the factor 1.1 was used.

Because the sample size is reasonably large, the distribution of the sample mean can be approximated by a normal distribution. Based on the assumption of normality, the sample mean of the energy effectiveness indicator and its standard error were computed and confidence intervals around the mean at three confidence levels: 50%, 75%, and 90% were constructed.

To compute the mean of the indicator R, which is the ratio of sample energy savings to total DOE funding, the following equation was used (Cochran, p.31):

$$\hat{R} = \frac{\sum_{i=1}^{57} OBE_i}{\sum_{i=1}^{57} f_i} = \frac{\overline{OBE}}{\overline{f}}$$

where:

$\hat{R}$ = mean of R

OBE_i = sum of direct and indirect energy savings in oil barrel equivalents for the ith project

f_i = DOE funding in $1000s for ith project

The standard error of the sample mean was computed from (Cochran, p. 32):

$$S\ (\hat{R}) = \frac{\sqrt{1-\frac{n}{N}}}{n\ \overline{f}} \sqrt{\frac{\sum (OBE_i - \hat{R}\ f_i)^2}{n-1}}$$

where:

S (R) = standard error of the sample mean

N = polupation size

(1-n/N) = population correction factor

To compute confidence intervals around the sample mean, the following formula was used (Wonnacott and Wonnacott, 1972, pp. 141-147):

$$\hat{R} \pm Z\ S(\hat{R})$$

where:

Z = number of standard deviations from the sample mean that the interval must extend at a given confidence level

The confidence intervals present the upper and lower bounds for the population mean at specific confidence levels and for this study measures the limits of the energy saving potential per $1000 of DOE funding. The level of confidence in these limits is expressed as the probability that the population mean will fall in the interval about the sample mean (Freedman, et.al., 1978, p. 345). For instance, a 75% confidence interval has a probability of 75% of containing the population mean.

PROGRAM ENERGY SAVINGS

The results of the sample analysis are presented in Tables 5-1 and 5.2. Table 5-1 shows at different confidence levels the interval within which the population mean can be found. At a 75% confidence level, the population mean is somewhere between 1190 OBE per $1000* and 4520 OBE per $1000. The reciprocal of this number multiplied by $1000 is the amount of DOE investment (in 1979$) per OBE of energy savings potential from all projects funded in FY 1979. At a 75% confidence level, the value ranges from $.20 per OBE to $.85 per OBE.** (See Table 5.2).

To estimate program energy savings from the 1979 projects, the sample mean was multiplied by total FY 1979 grant funding in $1000s. The program funded $8 million worth of grants in FY 1979, so the sample mean was multiplied by 8000 to estimate program savings and then the estimate converted into confidence intervals at the 90%, 75%,and 50% levels. (See Table 5.4).

The results of the analysis can be summarized as follows.

o Projects funded in FY 1979 can save 22.8 million OBE of energy over the lifetimes of the project energy systems and replicate systems, if the sample mean, R, is the same as the mean of the population.

o Annually, the program can save 1.2 million OBE of energy by 1985. Annual savings were computed by dividing OBE savings for each project by the lifetime of the project's energy system. Because 5 years is the maximum period over which indirect savings were considered, the annual savings will take 5 years to occur from the date of project completion.

Table 5-2 presents lifetime program energy savings as a range to reflect different levels of confidence in the estimates. For example, at a 75% confidence level, program energy savings range from 9.6 million OBE to 36 million OBE.

IMPROVING PROGRAM ENERGY SAVINGS

These estimates of program energy savings apply only to those projects funded in FY 1979. Future program cycles may have greater or lesser savings, depending on the type and quality of projects funded. Concerning project types, those involved in the development or demonstration of a commercial system had a far greater energy savings potential than others, such as laboratory research and educational projects.

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* OBE per $1000 = oil barrel equivalent energy savings per $1000 of DOE funding for the grants program.

** The inexpensive oil results from the use of DOE money as a catalyst to encourage others to replicate an energy system. In our definition of energy savings, we credit the DOE project with these savings.

