# AN ESTIMATE OF AGGREGATE ENERGY SAVINGS DUE TO THE DOE INSTITUTIONAL CONSERVATION PROGRAM

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## ABSTRACT

This study estimates the aggregate energy savings in the institutional sector attributable to the installation of energy conservation measures (ECMs) directly supported by matching grant funds from the DOE Institutional Conservation Program (ICP). The study was carried out as part of a broader evaluation of the ICP performed by Lawrence Berkeley Laboratory and Argonne National Laboratory. Energy savings are estimated separately for the three subsectors of the institutional sector: schools, colleges, and hospitals, and are based on comprehensive grantee audit savings estimates available from ICP, mail surveys of institutions in each subsector, and subsector stock and energy use data from ICP-independent sources.

Salient results are: (1) The estimated cumulative primary energy savings directly attributable to retrofits supported by ICP through ECM grants are 317 trillion Btu. (2) The current annual energy savings due to energy conservation measures installed with ICP support is 64 trillion Btu, about 3% of the total annual energy use in the institutional sector. (3) The cumulative energy cost savings are $1.9 billion; the total investment in the ECMs is $1.4 billion, including both federal grants and matching funds from the institutions. (4) The aggregate retrofit energy savings achieved by ICP participants, at approximately 12% for educational facilities and 8% for hospitals, are somewhat smaller than those found in some earlier studies. (While not estimated here, the ICP program has also most likely had a significant influence on retrofit activities *not* directly funded with federal matching grants.)

A broad range can be defined for the remaining opportunities for energy savings, depending on the scenario assumed. There is substantial variation across the subsectors in the magnitude of the remaining potential relative to either the ICP or total energy conservation impacts to date. Remaining opportunities for continued retrofitting of the existing stock at past levels of cost-effectiveness is declining, particularly in the colleges and hospitals subsectors. Increasingly, the energy consumption characteristics of the institutional subsectors are being determined by previously retrofitted and newly constructed buildings. Further retrofits, to be competitive, must be at least as attractive as the economic returns from other investments available to the institution.

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## 1. INTRODUCTION

In 1985 DOE provided support to Lawrence Berkeley Laboratory (LBL) and Argonne National Laboratory (ANL) to carry out an evaluation of the Institutional Conservation Program (ICP), a program of the U.S. Department of Energy (DOE) which provides energy conservation matching grants to not-for-profit elementary and secondary schools, colleges and universities, and hospitals. The Institutional Conservation Program is implemented through state energy offices via DOE regional offices. The two types of financial assistance available from ICP can support (1) technical analysis (TA) of the institution's facilities to identify appropriate energy conservation measures (ECMs), and (2) the design, purchase, and installation of ECMs. The federal grant must be matched by funds from the institution. Only buildings constructed prior to April 20, 1977 are eligible for ECM matching grants. ECM grants have been awarded in annual cycles since 1980, after a detailed energy audit and analysis of grant applications by state energy offices. During the period for which the savings estimates contained herein are calculated, total federal expenditures through ICP have been greater than $700 million.

The work reported here was part of the broader LBL/ANL evaluation effort and focuses on estimating: (1) the range of total energy savings directly attributable to ICP through ECM grants; and (2) the remaining opportunities for energy conservation in the institutional buildings sector. This work is described in detail in [1].* Both estimates focus on *aggregate energy savings*, in each of the three institutional subsectors. The energy savings estimate is retrospective, speaking to the national energy impacts of ICP activities to date. The estimate of remaining opportunities is prospective, identifying what ICP or other energy conservation programs could accomplish in the future. The past savings calculation is limited to examination of energy use in institutions that have received ECM grants, while the remaining opportunities estimates must also include examination of energy use in institutions that have *not* participated in ICP.

The concept of aggregate energy savings has a somewhat limited meaning in the context of this evaluation task. The savings estimates do *not* allow an unambiguous answer to the question of what the performance of the institutional subsector would have been if ICP had never existed. Rather, the estimates developed herein relate to performance changes caused *only* by particular kinds of retrofit activity, and do not attempt to assess the causes or effects of other

* Numbers in brackets refer to specific citations in the references section at the end of this paper.

kinds of changes in energy performance of the institutional stock, or the overall change in subsector performance.

