NISTIR 5565

An Evaluation of the Economic Impacts Associated with the NIST Power and Energy Calibration Services

Albert N. Link, Ph.D.
Consultant*

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* Professor of Economics at the University of North Carolina, Greensboro, NC

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EXECUTIVE SUMMARY

The National Institute of Standards and Technology (NIST) establishes and maintains the values of the primary electrical units in the United States. Toward meeting that responsibility, the Power and Energy Calibration Project within the Electronics and Electrical Engineering Laboratory invests approximately $80,000 per year [1] to maintain measurement responsibilities of the watthour and to conduct research to improve its calibration activities.

This study investigates the economic benefits that result from these two activities. More specifically, the purpose of this study is to identify, and quantify where possible, the net economic benefits associated with the NIST Power and Energy Calibration Project as related to:

- maintenance of the national standard for the watthour,
- research to lower the level of uncertainty associated with watthour revenue meters,
- general technical support to industry associated with measurement activities.

The three groups studied were:
(1) manufacturers of standard meters,
(2) manufacturers of watthour revenue meters,
(3) electric utilities and state utility commissions.

Based on the benefit data assembled from these three groups, the total average annual measured benefits to industry and society from the NIST Power and Energy Calibration Project are estimated to be $3.3 million. A comparison of these benefits to the annual cost of $80,000 of the Project produces a ratio of 41-to-1, which is comparable to an internal rate of return measure of 428 percent. This rate of return measure for the Power and Energy Calibration Project compares favorably with the upper end of the internal rates of return from other NIST projects.

[1] *This excludes the cost of performing calibration services which are purchased by the customer.*

I. INTRODUCTION AND OVERVIEW OF THE STUDY

The mandate for metrology

A. Background Information

The National Institute of Standards and Technology (NIST), formerly the National Bureau of Standards (NBS), has final authority in the United States for developing and maintaining measurements. According to the Organic Act of March 3, 1901, which established the NBS:

Custodian of standards

> ... the Office of Standard Weights and Measures shall hereafter be known as the National Bureau of Standards. ... the functions of the bureau shall consist in the custody of the standards; the comparison of the standards used in scientific investigations, engineering, manufacturing, commerce, and educational institutions with the standards adopted or recognized by the Government; the construction, when necessary, of standards, their multiples and subdivisions; the testing and calibration of standard measuring apparatus; the solution of problems which arise in connection with standards; the determination of physical constants and the properties of materials, when such data are of great importance to scientific or manufacturing interests and are not to be obtained of sufficient accuracy elsewhere.

Define units

On July 21, 1950, the Act of July 12, 1894 ("An Act to define and establish the units of electrical measure") was repealed by Public Law 617. Therein was stated:

> It shall be the duty of the Secretary of Commerce to establish the values of the primary electric and photometric units in absolute measure, and the legal values for these units shall be those represented by, or derived from, national reference standards maintained by the Department of Commerce.

Then on July 22, 1950, the Organic Act of 1901 was amended by Public Law 619 to read:

> ... the Secretary of Commerce ... is authorized to undertake the following functions: (a) The custody, maintenance, and development of the national standards of measurement, and the provision of means and methods for making measurements consistent with those standards ....

NBS becomes NIST

Finally, these responsibilities were transferred to NIST, new name for NBS, under the Omnibus Trade and Competitiveness Act of 1988.

NIST functional organization

The overall organizational structure at NIST is based on laboratories. Within each laboratory are multiple divisions, and within a division are several research groups. The Electronics and Electrical Engineering Laboratory (EEEL) is one of eight laboratories at NIST. The Electricity Division is one of five divisions within EEEL. And, the Electrical Systems Group is one of five groups within the Electricity Division.

The Electrical Systems Group, through its Power and Energy Calibration Project, is accountable for the NIST electric power and energy measurement responsibilities. For years, NIST has funded activities consistent with its mission of establishing and maintaining "the values of the primary electric units in absolute measure," that is, activities related to being the single measurement source against which all calibrations are made.

$80,000 calibration budget

Regarding the watthour, which is the focus of this study, the operating budget of the Power and Energy Calibration Project in 1994 was $230,000. This budget, which has remained fairly constant over time, has three components: fees received from calibrating electric power and energy measurement instruments for industry and others ($150,000), research and development costs for work on improved calibration activities ($60,000), and equipment ($20,000). Only the latter two budget elements, research and development and equipment, represent NIST investments to conduct research and improve calibration activities. Thus, $80,000 is the relevant annual cost figure for consideration in this study.[1]

The economic questions considered in this study are:

- What are the economic benefits that result from NIST resource investments in power and energy calibration services?
- How do these benefits compare to the NIST costs of generating them?