TABLE 5-1

Confidence Intervals for Sample Energy Savings

at the 90%, 75%, and 50% Probability Levels

Confidence Level	Sample Mean ($\hat{R}$)	Standard Error of Sample Mean $S(\hat{R})$	Z Value	Confidence Interval
90%	2855	1445	1.64	2855 ± 2375
75%	2855	1445	1.15	2855 ± 1665
50%	2855	1445	.68	2855 ± 985

TABLE 5-2

Estimates of Energy Saving Effectiveness and Program Energy Savings

at Three Confidence Levels (90%, 75%, and 50%)

Confidence Level	Range of Values (OBE/$1000 DOE Funding)	DOE Investment per Potential Barrel of Oil Savings	Program Energy Savings (Million OBE)
90%	485 to 5225	$.19 to $2.05	3.9 to 41.8
75%	1195 to 4515	$.20 to $ .85	9.6 to 36.1
50%	1870 to 3840	$.25 to $ .55	15.0 to 30.7

However, to favor commercial projects over R&D and educational projects in an attempt to maximize program energy savings would violate the philosophy and intent of the program. While we do not recommend changing the philosophy, we wish to emphasize that a trade-off is being made when program managers select projects that meet objectives such as R and D, information dissemination, and public demonstration rather than commercial projects with large energy saving potentials. Therefore, the program should not be judged only by its energy savings potential but by the multiple objectives set for it by Congress.

Nevertheless, even within this context, opportunities do exist for improving the quality of selected projects and for maximizing the energy impacts of selected projects. Below, are 3 ways in which DOE can improve project energy savings.

(1) Require outreach plans.

A number of projects developed promising energy systems but contained no plan to commercialize the system or demonstrate it to others. To ensure that these good projects have significant energy impacts, DOE should require of all grantees who propose to develop, test, or demonstrate commercial systems a statement that clearly describes their plans for commercialization and/or demonstration. In cases where the grantee does not provide an adequate plan, DOE should carefully consider whether the project has sufficient public benefit to merit funding.

(2) Increase project accountability.

A small but significant number of grantees reduced the scope of their projects after receiving government funding. As a result, energy savings estimated from the proposal were lower than estimates developed after talking with the grantee. In some cases, the grantee reduced the project's scope legitimately in response to inflation and problems in purchasing and installing equipment. In other cases, the reduced effort resulted from sloppiness in conceptualizing the proposal and implementing the project. DOE could reduce the number of such projects by emphasizing to each grantee that he (she) will be held accountable for the specific work agreement laid out in the proposal. Coupled with ongoing monitoring, emphasis on accountability should minimize the funding of projects that cannot deliver what they promise.

(3) Provide additional funding to high potential projects.

A few projects tended to account for most of the energy savings potential. In fact, 8 projects accounted for almost all of the savings. These high potential projects could have an even higher potential if DOE were to provide additional funding to speed up the process of commercialization and product development. The one-year grant is inadequate in many cases to bring a fledgling energy system or concept from the prototype design or even from the commercial testing stage to a point where mass marketing is feasible. We recognize that the suggestion to establish a follow-on funding cycle for promising projects is not a new idea and may violate existing statutes. Yet, such a program is necessary, and we reiterate the need in hopes that legislation can be enacted to start such a program.

DIRECTIONS FOR FUTURE RESEARCH

Additional research is needed to determine program potential more precisely. Two approaches are possible:

1. statistically inferring program energy savings from a random sample of projects; and

2. estimating program energy savings from a population subgroup determined to have high energy savings.

Statistical Inference

The sample was not selected randomly for this study. Estimates of population parameters, therefore, may be biased, and probability tests do not apply. One option for a future energy study is to select a random sample of projects from the population of grants funded and to duplicate the statistical analyses applied in this study. With a random sample, the population means and intervals about the sample mean at certain levels of probability can be estimated with a reasonable degree of scientific objectivity.

Two approaches to random sampling need to be considered: simple random sampling and stratified random sampling. Stratified random sampling might help improve the precision of the population estimates by reducing the variance between strata (Cochran, p. 101). DOE is currently developing an information management system that will contain detailed data on all projects funded by the Small Grants Program. Once completed, the system will facilitate the selection of stratified random samples.

The usefulness of a second statistical analysis can only be determined after consultation with DOE officials concerning acceptable levels of confidence and ranges for population estimates. With this information, the size sample necessary to achieve this confidence and range in the estimates and the approximate cost of conducting the analysis can be determined. DOE can then determine whether statistical methods are a cost-effective tool for evaluating program energy savings.

Subjective Sampling

A second, less scientific approach would be to select a small sample of projects (less than 30) that are judged by regional program managers and LBL researchers to have large saving potential. These projects would be evaluated for total energy savings and the estimates used as a lower bound of program energy savings for that particular funding cycle. The weakness with this approach is that savings cannot be confidently extrapolated to future years and to population strata. Nevertheless, the data may be adequate for DOE to make policy decisions and can be compiled at a lower cost than can data from a statistical analysis using a large sample.

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