## 2. APPROACH

Figure 1 is a schematic representation (not necessarily to scale) of the portions of the total stock of buildings in any of the three institutional subsectors (i.e., elementary and secondary schools, colleges and universities, and hospitals) considered in each of the four energy savings estimates reported here (i.e., direct energy savings, and three estimates of remaining opportunities). The bar on the left divides the stock into four components: (1) post-1978 construction, ineligible for ICP grants, (2) pre-1977 construction which is eligible, but for which neither a TA grant or an ECM grant has been awarded (hereafter referred to as nonparticipants), (3) pre-1978 stock for which a TA grant was awarded, but no ECM grant was awarded, and (4) stock which has received one or more ECM grants.

The four bars to the right identify which of the four components are considered in developing each of the estimates. The energy savings estimate includes only institutions for which ECM grants have been awarded; it estimates the energy savings that can be attributed only to those ECMs funded by ICP. The institution may have carried out other energy conservation activities without ICP support, but these savings are not considered in the direct energy savings calculation. The basic approach used in deriving the direct energy savings estimates is to sum up estimates of energy savings for all individual buildings based on pre-retrofit audit calculations.

The three estimates of remaining opportunities for energy savings in the institutional sector consider what ICP and/or other energy programs might accomplish in the future. The first of these estimates is a minimum potential, assuming that the average energy savings impacts of ICP retrofit activity to date can be achieved throughout the remainder of the eligible stock.* The second estimate of remaining opportunity assumes that all eligible stock is retrofitted as many times as necessary to achieve an energy performance equal to good design in new buildings; this represents an achievable potential that is assumed to be the maximum that could be economically feasible. The final estimate of remaining opportunity assumes that the entire subsector is retrofitted as necessary to achieve the technical limit of energy performance. As such, it is not to be interpreted as economically feasible, but rather a benchmark that represents the ultimate limit to savings to put the other two scenarios in perspective. For the remaining opportunities calculations, the basic approach is to allocate actual floorspace in each subsector among the four groups (ECM grantees, TA grantees, nonparticipants, and new construction), determine the pre- and post-retrofit aggregate energy use characteristics for the individual groups, and calculate a total energy savings for each group. Details of the calculations differ as described in the following subsections.

## 3. DIRECT ENERGY SAVINGS

The aggregated energy and related energy consumption cost savings that can be directly attributed to ICP-supported retrofit grants are estimated from a computerized data base of comprehensive grant information maintained by ICP on all grantees and retrofitted buildings known as the Grant Tracking System (GTS). The direct energy and related cost savings are

* It is recognized that retrofit activity has occurred in some off this stock independent of any connection to and/or financial support from ICP.

presented in Table 3-1 below.

The direct energy savings estimates reported here had to be derived from the engineering information in the GTS data base, rather than from measured post-retrofit energy use data from ICP participants. This is because (1) consumption data are not available from a sufficiently broad sample of institutions to allow reliable extrapolation to national aggregate savings, and (2) reductions in energy use determined from monitored data (even if the data are accurate, complete, and unambiguous, which is often not the case), are difficult to attribute to a particular cause, such as, for example, the installation of retrofits or a response to changes in energy prices. This was demonstrated in a companion study of energy use in schools in Minnesota, where a significant sample of high-quality data was available [2]. In this companion study, we found that while the GTS-based energy savings estimates reported here are consistent with monitored energy use reductions, these reductions cannot be unambiguously attributed to ICP as energy savings directly and solely caused by retrofits; the possibility exists that the average energy savings could be either greater or less than the overall building energy use reduction determined from the pre- and post-retrofit monitored data. This difficulty with attribution is endemic to available longitudinal (in time) energy consumption data, even though it does not reflect adversely on the quality of the data or its value for other purposes.

The values in Table 3-1 include corrections for overestimation on the part of the technical analyses performed during the audits and discovered during an independent re-analysis of the audit procedures using a validated energy consumption modeling tool [1]. The magnitudes of the corrections applied to the original projection of savings ranges from reductions of 0% to 45%, and depends on the type of ECM. These corrections were applied on an ECM-by-ECM basis and have resulted in a reduction of the savings estimates taken from GTS. The estimates also include all imputations for missing data and corrections for anomalous data in GTS. Imputations and corrections of ECM installation costs and energy cost savings were made before the conversion to 1987 dollars was made and cumulative aggregations were performed. The methods for extraction, correction, and imputation are discussed in detail in Appendix 1 of reference [1]. Finally, the cumulative aggregations all assume that installed ECMs have been maintained so that they have continued to save the same amount of energy annually since they were installed.