B. Purpose of the Study

Assessment of economic benefits

It is well established in the economics literature that investments in measurement-related technology research by Federal laboratories represent an important resource commitment to the innovation process, and that these investments have a significant impact on economic growth.[2] The purpose of this study is to identify, and quantify where possible, the net economic benefits associated with the NIST Power and Energy Calibration Project.

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1. *These data, which include overhead, were provided by the Electrical Systems Group.*

2. *More specifically, such investments are often called investments in infratechnology, meaning the process of creating basic scientific and engineering data, measurement and other methods, test procedures, interface dimensions, and any other technical entity or procedure which increases the productivity of R&D, product technology, or market transactions for technology-based products. See Leyden and Link (1992) and Tassey (1992).*

Three services from NIST

The NIST services from the project that are considered in this report are:

- maintenance of the national standard for the watthour,
- research to lower the level of uncertainty associated with watthour revenue meters,
- general technical support to industry associated with measurement activities.

C. Overview of the Methodology

Benefit-to-cost ratio

Fundamental to any evaluation study of a Federal laboratory is a comparison of the benefits, both quantitative and qualitative, that economic units receive from the laboratory (affected industries, in particular, and society, in general) to the costs incurred to generate these benefits. One metric commonly used to evaluate such net value is the ratio of benefits to costs.

Internal rate of return

For this particular study, the calculation of a benefit-to-cost ratio is believed to be the most reliable evaluation metric. This ratio is computed as the ratio of benefits (received by economic units directly dependent on the activities of the NIST power and energy calibration services) to the costs to society to generate those benefits, namely the cost to operate the Power and Energy Calibration Project. An alternative metric, an internal rate of return measure, is also presented in this report in order to facilitate a comparison of the benefit-to-cost result to the results from similar studies.

Four evaluation steps necessary

The first step in the evaluation process was to determine the scope of benefits to be evaluated. Through discussions with individuals within the Electrical Systems Group, three specific categories of activities were identified, as discussed in Section II. The second step was to determine the scope of the costs to consider. The costs to operate the Power and Energy Calibration Project, exclusive of the incremental costs of performing calibrations which are paid by customers, are the relevant costs, given the defined nature of the study. The third step in the evaluation process was to formulate a strategy for collecting information and data from identified benefit recipients, and this process is discussed in Section III. Finally, as discussed in Section IV, measurement benefits are compared to costs to arrive at a final evaluation measure.

II. ACTIVITIES RESULTING FROM THE NIST POWER AND ENERGY CALIBRATION SERVICES

A. Classification of Activities

Three primary activities

Fundamental to the evaluation of economic impacts associated with the services of any laboratory is the identification of specific activities, or outputs to use an economics term, that result from the services being evaluated. In the case of Power and Energy Calibration Services, there are three primary activities or outputs to consider:

- maintenance of the national standard for the watthour,
- research to lower the uncertainty associated with watthour revenue meters,
- general technical support to industry associated with measurement activities.

Each of these activities is discussed in this section. Then in Section III, the methodology used to quantify the economic benefits from each service is described, and the values associated with those benefits are discussed.

B. Maintenance of the National Standard for the Watthour [3]

A $190 billion business

Electric utilities generate and provide electric power throughout the United States. The basic instrument used by power companies to measure the flow of electric energy, both internally and ultimately to their customers, is the watthour revenue meter. In 1992, the more than 100 million watthour meters in use accounted for the measurement of 2,800 billion kilowatt hours, or $190 billion of revenue.[4]

Three groups affected

There are three primary groups affected by NIST meter measurement services:

(1) manufacturers of meters which serve as "calibration reference standards,"

(2) manufacturers of user-premises watthour revenue meters,

(3) electric utilities and their state utility commissions.

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3. *This section draws from Ramboz and Martzloff (1995).*

4. *See Ramboz and Martzloff (1995) and Energy Information Administration (1994).*

Standard meter manufacturers

A reference standard meter, or simply "standard meter," is used to maintain the unit of electric energy, the watthour. The meter is usually designed and operated in a controlled laboratory environment to obtain the highest accuracy and stability.[5] Manufacturers of standard meters must calibrate each meter produced. They test them against their own standard meters, which have been calibrated at NIST.[6]

Revenue meter manufacturers

All of the domestic manufacturers of revenue watthour meters in the United States maintain traceability to NIST. Their meters are tested against their own standard meters, which have been calibrated either at NIST or at an independent laboratory which in turn maintains traceability to NIST. Independent laboratories benefit from the maintenance of the national watthour standard by NIST; however, they are not investigated in this study nor are other secondary groups that receive spillover benefits.

Traceability to NIST at the electric utilities

The American National Standard Code for Electricity Metering, ANSI C12.1-1988, recommends that each utility establish and maintain traceability of the watthour to the national standard. Traceability can be achieved in a number of ways. It could be argued that each utility could send every revenue meter that it purchases, and on a rotating basis every revenue meter in service, to NIST for calibration. Such a practice would be neither cost effective nor practical.

All electric utilities that have meter laboratories have their own standard meters, and these utilities achieve traceability to NIST by testing their watthour revenue meters against standard meters. Utilities that do not have meter laboratories can send their watthour revenue meters to independent laboratories (and these laboratories can, in turn, calibrate them against one of their own standard meters), to a larger electric utility that has standard meters, or to the manufacturer of watthour meters.[7] Or, the utilities can choose not to comply with the ANSI voluntary standard, provided that the state utility commission permits it.

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5. *A portable standard meter is used primarily as a standard for testing revenue meters. See definition 2.102 and 2.106 in ANSI C12.1-1988.*

6. *The term calibration should not be misinterpreted. NIST measures a standard meter against its in-house standard and quantifies the error at various test conditions. NIST does not "tweak" these standard meters to bring them into conformity with the in-house standard. To do so would lose the historical performance record of the instrument. In contrast, manufacturers and utilities adjust revenue meters if they are out of tolerance. See ANSI C12.1-1988.*

7. *NIST also makes available its own transport standard meters through its Measurement Assurance Program (MAP).*

C. Research to Lower the Level of Uncertainty

Accuracy is critical to the process

Accuracy is critical to manufacturers of watthour meters, as it is to the utilities and their customers. Although the American National Standard Code for Electricity Metering, ANSI C12.1-1988, requires a minimum average revenue metering performance of ±2 percent in service, higher accuracies are required by manufacturers that, in many cases, must rely on acceptance testing by sampling.[8] To reduce the probability of having a good lot of meters falsely rejected (producer's risk) and the consequent economic loss, meter performance is typically adjusted by the manufacturer to a tolerance of ±0.1 percent. To achieve the appropriate level of uncertainty for this adjustment, the hierarchy starting with NIST reference standards, transportable standards, local reference standards, and ending with portable standards with which the calibration of revenue meters is actually carried out, requires an uncertainty of better than ±0.01 percent at the NIST level. Even that level many not be sufficient in the future if higher accuracy meters are put into service for large customers or inter-utility energy purchases.

A ten-fold improvement

Driven by the users of the NIST meter measurement activities, NIST had been able to achieve a level of uncertainty of 0.05 percent. In 1986, on the basis of the ongoing research within the Power and Energy Calibration Project, the level of uncertainty achievable for watthour standard meters was reduced to 0.005 percent, or 50 parts per million.

D. Technical Support to Industry

Hot-line service

Experts within the Power and Energy Calibration Project are regularly available to help both the utilities and the instrument manufacturers to solve problems involving electrical measurements. Such help can often be given over the telephone, for instance information on measurement standards, or in the form of special calibrations, for example to verify performance of newly designed instruments. Frequently, utility meter-laboratory personnel will visit NIST to pick up their calibrated instruments and use the opportunity to discuss some of their technical problems with NIST staff.

Seminars and conferences

From time to time, NIST staff members have given tutorials on metering at seminars and conferences. Such tutorials help to promote good measurement practices on all levels throughout the utility industry. Results of NIST research in the measurement field are also disseminated through papers given by staff members at conferences organized by various engineering societies.

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8. *See ANSI C12.1-1988, definitions 8.1.3.3, 8.1.3.4, and 6.1.8.*

III. MEASUREMENT OF BENEFITS AND COSTS

A. Measurement of Benefits

Data collected by telephone interviews and by mail

Two alternative methods were used in this study for collecting data on the following three benefit categories: maintenance of the national standard for the watthour, research to lower the level of uncertainty associated with watthour revenue meters, and general technical support to industry associated with measurement activities.

The data collection methods relied upon telephone interviews and mail inquiries with follow-up telephone interviews. Two groups were included in this study:

(1) manufacturers of standard meters,

(2) manufacturers of watthour revenue meters.

Independent complementary information included

Information collected through an independent investigation of electric utilities and state utility commissions was also incorporated into this study.

Telephone interviews were the primary vehicle used to obtain information from the manufacturers of standard meters and watthour revenue meters.[9] The estimated benefit values are summarized in Table 3 at the end of this section.