The uncertainty associated with these direct savings estimates is an important issue. The primary source of uncertainty in the estimated direct savings is in the combination of the audit savings estimate for each ECM, and the correction factor that was applied to adjust the GTS-based estimate for overprediction. The net effect of the overprediction correction was about a 15% reduction in the GTS-based audit savings estimate. We estimate that the overprediction correction itself is correct within a factor of two (*i.e.*, no greater than a 30% reduction), which translates into an estimated uncertainty in the reduced energy savings of no more than 18%. There is an additional uncertainty due to the use of the same correction for all three subsectors, which was necessary because the study on which the correction is based did not have an adequate sample size to statistically differentiate the corrections for each ECM category between institutional subsectors. We have deduced a systematic overestimation of the audit correction of 10% for colleges, and an underestimation of the correction of about 5% for hospitals. We thus estimate the overall uncertainty in the direct savings estimates is no more than 25%.

Over the life of the ICP program, about 317 trillion Btu have been saved. The retrofits necessary to achieve these savings have cost about \$1.4 Billion (both Federal and grantee contributions included)‡, and have led to a cumulative energy cost savings of about \$1.9 Billion, *i.e.*,

‡ GTS reports Federal and grantee contributions only at the building level, and not for individual ECMs. Because other costs may also be included at the building level, it is not possible to unambiguously determine the Federal con-

the ICP-motivated retrofits have already more than paid for themselves and will continue to save approximately an additional $0.4 Billion annually during their effective lifetime, even if no additional retrofits are added in the future.

**TABLE 3-1: Aggregate ICP Energy Savings Estimates — Summary (Primary Energy, 1987 Dollars)**

| Quantity/Unit | Schools | Colleges | Hospitals | All* |
|---|---|---|---|---|
| Number of ECMs Installed | 45483 | 14807 | 9645 | 69935 |
| Total† ECM Installation Costs (million $) | 522 | 349 | 524 | 1386 |
| Total† Energy Savings (trillion *Btu*) (ICP start through 1987) | 91 | 88 | 137 | 317 |
| 1987 Annual Energy Savings (trillion *Btu /yr*) | 19 | 18 | 28 | 64 |
| Total† Utility Cost Savings (million $) | 670 | 508 | 745 | 1924 |
| 1987 Annual Utility Cost Savings (million $ */yr*) | 132 | 102 | 153 | 387 |

* Numbers may not add due to rounding.

† Totals are from program inception through calendar year 1987.

The bulk of the ECMs installed with ICP grants have been in schools (65%). Although hospitals account for only 14% of the ECMs, they account for (1) nearly 40% of the total installation cost of all ECMs, (2) more than 40% of both the total and current annual energy savings, and (3) about 40% of the total and current annual energy cost savings. The much larger number of ECMs in schools have had about the same total installation cost as those in hospitals, but they account for only about 30% of the energy savings and 35% of the energy cost savings. The fractional involvement and impacts for colleges is less skewed; they account for 21% of the ECMs and between 25% and 30% of the total installation cost, energy savings, and energy savings.

Clearly, ICP has supported a relatively small number of high-cost, high-impact measures in hospitals. This may be a reflection of the complexity of these institutions, their high-intensity energy consumption characteristics, or their technical sophistication. In schools, the ECMs have had smaller overall impacts. This is not entirely unexpected; as will be discussed later, schools are far less energy-intensive, and in total Btus, it is more difficult to achieve substantial savings with the same cost-effectiveness as in more energy-intensive building types.

Table 3-2 places the energy savings results in the context of the overall energy use in ICP-grantee buildings. As could be expected based on the ECM differences between the subsectors, the bulk of the buildings receiving ICP-supported retrofits have been schools (62%), with college buildings second (25%), and hospitals third (13%). Aggregating to institutions[§], 85% of the total that have received grants have been schools, 6% have been colleges, and 9% have been

tribution to each individual ECM in all cases. The best rough estimate to use is half of the total.

§ The number of institutions in each subsector that have participated in ICP are taken from earlier analyses of GTS; in part, these results are repeated in [3]. This reference included institutional penetrations for hospitals and colleges, and estimated the institutional penetration for schools. More recent analyses of GTS, currently unreported, have led to the revised number of schools that have participated in ICP. This figure includes both public and private schools.

hospitals. These distributions are not unexpected. There are far more school buildings in the U.S. than either college buildings or hospital buildings.† At the institutional level, there are also far more schools than colleges or hospitals, and more hospitals than colleges. Thus, at the institutional level, a higher percentage of grants went to hospitals than to colleges. However, because colleges typically have many buildings compared with hospitals, a higher percentage of the buildings touched by these grants were colleges rather than hospitals.