1. Manufacturers of Standard Meters

Three manufacturers of standard meters

With the assistance of individuals within the Electrical Systems Group, knowledgeable individuals at each of three domestic manufacturers of standard meters were identified as possible interview contacts within the companies. The three manufacturing companies that comprise the domestic industry are (alphabetically) Radian Research, Rotek Instruments, and Scientific Columbus.

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9. *Inaccurate watthour revenue meters can create an equity problem between the seller of electricity and the buyer. While equity is an important concern, there is not an aggregate economic loss from meter inaccuracy in the short run because the benefits to one party from mis-measurement are equal to the gains of the other party. In the long run, the issue of systematic bias is moot in states where rates are set on the basis of a fair return on capital (i.e., the utility's rate base). If the revenue meters were systematically biased in favor of the utility, then the utility's revenues would be higher than permitted on the basis of a fair return on its rate base and consumer rates would be decreased by the regulatory commission. If revenue meters were systematically biased in favor of the consumer, then the utility's revenues would be lower than permitted on the basis of a fair return on its rate base and consumer rates would be increased by the regulatory commission. However, outside of conventional economic measurement criteria, consumer psychology and industrial experience teaches that when there is concern about inaccuracy there would be sufficient public and political concern to make avoiding such a situation a valuable, even if intangible, benefit of ensuring accurate measurements.*

It is also important to emphasize that the net revenue gain or loss when power crosses national borders (e.g., Canada) is not considered in this study.

These companies have each been producing standard meters for an average of 20 years. In 1994, approximately 2,000 standard meters were produced, with about 70 percent being sold domestically. These companies will typically send about seven standard meters to NIST each year for calibration.[10]

Duplicating the NIST services would be expensive

Data were collected from each manufacturer regarding two types of benefits that they receive from the NIST services. Using a structured interview format, each participant what it would cost them to duplicate the NIST measurement environment. Individuals contacted stated that they could, with cost, duplicate the NIST environment, and that they would have to do so if NIST did not provide its energy and calibration services. In addition to an estimated collective up-front cost of $750,000, the total steady-state costs to the industry were estimated by the manufacturers at approximately $600,000 per year.

Then, after each participant listened to the following statement: *I understand from NIST that between 1960 and 1986 uncertainty for the watthour meter was 0.05%, and then it dropped to 0.005% after 1986,* each participant was asked to describe and quantify the benefits they receive from lower uncertainty.

Reducing uncertainty brings some benefits

Each company described a different method for quantifying the economic value of reduced uncertainty.[11] All stated that there was an economic value to the NIST research to lower the level of uncertainty, and the aggregate annual estimate of that value is $70,000.

In summary, the manufacturers of standard meters estimated that the collective annual (ongoing) economic benefit associated with the maintenance of the national standard for the watthour by NIST is $600,000 (quantified in terms of the estimated cost to duplicate the NIST measurement environment). The annual economic benefit associated with the research conducted at NIST to lower the level of uncertainty is estimated at $70,000 (quantified in terms of estimated production cost savings).[12] This value is listed in summary Table 3 at the end of this section.

2. *Manufacturers of Revenue Meters*

Five domestic manufacturers polled

With the assistance of individuals within the Electrical Systems Group, knowledgeable individuals at each of five domestic manufacturers of watthour revenue meters were identified as points of entrance into the companies.

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10. NIST charges for all of its calibration services.

11. For example, one individual calculated the economic value in terms of labor effort saved on the production floor to maintain a desired level of uncertainty.

12. The initial up-front cost of $750,000 was not included as a steady state benefit. Sufficient information was not obtained during the interviews to estimate the economic life of such equipment or the alternative use that it might have. Thus, this cost-saving component was ignored in adherence to the policy of conservative use of the data.

The five manufacturing companies that comprise the domestic industry are (alphabetically) ABB Power T&D Corporation, General Electric Company, Landis & Gyr Metering, Schlumberger Industries, and Scientific Columbus. All companies were willing to participate in the study, although General Electric declined to provide any quantitative estimates of benefits. Therefore, the estimated economic benefits to the manufacturers of revenue meters is based on responses from only 80 percent of the domestic industry.

One manufacturer not included

Because General Electric stated that they did receive economic benefits from the NIST services, a value could have been imputed to General Electric that was equal to either the mean or median value reported by the other four companies in the industry. If General Electric has greater than a 20 percent market share, then their cost savings could be much higher than the mean or median. However, in an effort to be conservative, no value was imputed. Thus, the final benefit-to-cost ratio explicitly assumed $0 value received by General Electric based on their decision to limit their participation in this study.

These companies have been producing watthour revenue meters for an average of 80 years. A best estimate is that about two million meters are produced annually and sold domestically. The structured telephone interviews with each company focused on the transaction-cost savings associated with having traceability to NIST. For the manufacturer of a watthour revenue meter, the economic value of traceability to NIST is the time and effort saved by not having to reconcile disputes about the accuracy of a meter (and economists refer to the collective resources devoted to reconciling such a dispute as a transaction-cost saving).

Traceability lowers costs

There was no question in the minds of the participants interviewed that traceability to NIST does lower transaction costs when selling meters to utilities. Each respondent recounted instances where disputes were easily resolved because of traceability, and no participant seemed to have a difficult time quantifying these benefits. The aggregated collective estimate of such savings is $1.21 million per year.[13]

Both utilities and State commissions benefit

Because these transaction-related disputes would have taken place with electric utilities, it is reasonable to assume $1.21 million also approximates the transaction-cost savings to the utilities.[14] Thus, the total transaction-cost savings to this segment of society is estimated at $2.42 million. This amount is shown in Table 3 to be equally divided between the revenue meter manufacturers and the electric utilities.

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13. The focus of the telephone interview was on domestic production.

14. The utility costs might be much higher. While meter manufacturers can maintain specialists to deal with the utilities, the utility generally has little experience and a lot of learning to do when attempting to resolve a dispute with a manufacturer.

3. *Electric Utilities and State Utility Commissions*

Data from independent investigation

Information regarding the economic value of traceability to the national watthour standard maintained by NIST to the electric utilities and state utility commissions was gathered through an independent investigation with each state utility commission, including the District of Columbia (hereafter referred to as "the states").[15]

No effort was made to contact representatives at the electric utilities for two reasons.[16] One, it was believed that the transaction-cost savings estimates obtained from the manufacturers of watthour revenue meters already approximated the collective transaction-cost savings to the utilities as previously noted -- $1.21 million per year. And two, it was believed that the transaction-cost savings to utilities that are involved in reconciling meter disputes with residential customers could more easily (and more cost effectively) be estimated by limiting the interviews to the utility commissions only.

Each commission was asked to respond qualitatively to a number of questions, and then additional quantitative estimates were obtained during the telephone interviews. Two states were omitted from the final sample population. Nebraska was omitted because the respondent did not complete the mailed questionnaire, stating that all electric utilities there are publicly owned and operated and are not subject to commission regulations. Tennessee was also omitted because the respondent did not complete the questionnaire, stating that the nature of the inquiry was not relevant because of the control of TVA.

Not all States require traceability

The first question asked was: *Do the regulations in your state ensure that the values for the watthour and other related units used by the utilities are traceable to the national standard maintained by NIST? Please answer this question on a 0 to 10 scale where 0=no regulations and 10=extremely stringent regulations.*

Nineteen of the 49 states reported that there was no regulation to ensure traceability to NIST. Of the remaining 30 states, 8 responded "yes" rather than with a numerical value. Of the 22 that did answer this question with a numerical value greater than 0, the median response was 8.5. Hereafter, states are dichotomized as those without traceability regulations (n=19) and those with (n=30).

The second question asked for a response to six statements using a 0 to 10 scale, where 0=strongly disagree and 10=strongly agree. These statements are listed in Table 1, along with the median response for the group of states without

15. *The underlying data, obtained in a separate study that is not part of the present study, are summarized in this section. For a more complete discussion, see Link (1994).*

16. *See Ramboz and Martzloff (1995) on the difficulty of obtaining economic information from the technical personnel of the utilities.*

traceability regulations (and only 12 of the 19 completed this question) and the group of states with traceability regulations (and only 23 of the 30 states completed this question). Mean responses to each of the statements are listed in Table 2.

A range of replies

Table 1
Median Responses from State Utility Commissions

Statement	No traceability regulation (n=12)	Traceability regulation (n=23)
Traceability to NIST...		
... reduces the cost of assuring the accuracy of watthour meters.	5	9
... reduces the time needed to assure watthour meter accuracy.	5	9
... reduces the cost of testing new watthour meters for approval or acceptance.	5	7
... reduces the incidence of watthour meter disputes.	5.5	9
... reduces the time needed to resolve a watthour meter dispute.	5	9
... represents an unnecessary cost to utilities.	0	0

Table 2
Mean Responses from State Utility Commissions

Statement	No traceability regulation (n=12)	Traceability regulation (n=23)
Traceability to NIST...		
... reduces the cost of assuring the accuracy of watthour meters. *	5.7	8.1
... reduces the time needed to assure watthour meter accuracy. *	5.8	8.3
... reduces the cost of testing new watthour meters for approval or acceptance. *	5.4	7.0
... reduces the incidence of watthour meter disputes. *	5.1	7.7
... reduces the time needed to resolve a watthour meter dispute. *	5.3	7.7
... represents an unnecessary cost to utilities.	2.4	1.6

* Denotes that the means are statistically different from each other at a 0.05 level or better, assuming either equal or unequal variances.