**TABLE 3-2: ICP Aggregate Energy Savings Estimates — GTS Context (Primary Energy)**

| Quantity/Unit | Schools | Colleges | Hospitals | All* |
|---|---|---|---|---|
| Number of Institutional Grantees | 17112 | 1204 | 1802 | 20118 |
| Number of Buildings Retrofitted | 17465 | 6993 | 3752 | 28210 |
| Stock Penetration (million $ft^2$) | 979 | 618 | 716 | 2314 |
| Est. Cum. Energy Consumption without ICP Retrofits (trillion *Btu*) (ICP start to present) | 687 | 772 | 1627 | 3086 |
| Total Energy Savings (trillion *Btu*) (ICP start to present) | 91 | 88 | 137 | 317 |
| Average ECM Energy Reduction in ICP-Retrofitted Buildings | 13.3% | 11.5% | 8.5% | 10.3% |

* Numbers may not add due to rounding.

Table 3-2 also shows the aggregate energy use and energy savings for all ECM grantees for each subsector. These results imply an average reduction in energy use for buildings retrofitted with ICP-supported ECMs of 13.3%, 11.5%, and 8.5% for schools, colleges, and hospitals, respectively. In spite of the relatively large savings per ECM for hospitals implied by Table 3-1, the percentage savings are smallest. This is a reflection of the much greater energy intensity for hospitals.

Our estimates of aggregate direct savings, when expressed as an average for all of the buildings which contribute to the aggregate, are at the lower end of the range defined by past studies of energy savings in institutional buildings in references [4-14]. In particular, although our savings estimate for hospitals (8.5%) is consistent with the results of an earlier national evaluation of ICP [9], where 8% savings are quoted, our results for schools (13.3%) are considerably lower than the 22% quoted there. The documentation for the earlier evaluation does not clearly state whether the energy savings are expressed in site units or primary resource units, as used in our estimates. Our results are consistent with a study of energy savings for Minnesota schools [2], which was carried out as a companion study to the effort reported here. As discussed in the Minnesota data report, we believe that the reason our estimates are lower than those for many of the other studies is due to differences in methodology. Most of the other studies have used an individual case study approach. Unless one can be confident that the case

† The actual number of buildings in each subsector is not well known.

study sample is truly representative of the subsector, results from it cannot be reliably extrapolated to the entire subsector. It is not clear that this condition has been met in any of the other studies.

Table 3-3 places the aggregate results in the overall context of the stock and energy use of the entire subsector for each of the individual subsectors.

**TABLE 3-3: ICP Aggregate Energy Savings Estimates — Subsector Context (Primary Energy)**

| Quantity/Unit | Schools | Colleges | Hospitals | All* |
|---|---|---|---|---|
| Total Institutions | 104268 | 3434 | 6915 | 114617 |
| Institutions Penetrated by ICP | 17112 | 1204 | 1802 | 20118 |
| Fraction of total | 16% | 37% | 26% | 18% |
| Total Subsector Stock (million $ft^2$) in 1987 | 5300 | 3100 | 1700 | 10100 |
| Pre-78 Subsector Stock (million $ft^2$) Remaining in 1987 | 4500 | 2250 | 1300 | 8000 |
| ICP Stock Penetration (million $ft^2$) | 979 | 618 | 716 | 2314 |
| Fraction of pre-78 Stock | 22% | 28% | 55% | 29% |
| 1987 Subsector Annual Consumption§ (trillion *Btu /yr*) | 680 | 740 | 720 | 2140 |
| Current Annual ICP Savings‡ (trillion *Btu /yr*) | 19 | 18 | 28 | 64 |
| Fraction of 1987 Subsector Consumption | 2.8% | 2.4% | 3.9% | 3.0% |

* Numbers may not add due to rounding.

§ For comparison, approximate 1979 estimates are 790 and 760 trillion *Btu /yr* for schools and hospitals subsectors, respectively.

‡ This is not an estimate of all retrofit activity in the subsectors — only that part directly supported by ICP.

This context provides the means to determine whether the ICP impacts are "small" or "large" relative to overall subsector performance. It shows the total number of institutions and ICP penetration, the total stock (building floor area) and ICP penetration, and total energy consumption and the fraction thereof that is represented by ICP energy savings. The differences in the penetrations by institution count and by floor area (stock) indicate that ICP has preferentially impacted the larger hospitals and schools, and the smaller colleges. The sources of the subsector information are discussed in Appendix 2 of reference [1].

ICP grants have led to retrofits in a significant fraction of the eligible building stock in each of the institutional subsectors, when based on floor area as the measure of penetration.† While the actual penetrations vary from a low of 22% in the schools subsector to between two and three times that (55%) in the hospitals subsector, the overall floor area penetration is 29% in all three subsectors. The significance of this level of penetration is that more than one fourth

† For energy consumption and savings estimates, this measure is the rational one, since energy use is closely correlated to the floor area of a particular building type. For other purposes in this Evaluation Project, a different measure of penetration has been used: the fraction of total institutions that have received grants. Differences in penetration using these two different measures are not surprising. . .

of the *total* potential savings that might be achieved by continuing the current grant/retrofit approach of the ICP program with the same payback eligibility rules have already been realized by the ICP program alone. Correspondingly, the overall current annual energy savings of about 3.0% of total sector energy consumption are consistent with the overall 29% stock penetration, *if* all buildings were retrofitted at the average 10.3% reduction shown in Table 3-2.

## 4. REMAINING OPPORTUNITIES

Three estimates of the remaining opportunity for saving energy in institutional buildings are provided. The first is a conservative estimate that assumes that ECMs are installed in the entire stock of eligible buildings that have not as yet received ICP grants for ECM installation, and that these buildings experience the same performance improvement achieved by ECM grant recipients to date. The second assumes that the energy performance of "good practice" new buildings can be achieved in existing buildings, and represents an optimistic but economically feasible scenario. The third estimate assumes the "technical limit" of new building performance can be achieved in existing buildings, and is used as a reference benchmark to provide perspective to the other two estimates. The cost-effectiveness and related economic feasibility of achieving these levels of performance is not considered here.

The calculation of the lower limit of remaining opportunity is outlined in Table 4-1. In this table, the total remaining stock of pre-1977 construction, the ICP stock penetration, and the annual direct energy savings are taken from reference [1]; the stock estimate includes all eligible institutions. The EUI reduction for ICP participants is the ratio of the annual direct energy savings to the penetrated stock. The lower limit of energy savings assumes that this performance improvement can be achieved in the entire stock of eligible, unpenetrated buildings. In the table, the unpenetrated stock is the difference between the total stock of pre-1977 buildings and the penetrated stock. When the EUI reduction achieved by participants to date is applied to the unpenetrated stock, the lower limit of remaining opportunity is obtained.

**TABLE 4-1: Lower Limit of Remaining Opportunity for Energy Savings**

| | Schools | Colleges | Hospitals |
|---|---|---|---|
| Total remaining stock of pre-1977 construction (million $ft^2$) | 4480 | 2236 | 1296 |
| ICP Impact | | | |
| Stock penetration (million $ft^2$) | 979 | 618 | 716 |
| Current annual direct energy savings (trillion $Btu/yr$) | 19 | 18 | 28 |
| EUI reduction ($kBtu/ft^2 \cdot yr$) | 19 | 29 | 39 |
| Remaining Opportunity | | | |
| Unpenetrated stock (million $ft^2$) | 3501 | 1618 | 580 |
| Energy savings (trillion $Btu/yr$) | 67 | 47 | 23 |

The second estimate of remaining opportunity is performance-based and assumes that retrofits can be installed in the entire stock of eligible buildings to achieve the performance of "good design practice" new buildings. This estimate is optimistic but achievable, at least in

principle, with existing technologies, and represents the maximum economically feasible potential. The calculation is outlined in Table 4-2. As before, the data are taken from reference [1]. The ratio of the total annual energy use to the total stock is the current aggregate EUI for all eligible institutions.