Traceability pays off

A major finding of this investigation is that in those states where there are traceability regulations, the economic value of these savings was reported to be greater than in states that do not have such regulations. Qualitative evidence of this finding can be seen from Tables 1 and 2. For each of the first five statements, the median and mean responses from states with traceability regulations are numerically greater than from states without traceability regulations. In other words, the perception is that traceability has an economic value measured in both time and cost savings. Related quantitative evidence of this finding is discussed below. However, it should also be noted here that on the basis of the responses to the last statement listed in the tables, all states, whether they have traceability regulations or not, agree that traceability to NIST is a necessary cost to utilities.

Traceability reduces the incidence of disputes

As part of the telephone interviews, each respondent was asked to approximate the number of revenue meter disputes in which the commission had become involved during the past 12 months. As a first step toward evaluating the interview data, the responses were compared between states with and without traceability regulations. From these responses, the median number of disputes in states without traceability regulations is 12 (total: 340), versus 5 (total: 680) in states with traceability regulations. This quantitative finding is consistent with the qualitative difference reported in Tables 1 and 2 -- traceability to NIST appears to be correlated with a reduction in the incidence of watthour meter disputes.

Adjusting for the number of residential customers in each state, the median number of disputes per 1000 residential customers in states without traceability regulations is 0.011, and in those states with traceability regulations it is 0.005.[17] However, *a priori*, there is no economics-based reason to expect that the incidence of disputes would vary across states after adjusting for the number of customers.[18]

The commission respondents were also asked the average number of person-hours required on the part of the commission and its staff to resolve a typical residential customer complaint about meter accuracy. In those states that do not require traceability, the median number of commission person-hours per dispute is 12, compared to 5.25 in those states that do require traceability.[19]

17. Data on the number of residential customers, by state, came from the publication Energy Information Administration (1994).

18. In those states without traceability regulations, the mean number of disputes per 1000 residential customers is 0.017, and in those states with traceability it is 0.012 (means are not statistically different). For a more complete analysis, see the statistical results in the Appendix.

19. The mean number of person hours per dispute in those states not requiring traceability is 13.2, compared to 8.1 in those states that do require traceability (differences are statistically significant at the 0.05 level or greater).

Residential customers trust traceability

This finding is consistent with the qualitative finding from Tables 1 and 2 that traceability to NIST reduces the time needed to resolve a watthour meter dispute. In fact, one can infer that, on average, the time needed to resolve a watthour meter dispute decreases by nearly 60 percent, due to the ability of members of the commission to explain to residential customers that the electric meters of the utility are traceable to a national standard.[20]

Using an average of 6.75 hours saved per commission engineer per dispute (differences in median values) as a result of traceability, and using the difference between the total number of disputes in states with and without required traceability of 340, then the savings to the commission due to traceability requirements is 2,300 person-hours per year.

As part of the telephone interview, engineers were asked the cost to the commission of a fully-burdened person-hour. The average (median and mean) response was $21.00, burdened by a factor of 1.85, or $38.85 per hour. Using this value, the annual estimated transaction-cost savings from traceability is, from the perspective of state utility commissions, $89,000 (rounded). And assuming that the same transaction-cost savings apply to the electric utilities, the total social transaction-cost savings associated with the maintenance of the national standard for the watthour by NIST is $178,000 per year.

An additional benefit of the reduction in disputes is the value of time saved to the residential customer. If, by assumption, one values the 2,300 hours saved per year at minimum wage, then the transaction-cost saving to residential customers is $8,000 (rounded).