**TABLE 4-2: Maximum Economically Feasible Estimate of Remaining Opportunity for Energy Savings**

| | Schools | Colleges | Hospitals |
|---|---|---|---|
| Total remaining stock of pre-1977 construction (million $ft^2$) | 4480 | 2236 | 1296 |
| Current total annual energy use of pre-1977 construction (trillion *Btu*) | 580 | 542 | 562 |
| Aggregate EUI ($kBtu/ft^2 \cdot yr$) | 129 | 242 | 434 |
| Good-practice EUI ($kBtu/ft^2 \cdot yr$) | 85 | 205 | 363 |
| Remaining opportunity for energy savings (trillion $Btu/yr$) | 197 | 83 | 92 |

The "good practice" EUI shown in the table is based on our analysis of results from a survey of energy experts carried out by Pacific Northwest Laboratory [15]. The survey results for individual building types as reported by PNL showed a roughly linear relationship between average practice performance and both good practice and technical limit performance. The linear relationship was used in the estimate of good practice performance for colleges and universities, and hospitals, assuming that the aggregate performance of the existing stock represents average practice. For all three institutional subsectors, the "good practice" EUIs shown in Table 4-2 are taken from the extrapolation of the PNL survey results. The difference between the aggregate EUI from the subsector analysis and the good practice EUI from the PNL survey is an estimate of the "probable" attainable performance improvements. This improvement in performance is applied to the entire stock of pre-1977 construction to obtain the second estimate of remaining opportunities for energy savings shown in Table 4-2.

The third estimate of remaining opportunities assumes that the entire stock of institutional buildings, including pre- and post-1977 construction, can be retrofit to achieve the technical limit of energy performance. The calculation is outlined in Table 4-3. In this case, the total stock and total energy use by subsector are shown; the aggregate EUI, therefore, averages across all existing buildings, including those both eligible and ineligible under existing ICP regulations. The technical limit EUI is taken from the PNL survey as described above. The EUI reduction is applied to the entire stock to obtain the estimate of the "maximum" remaining opportunity. We believe this upper limit represents the engineering potential for energy efficiency in institutional buildings. It is stressed again that this technical limit estimate has been derived to provide a benchmark for the other estimates in order to place them into better perspective, and is not meant to imply that implementation of such a scenario is feasible. Rather, it is meant to answer the question: Compared to what might actually be done with retrofits, what would the lowest energy use in the subsector stock be if all buildings were new and as energy efficient as

technology allowed?

**TABLE 4-3: Technical Limit Benchmark for Remaining Opportunity for Energy Savings**

| | Schools | Colleges | Hospitals |
|---|---|---|---|
| Total subsector stock (million $ft^2$) | 5290 | 3125 | 1695 |
| Current total annual energy use (trillion *Btu /yr*) | 677 | 742 | 715 |
| Aggregate EUI ($kBtu / ft^2 \cdot yr$) | 128 | 237 | 422 |
| Technical limit EUI ($kBtu / ft^2 \cdot yr$) | 60 | 139 | 273 |
| Remaining energy savings opportunity (trillion *Btu /yr*) | 360 | 306 | 253 |

## 5. CONCLUSIONS

The most important conclusions related to the derivation of direct savings estimates are:

- The estimated cumulative primary energy savings directly attributable to retrofits supported by ICP through ECM grants are 317 trillion Btu.
- The current annual energy savings due to energy conservation measures installed with ICP support is 64 trillion Btu, about 3% of the total annual energy use in the institutional sector.
- The cumulative energy cost savings are $1.9 billion; the total investment in the ECMs is $1.4 billion, including both federal grants and matching funds from the institutions.
- The aggregate retrofit energy savings achieved by ICP participants are approximately 12% for educational facilities and 8% for hospitals.
- The average savings for ICP participants estimated here are somewhat smaller than those found in some earlier studies.

Table 5-1 summarizes all of the energy savings estimates due to past ICP grants and the estimates of what could potentially be accomplished in the future. The relative magnitudes of the savings to date and any of the three estimates of opportunities is revealing. Relative to what has been accomplished by ICP to date, the minimum opportunity is small for hospitals and large for schools, with colleges in between.* This minimum can be achieved by continuation of existing programs, and can be exceeded by multiple penetrations by ICP and/or other energy programs. For schools, even the minimum is far off; at the current level of ICP activity in this subsector, about 50 more years of grants would be required to reach the minimum with direct savings. Even for hospitals, achieving the minimum would require additional expenditures nearly as large as the total to date. Alternatively, from the perspective of non-ICP energy conservation efforts, the minimums will be achieved this year for colleges and hospitals, but substantial effort is needed to achieve the minimum opportunity in schools.

* It is recognized that retrofit activity in addition to that directly supported by ICP has also occurred during the time the program has been in place. We do not attempt to provide estimates of that activity here.