Commissions, utilities, and consumers all benefit

The estimated total annual value associated with the maintenance of the national standard for the watthour by NIST from reduced residential customer disputes can be approximated as the sum of the social transaction-cost savings to state commissions and utilities associated with the maintenance of the national standard for the watthour by NIST ($178,000), plus the related transaction-cost savings to residential customers ($8,000). The total for this benefit is $186,000, as shown in Table 3.[21]

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20. *The validity of this inference was explored with the survey respondents. In general, an engineer from the commission accompanies a representative from the electric utility to conduct an on-site test of a meter that is in dispute. The role of the commission engineer is generally only to witness the test. It was not uncommon for commission engineers to explain to customers the concept of traceability to a national standard, and the majority believed, as shown in Table 2, that this fact reduced the time needed to resolve the dispute. In the rare instance when a dispute went to a formal hearing, traceability was a critical piece of evidence.*

21. *It is assumed, based on interview information, that the 1.85 burden factor includes the administrative as well as technical costs associated with resolving a dispute. Not included in this estimate is the time of other electric utility officials or commissioners to resolve a dispute that reaches the stage of a formal hearing. No information is available on the cost of that process.*

Additional intangible benefits

An important category of benefits associated with power and energy calibration services is the general technical support given to industry by members of the Project. Members of the Project estimate that they spend a total of between 5 and 10 hours per week interacting over the telephone with industry personnel on a variety of technical support matters. Although this interaction benefits industry, no dollar value was estimated as part of this study because of the speculative nature of quantifying the technical information exchanged.

B. Measurement of Costs

As previously noted, the 1994 investments by the Power and Energy Calibration Project were $80,000 for both research and development, and equipment costs. This is a steady-state level of investment.

Over $3 million of benefits

Table 3
Summary of the Estimated Average Annual Benefits Associated with Power and Energy Calibration Services

Category of Benefit*	Manufacturers of Standard Meters	Manufacturers of Revenue Meters	Electric Utilities and State Utility Commissions
Maintenance of the national standard for the watthour	$600,000	$1,210,000	$1,210,000 + $186,000
Research to lower the uncertainly associated with watthour revenue meters	$70,000	---	---
	Total (rounded):	$3,300,000	

* Technical support to industry not included

IV. COMPARISON OF BENEFITS TO COSTS

41-to-1 is the benefit-to-cost ratio of the Project

The benefit and cost data collected as part of this study are specific to 1994, although it is believed that they represent steady-state values. The total average annual investment in operating the Power and Energy Calibration Project at NIST is $80,000. The total average annual measured benefits to industry and society are estimated to be $3.3 million. A comparison of benefits-to-costs produces a ratio of 41-to-1.

The approach of comparing benefits to costs at one point in time is appropriate in this instance of evaluating the support by NIST of the national standard for the watthour. NIST has been involved in this activity since 1901, and industry and residential customers have been realizing benefits since then. Therefore, it is reasonable to assume that at any point in time the benefits received from the ongoing activities at NIST are a blend of benefits from the past and benefits stemming from current investments. If the blend is relatively stable over time, then the ratio of benefits-to-costs will also be stable, assuming costs are similarly stable. In other words, at any point in time a snapshot of the portfolio of benefits associated with the watthour standard and the costs to produce, maintain, and transfer it will be like that taken at another point in time.

More formally, if data on future benefits (B) and on future costs (C) were available, then the ratio of the present value of future benefits to the ratio of future costs is:

$$[\ \Sigma_t\ B_t\ /\ (1+r)^t\ ]\ /\ [\ \Sigma_t\ C_t\ /\ (1+r)^t\ ]$$

for an annual index of time, t, and for an appropriate discount rate, r. If benefits and costs are constant in future years, or if each grows at the same rate, and if the rate of discount is the same for both benefits and costs, then the ratio of the present value of future benefits to the present value of future costs is equal to the ratio of benefits-to-costs in one time period.

Internal rate of return

The internal rate of return is a generally accepted metric for evaluating research projects, especially Federally-funded research projects from which society is the beneficiary. The internal rate of return is defined as the rate of discount, i, for which the present value of future net benefits equals zero. In other words, the internal rate of return is the value of i for which:

$$[\ \Sigma_t\ B_t\ /\ (1+r)^t\ ]\ -\ [\ \Sigma_t\ C_t\ /\ (1+r)^t\ ]\ =\ 0.$$

There is a predictable relationship between the internal rate of return and a benefit-to-cost ratio, and this relationship can be approximated as:

$$i = \frac{B\,(1+g)}{(C\,/\,k)} + g$$

where i is the internal rate of return, B/C is the calculated benefit-to-cost ratio, g is the expected rate of growth in benefits, and k is the average cost of capital to the affected industry.[22] This relationship is used in this study to approximate the internal rate of return associated with the NIST investments in energy and power calibration owing to the fact that historical cost data were not available and future benefit data were not collected. In order to estimate the internal rate of return from the data available from this study, judgment was imposed regarding a reasonable estimate of the expected growth rate in benefits (g) and the average cost of capital to the affected industries (k).