TABLE 5-1: Summary of Savings and Remaining Opportunities (trillion Btu/yr)

| | Schools | Colleges | Hospitals |
|---|---|---|---|
| Cumulative ICP Savings | 19 | 18 | 28 |
| Remaining Opportunities | | | |
| Minimum | 67 | 47 | 23 |
| Maximum Feasible | 197 | 83 | 92 |
| Technical Limit | 360 | 306 | 253 |

Technically, the minimum opportunity is "easy" to achieve in all subsectors; it is based on extrapolation of ICP grantee experience to date. There is little reason to doubt that it will be reached by hospitals, and probably by colleges and universities, independent of ICP. There is little evidence that it will be reached by schools in the foreseeable future, without substantial additional attention—or perhaps, different forms of attention. This table suggests that leadership in energy conservation in institutional buildings might take very different forms for the three subsectors. For hospitals, there is a need to focus on understanding how the performance of new, low-energy buildings can be approached in existing buildings. Among the questions to be answered are the following. In comparing low energy new buildings to existing buildings, what are the differences in energy end use distributions—where are the technological opportunities? Are new retrofit technologies needed or will advanced technologies currently being developed be adequate? And, what of more recent (post-1977) construction which has become an appreciable fraction of the total stock?

For schools the questions are quite different. Independent of how energy conservation actions are ultimately supported, how can they be motivated? What information is needed to allow the general experience of hospitals, and to a lesser extent higher education, to be replicated? And again, what of the growing stock of newer buildings which appear to have an energy performance not much better than the old stock?

Key conclusions from the remaining opportunities calculations are:

- A broad range can be defined for the remaining opportunities for energy savings in each of the subsectors, depending on the assumptions as to the attainable performance improvements. There is substantial variation across the subsectors in the magnitude of the remaining potential relative to either the ICP or total energy conservation impacts to date.
- When the cumulative impact of all institutional sector retrofit activities are considered, the pool of remaining opportunities for continued retrofitting of the existing stock at past levels of cost-effectiveness or payback are declining, particularly in the colleges and hospitals subsectors. Increasingly, the energy consumption characteristics of the institutional subsectors are being determined by previously retrofitted and newly constructed buildings. Further retrofits, to be competitive, must be at least as attractive as the economic returns from other investments available to the institution.

## 6. REFERENCES


1. W. L. Carroll, R. C. Kammerud, B. E. Birdsall, B. Lebot, B. Hatfield, E. Vine, "An Estimate Of Aggregate Energy Savings Due to the ICP Program," Lawrence Berkeley Laboratory, LBL-24053, October, 1987.
2. E. Vine, B. Hatfield, B. Lebot, R. Kammerud, W.L. Carroll, "Energy Use in Minnesota Schools: Aggregate Performance and Perspectives on Energy Savings," Lawrence Berkeley Laboratory, Draft Report LBL-24052, September, 1987.
3. N.E. Collins and R.C. Kammerud, "Institutional Conservation Program Evaluation Project: Review of Existing Data," Lawrence Berkeley Laboratory, LBL-22335, unpublished.
4. Maryland Energy Office, "Institutional Conservation Program Evaluation." Baltimore, Md., 1985.
5. E. Hirst, J. Stelson, J. Carney, and R. Goeltz, "Analysis of Energy Audits at 48 Hospitals." ORNL/CON-77. Oak Ridge National Laboratory, Oak Ridge, Tenn., 1981.
6. K. Griffin, "Energy Management in California's Public Institutions: An Assessment of the Schools and Hospitals Program." Report P400-85-012. Conservation Division, California Energy Commission, Sacramento, Calif. 1985.
7. B. Gardiner, M. Piette, and J. Harris, "Measured Results of Energy Conservation Retrofits in Non-Residential Buildings: An Update of the BECA-CR Data Base." In the Proceedings of the ACEEE 1984 Summer Study on Energy Efficiency in Buildings, American Council for an Energy-Efficient Economy, Washington, D.C., 1984.
8. K. Keating and S. Blachman, "In Search of an Impact: An Evaluation of an Institutional Buildings Program." In the Proceedings of the 1987 Conference on Energy Conservation Program Evaluation: Practical Methods, Useful Results. Chicago, Ill., 1987.
9. The Synectics Group, Inc., "An Evaluation of the Institutional Conservation Program: Results of the On-Site Analyses." Washington, D.C., 1983.
10. Idaho Department of Water Resources, "Evaluation of the Schools and Hospitals Program, Cycles I and II." Boise, Idaho, no date.
11. Beling Consultants, Inc., "Evaluation of Effectiveness of FY 1980 and 1981 Energy Audits in Illinois." Prepared for the Illinois Institute of Natural Resources. Joliet, Ill., 1981.
12. J. Quintrell, "Evaluation of the Institutional Conservation Program in Maine (Draft)." Office of Energy Resources, Augusta, Maine, 1985.
13. J. Rudy, H. Sigworth, Jr., and A. Rosenfeld, "Saving Schoolhouse Energy: Final Report." LBL-9106. Lawrence Berkeley Laboratory, Berkeley, Calif., 1979.
14. M. Olle and J. Howlett, "Energy Management in Wisconsin Schools and Hospitals: 1985 ICP Performance Review." Wisconsin Division of State Energy and Coastal Management, Madison, Wisc., 1986.
15. D.B. Crawley, R.S. Briggs, J.S. Jones, W.W. Seaton, J.E. Kaufman, J.J. Deringer, and E.W. Kennett, "Development of Whole-Building Energy Design Targets for Commercial Buildings—Phase 1 Planning," Pacific Northwest Laboratory, PNL-5854 Vol. 1, April 1987.

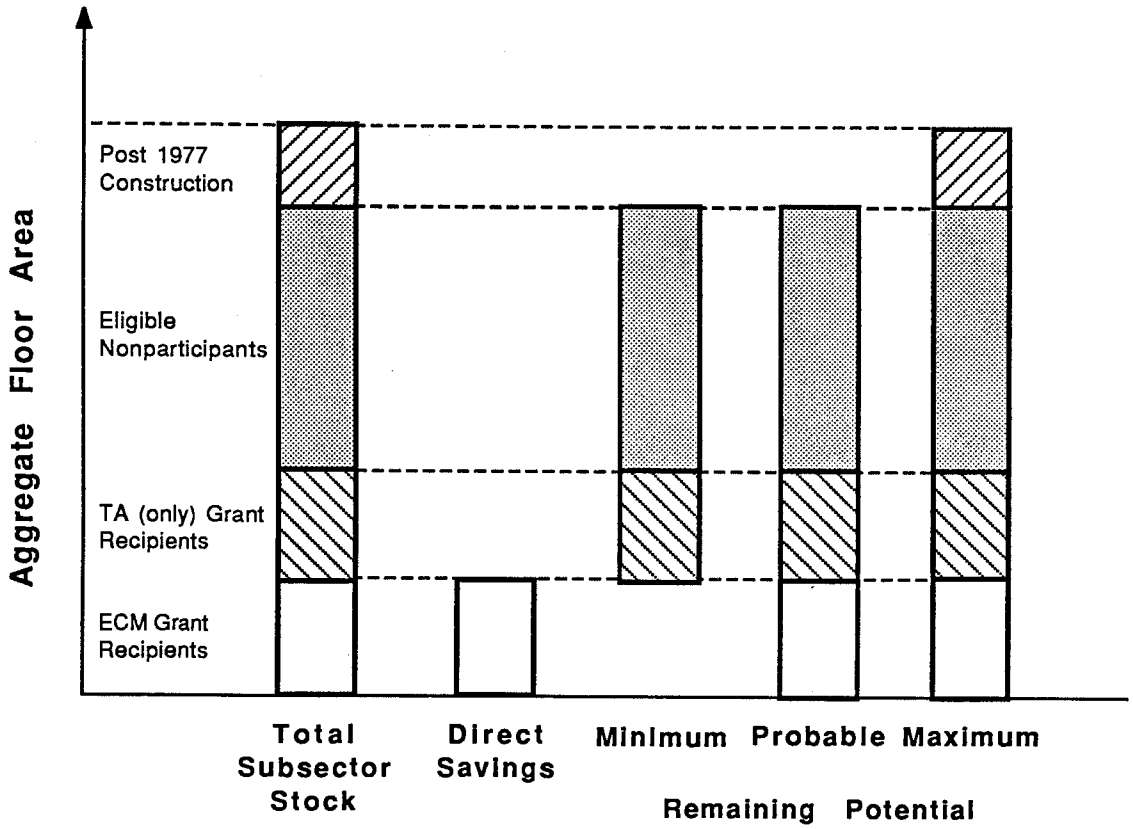


**Figure 1. Building Stock Included in Energy Calculations**