Using the B-to-C ratio of 41-to-1 for the Energy and Power Calibration Project from above, a future rate of growth of benefits (approximated by the rate of growth in research and development expenditures for the professional and scientific instruments industry during the past decade[23]) of 5.7 percent, and assuming a cost of capital (conservatively estimated at 2 percentage points above the current prime rate of interest[24]), of 9.75 percent, then the corresponding internal rate of return, based on the above expression, is 428 percent.

Other economic evaluation studies have been conducted to estimate the social rate of return to Federally-funded projects. These analyses have relied on a variety of methods, one being the calculation of an internal rate of return. Previous internal-rate-of-return estimates have ranged from 20 to 400 percent.[25]

Most comparable to this study are other studies of NIST projects. One study of the NIST investments to implement standards for the optical fiber industry reported an internal rate of return of 423 percent, and another study of the NIST research program on electromigration concluded the internal rate of return was 117 percent.[26]

The internal rate of return estimate of 428 percent for the Power and Energy Calibration Project compares favorably with the upper end of the internal rates of return estimated from previously evaluated NIST projects.

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22. *See Sharpe and Alexander (1990).*

23. *See National Science Foundation (annual).*

24. *Following Pakes and Shankerman (1984), no risk premium was added to this cost of capital estimate. Also, when interviewing the manufacturers of meters, it was their opinion that 9.75 percent was a reasonable approximation of their current cost of capital.*

25. *These findings are summarized in Tassey (1992).*

26. *See Leyden and Link (1992).*

V. CONCLUSIONS

It is well established in the economics literature that investments in measurement-related technology research by Federal laboratories represents an important resource commitment to the innovation process, and that these investments have a significant impact on economic growth. This study provides additional evidence of the importance of Federal laboratory research in the area of measurements, and compares the industrial and social benefits associated with that research to the cost of achieving these benefits.

A rate of return of 428 percent

The rate of return from the NIST investments in the Power and Energy Calibration Project is estimated to be 428 percent. Because in several instances no benefit was assigned to an activity which was known to be beneficial but for which no quantitative data could be obtained, this evaluation of the rate of return is quite conservative. Not only does this estimate compare favorably with return measures from other NIST activities, but also it validates the importance of continued Federal funding of similar research that serves both industry and society.

REFERENCES

Energy Information Administration, *Electric Sales and Revenue, 1992,* Washington, DC: Government Printing Office, 1994.

Institute of Electrical and Electronics Engineers, *American National Standard Code for Electricity Metering* (ANSI C12.1), 1988.

Leyden, Dennis P. and Albert N. Link, *Government's Role in Innovation*, Norwell, MA: Kluwer Academic Publishers, 1992.

Link, Albert N., "An Economic Analysis of Traceability Standards," University of North Carolina at Greensboro working paper, December 1994.

National Science Foundation, *Research and Development in Industry*, Washington, DC: Government Printing Office, annual.

Pakes, Ariel and Mark Shanakerman, "The Role of Obsolescence of Patents, Research Gestation Lags, and the Private Rate of Return to Research Resources," in *R&D, Patents, and Productivity* (edited by Z. Griliches), pp. 73-88, Chicago: University of Chicago Press, 1984.

Ramboz, John D. and François D. Martzloff, "The Technical Impact of the NIST Calibration Services for Electrical Power and Energy," *NISTIR 5564 Report*, 1995.

Sharpe, W. and G. Alexander, *Investments*, Englewood Cliffs, NJ: Prentice Hall, 1990.

Tassey, Gregory, *Technology Infrastructure and Competitive Advantage*, Norwell, MA: Kluwer Academic Publishers, 1992.

APPENDIX

As discussed in the report, the mean number of revenue meter disputes between electricity customers and electric power utilities per 1000 residential customers is not significantly different between states with traceability regulations and states without. More formally, this same result can be demonstrated by the results from the following cross-state least-squares regression (t-statistics reported in parentheses):

$$\underset{}{RDPY} = \underset{(0.72)}{7.46} + \underset{(2.32)}{6.59\ RC} + \underset{(0.05)}{0.57\ REG}$$

$$R^2 = 0.11$$

where RDPY represents the number of residential disputes per year in each state, RC represents the number of residential customers in each state, and REG is a binary variable equalling 1 in those 30 states with traceability regulations and 0 in those states without traceability regulations. The estimated coefficient on the binary variable, REG, is positive as expected from the qualitative information in Tables 1 and 2 in the report, but it is not statistically significant.